# The potential for CO2 emissions trading in transport: the case of personal vehicles and freight

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# THE POTENTIAL FOR $CO_2$ EMISSIONS TRADING IN TRANSPORT: THE CASE OF PERSONAL VEHICLES AND FREIGHT

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Abstract:

Transport currently accounts for around 25-30 per cent of global $CO_2$ emissions and this contribution is growing rapidly. Moreover, road transport holds by far the major part in these emissions. Because of the social and political reluctance to increase fuel taxation, it is of some interest to explore the inclusion of road transport in emission trading schemes. Starting from the theory about tradable permits, their relevance in transport emissions, their appropriate targets and their potential for practical implementation are analysed. Two proposals of "tradable rights for fuel consumption" are presented, the one for drivers of private vehicles, the other for freight transportation. Finally potential pitfalls and implementation issues are also discussed. It is concluded that the cost of operating markets of fuel rights would be the price to be paid for an effective involvement of the transport sector in the effort to reduce emissions.

Keywords: transport, $CO_2$ emissions, tradable permits, private cars, freight transport

## INTRODUCTION

Transport generated approximately 25 per cent of emissions of $CO_2$ in the world in 2003, and this share amounted to 30 per cent in OECD countries. Among these emissions of one of the main greenhouse gases (GHG), 18 per cent come from road transport; 3 per cent from air and 2 per cent from maritime transport (OECD 2007). Moreover, emissions from transport have increased sharply by 31 per cent in the world between 1990 and 2003.

There are two factors which combine themselves to increase $CO_2$ emissions from transport: the first is the dependency on the internal combustion engine with no wide-scale economically viable alternative available in the next decades; the second is the sharp increase in vehicle-kilometres travelled, which seems to be an inherent feature of economic growth. This technological and economic dependency points out a challenging energy efficiency issue.

One might well guess, given announcements that oil reserves will run out rapidly, whether one should not simply wait until reserves dry up to obtain a reduction in transport-related emissions. This said, rising oil prices in the long term are gradually making it more viable to exploit unconventional reserves, leaving aside innovations in technology which are reportedly opening up prospects for new fossil fuels (including fuels derived from coal, which is in plentiful supply world-wide). Hence, there is every reason to believe that the use of fossil fuels could continue on a large scale in the future.

If the aim is to achieve ambitious GHG reduction for transport within the next few decades, the policies will have to be more determined: among other things, they should aim at reducing total consumption which means reducing vehicle kilometres travelled, not just vehicle specific consumption.

Among the measures identified to reduce transport intensity, carbon taxes and vehicle taxes are the most cost-effective (OECD 2007; Parry et al. 2007). However, the “fuel tax protests” of September 2000 in several European countries show that public opinion is very resistant to fuel tax increases (Lyons and Chatterjee 2002). This resistance can also be explained by concerns about fairness, since many households depend on the car for day-to-day living and for getting to work. Moreover, fuel tax increases would require the international harmonisation of fuel taxation in different countries, which considering the European Union treaties appears to be extremely difficult.

In the light of these difficulties, another instrument which combines economic incentives and quantity control, namely marketable or Tradable Permits (TPs), might be of interest. This category of instruments is part of a wider one, namely transferable permits. According to a general definition given by O. Godard (OECD 2001), transferable permits cover a variety of instruments that range from the introduction of flexibility into traditional regulation to the organisation of competitive markets for permits. These instruments have in common: the setting of quantified physical constraints in the form of obligations, permits, credits or rights allocated to target groups of agents consuming scarce resources; and the permission granted to the agents to transfer these quotas between activities, products or places (offsetting), periods of time (banking) or to other agents (trading, hence “tradable permits”).

These tradable emissions permits (or quotas[1]) are frequently referred to as "pollution rights", implying that those who can afford to are allowed to purchase the right to harm the environment. However, the allocation of emission quotas does not involve the creation of "pollution rights", but the restriction of these rights when previously they were unlimited. Making these quotas "tradable" therefore amounts to introducing flexibility and minimising the total cost to the community of reducing emissions.

As shown hereafter, there are plans to include air transportation in emission trading schemes at least in Europe, while international maritime transportation may come soon under consideration. However, the major share of road transport in overall transport emissions is an incentive to consider also the inclusion of this transport mode in emission trading schemes.

It is generally considered that tradable permits schemes with a large number of mobile sources involve huge implementation costs. It will be argued that allocation methods and emission caps can be defined with no excessive complexity and that administrative running costs can be significantly lowered with a smart design. Adding the advantages of better acceptability and more effective influence on behaviour given by the possibility of free allocation, TP schemes decentralised in the transportation sector deserve a thorough exploration.

The paper is structured as follows. First, starting from the theory about tradable permits, their relevance in transport emissions, their appropriate targets and their potential for practical implementation are analysed. Second, a proposal of tradable rights for fuel consumption by drivers of private vehicles is presented. In the third section, a similar proposal for freight transportation is developed. Finally in the fourth section, potential pitfalls and implementation issues are discussed.

# 1 FROM THEORY TO POTENTIAL IMPLEMENTATION IN TRANSPORT

## 1.1 From theory to relevance in transport emissions

The economic theory behind pollution permit markets can be traced back to the work of Coase (1960) on external costs, followed by that of Dales (1968) on regulating water use, and the formalisation of pollution permit markets by Montgomery (1972).

A system of tradable permits equalises the marginal costs of reduction between all emission sources. Under some assumptions this is a sufficient condition for minimising the total cost of achieving a given emissions reduction objective (Baumol and Oates 1988). This result is obtained independently of the initial allocation of rights: it should be stressed that this makes it possible to separate the issues of efficiency and equity.

However, Stavins (1995) has shown that when transaction costs are involved – the search for trading partners, negotiation, decision-making, follow-up and compliance with the rules – the initial allocation of rights affects the final balance and the total cost of reducing emissions. The authorities may therefore attempt to reduce these transaction costs, for example by avoiding finicky regulations or by facilitating the activity of intermediaries between vendors and purchasers (Hahn and Hester 1989; Foster and Hahn 1995).

[1] The terms "quota", "permit" or "right" will be used interchangeably in what follows.

Transferable permits have been used in the fisheries, and in the fields of construction rights and water pollution. The US "Acid Rain" scheme has been developed as a large-scale system of tradable sulphur dioxide emission permits (Godard 2000). Experiences in implementation of tradable permits markets (OECD 1997 1998) make it possible to identify some general criteria of success which include among others: the simplicity and the clearness of the system; the possibility of effective market operation; the credibility of emissions monitoring and sanctions; and the long term validity of permits.

With regard to the quantitative reduction objective, the essential difference between taxes and permits lies in the fact that in practice the public authorities do not possess full information on the reduction costs for the different agents. With a permit-based approach, achieving the quantitative objective of emissions reduction is guaranteed, but there is no guarantee with regard to the actual level of the marginal costs of reduction. On the contrary, in the case of the tax, the marginal cost of reduction for each agent is fixed, but there is no guarantee with regard to the amount of emissions reduction.

This uncertainty makes it difficult for the regulator to make a choice as errors regarding reduction costs for agents, particularly with regard to the distribution of efforts over time and between agents, may be very costly to the community. Nevertheless, a number of criteria may be of use when making this choice (Baumol and Oates 1988).

A first criterion for the appropriateness of a quantity-based approach (i.e. emission quotas) is whether the damage to the environment is increasing very rapidly or becoming irreversible when certain emission thresholds are reached or exceeded. In this case, tradable permits provide a relative advantage over a tax approach since quotas control reduces the cost of errors (Weitzman 1974).

There is a controversy regarding the pace of damage cost function of greenhouse gas emissions, between those who argue it is rather steep relative to the abatement cost function (e.g. Stern 2006), and those who argue the opposite (see for instance Nordhaus 2006). In order to overcome this uncertainty about the costs of (in)action, a hybrid approach combining permits and a "safety valve" for price (see below) would provide a pragmatic solution.

Nevertheless, the choice between taxation and permits requires a case-by-case analysis. A general solution to this problem of uncertainty with regard to the costs of emissions reductions has been proposed by Baumol and Oates (1988, pages 74-76), on the basis of an idea developed by Roberts and Spence (1976). It involves setting a payment in full discharge (i.e. a "safety valve"): this way, the emitter could be discharged of his/her obligation to return permits by paying the payment in full discharge for each unit of emission exceeding the rights he/she holds. This payment in full discharge would then set the upper bound of the permit price. This hybrid solution is to be applied when the regulator must make decisions either with regard to the temporal distribution of efforts (for example annual objectives) or with regard to the distribution of this effort between the different actors or sectors.

A second criterion is whether agents are more sensitive to quantitative signals than price signals, particularly if the price-elasticity of demand is low in the short or medium term as is the case in transportation. Here again a permit system is more appropriate.

For example, emissions from travel may be reduced by various means: changing driving style, reducing vehicle-kilometres of travel (by increasing the number of passengers in vehicles, reorganising trips or changing the locations of activities); by changing one's vehicle or changing mode in favour of one which consumes less energy. Some of these actions may be implemented in the short term, while others such as changing one's vehicle, changing one's place of work or residence, may take much longer. The result of this is elasticities which are

generally low in the short term and considerably higher in the long term. For example, for fuel consumption, the price-elasticity values are between –0.2 or –0.3 in the short term[2] and –0.6 or –0.8 in the long term (Goodwin 1988; Graham and Glaister 2000; Brons et al 2006).

Furthermore, a third criterion that is an important factor for the effectiveness of TPs is the heterogeneity of the agents involved in the system. This means that the marginal costs of abatement must be sufficiently different between agents in order to allow benefits from trading permits, thereby making the market function effectively.

For instance, if one considers the use of private car, the marginal abatement cost curves are highly varied and, in particular, rise as one moves from urban to suburban and then to rural settings. On two essential points, namely changes in the locations of activities and changes in transport mode, the possibilities for action differ very greatly in both nature and degree on the basis of the residential locations of the individuals (urban, suburban, rural). Changes in the locations of activities in order to reduce the distances between different activities are much easier to make in urban areas than in suburban or rural locations, as a result of the density of available activities: changes are possible in the short term for activities where the location imposes little constraints, such as shopping or leisure; reducing distances between home and work is easier in a conurbation which provides a high density of job and housing opportunities. Likewise, public transport which provides an alternative to the private car is more frequently available in urban areas.

Finally, last but not least, in political terms, systems where permits are allocated free of charge may be seen as a means of avoiding an additional tax, and this can enhance the acceptability of the new instrument. With this free allocation, economic agents have a supplementary incentive to save whether emissions, trips or distance travelled, beyond their initial allocation of permits, because they can sell unused permits and receive a tangible reward for their “virtuous” behaviour.

The main arguments against the use of permits in the transport system are the cost of administration and monitoring over a large number of mobile sources and the transaction costs of quotas transfer. However this issue happened to be similar in the case of road pricing and is now better addressed and effectively implemented, thanks to electronic technology which is affordable today.

## 1.2 Which targets for reducing transport emissions?

Emissions from transportation stems essentially from the technical characteristics of vehicles (energy source and vehicle specific consumption) and the intensity of travel (distances travelled) as a function of economic and social trends. Moreover, this intensity of travel results from the supply of transport infrastructure and services (price and quality of service for different transport modes) and land use through location of activities.

There is potential for controlling nuisances arising from transport in several but not all of these areas: transport supply, vehicle specific emissions, fuel standards, car ownership, car use (vehicle-kilometres travelled), land use and end-user fuel consumption (for a detailed review of these actual or potential implementations, see Raux 2004).

Regarding the supply of transport infrastructure and services, local and central governments which plan land use and define transport policy, and hence provide transport infrastructure and services, could be involved in emission trading schemes. However, the basic difficulty is

[2] i.e. a 10 per cent increase in price would lead to a 3 per cent reduction in fuel demand.

to monitor mobile sources which can be fuelled at a number of locations in a specific administrative area and can travel through other administrative areas (Salon and Sperling 2008).

Obviously the road vehicle industry, which influences specific emissions of new cars and trucks, should take its share of the burden. However, apart from problems of coordination with other upstream or downstream approaches (see discussion below), there is poor relation with actual emissions, because of the driving pattern of the car user. Car ownership is another indirect way of controlling car travel but the linkage with actual fuel consumption is also very crude.

The amount of distance travelled is one of the main drivers of greenhouse gases emissions, given the current transport technologies. Controlling land use is in principle an attractive way of reducing these distances, but its effects are controversial: it has still not been proven that it is possible to reverse the tendency to travel longer distances by compacting locations. However, one must recognise that the spatial concentration of activities yields more opportunities for cost-efficient transport alternatives such as mass transit, which is less energy consuming per passenger-km.

Targeting the fossil fuel consumption of end users with tradable permits is the most decentralised incentive for reducing $CO_2$ emissions. End-users are an important target for emissions reduction since vehicle use represents about 75 to 80% (tank to wheel) of whole emissions from the point of view of vehicle life-cycle analysis (from cradle to grave). End-users as the final decision-makers can modify, albeit with more or less constraints, their travel choices, activity locations, or choice of vehicle or transport mode.

### 1.3 $CO_2$ tax, upstream or downstream permits?

The fiscal instrument is widely used in the transport sector, essentially because of its tax yield. Fuel excise duties levied in the European Union in 2002 varied widely in Member States, from €0.296 to €0.742 per litre for premium grade petrol and from €0.242 to €0.742 per litre for diesel oil (CEC 2002). Although the current level of taxation might be considered high, it is not high enough to further reduce fuel consumption by transport.

The “tax rebellion” that took place in several European countries during the high rise of oil price in September 2000 shows how sensitive public opinion is to fuel taxation. Central government is a focus for opposition as it benefits from the tax, although it has little control over oil prices. Proposing a “$CO_2$ tax” in view of emissions reduction is likely to start again the debates on the use of the fiscal revenues from the excises, which currently in the majority of the European countries are not earmarked and play an essential part in the balance of public finances.

If one considers the development of stringent objectives of emissions reduction in the future, a fuel rationing seems unavoidable: this rationing can basically take the form of either price rationing (tax) or quantities rationing (permits). From this point of view the acceptance of rationing is an identical precondition for the two instruments and needs at least an information campaign and a political willpower in order to introduce any measure of emission control. This is the first step which needs to be achieved. It is in this context of “accepted rationing” that the relative acceptability of permits can be evaluated.

Although for the economist the marginal effects of tax or permits on microeconomic decisions about fuel demand are equivalent, the political perception of the instrument can have some

importance. There would be thus some interest to elaborate mechanisms which explicitly separate the objective of fiscal revenues from the objective of reduction of $CO_2$ emissions.

In order to reduce the administrative costs, it seems relevant to set up the system of permits at the very upstream, on a level where the actors are very few: it could be the fuel refiners or distributors, which already transmit the current excise duty to the ultimate consumer and return the product of the excises to the central government. By imposing to the producers and the importers of oil, natural gas and coal to return the quotas, the system would cover the whole $CO_2$ emissions resulting from the combustion of the hydrocarbon fuels by the end-users (Winkelman et al 2000).

However, this advantage of complete coverage by an upstream permit system has lost its strength today in Europe, with the operation of the $CO_2$ Emission Trading Scheme (ETS) between energy intensive fixed industrial facilities since 2005. An upstream permit system should now be modulated as a complement to the ETS.

Moreover an upstream system is prone to two disadvantages.

Firstly, there is a risk of diluting the incentive effect of permits on the final emitter, so that they implement the complete panoply of behavioural adaptations which are available to them. Indeed, whether the permits are acquired by auction or distributed free to the fuel suppliers, these suppliers would pass opportunity costs[3] relating to these permits to their customers as a simple additional fee. In this case, the advantage vis-à-vis the current system of fuel taxation is null.

The second disadvantage appears in the event of free allocation of quotas to the fuel suppliers. If the permits are allocated free what would be the use of revenue generated by this initial distribution? The fuel suppliers could transmit the opportunity costs relating to these permits which they would have received free: that would not call into question the economic efficiency of the system but certainly its acceptability, since those supporting the effort of reduction would not benefit from the revenue created by the free allocation. An upstream permits system thus seems, for reasons of political acceptability, incompatible with a free allocation[4].

Lastly, the European Commission has said it wishes to include transport in the ETS gradually, starting with air transport. Given the slow progress of negotiations regarding international air transport emissions at the International Civil Aviation Organisation (ICAO), the European Commission issued a communication in September 2005 and then a Directive in December 2006 (CEC 2006), proposing to bring aircraft operators into the EU ETS for all flights arriving or departing from the European Union. After numerous and lengthy discussions with the Member States and the European Parliament, a deal has been set in June 2008, which still needs to be approved. According to this deal, the scheme will concern all the flights beginning in 2012 (despite the opposition of the United States till now), and the method of allocating allowances will be harmonised across the EU, especially the benchmark for calculating allowance allocations, i.e. the ratio of total quantity allowances to the tonnes-kilometres achieved by the operators. The total quantity of allowances would be calculated on the basis of average $CO_2$ emissions for the aviation sector over the period 2004-2006 (97 per cent of this quantity) and set to decrease gradually after the starting of the scheme. A fixed

[3] As the permits will have a value on the market, the opportunity cost for a fuel supplier would consist in not selling on the market the permits received for free, or not recovering their value in the form of extra costs to their consumers.

[4] Unless this revenue is taxed, from which arises a new complexity.

percentage of this total would be allocated free of cost (85 per cent in 2012) and the remainder would be auctioned. Each aircraft operator could then apply for a free allowance based on its historical activity (tonne-kilometres). In addition, operators would be able to buy allowances from other sectors covered by the ETS.

In a study on the design of a GHG emissions trading system for the United States, Nordhaus and Danish (2003) ruled out a downstream system from the outset, judging that it would be too difficult to administer millions of sources. Like Winkelman *et al.* (2000), they argue the case for a hybrid approach which would combine an upstream procedure for fuel producers with a downstream procedure for automobile manufacturers. However, as German (2006) points out, an analysis of the detailed implementation of a hybrid scheme such as this shows that there are a number of difficulties: one of the main problems is the risk of double counting both in terms of credits to automobile manufacturers for fuel efficiency improvements and in terms of allowances for fuel producers. This risk of double counting arises mainly from the timing of calculations of allocations and credits: allocations for vehicle manufacturers are based on the entire lifetime of the vehicle, while those for fuel producers are for emissions in the current year. Generally, the incorporation of vehicle manufacturers in an upstream permit scheme would mean subtracting manufacturer efficiency allocations from annual allocations to fuel producers each year, which would require accurate monitoring of vehicle kilometres actually travelled, driving conditions that influence actual consumption and vehicle scrapping. Furthermore, this type of programme does not cover the existing vehicle fleet, which is known to have a lifespan of around 15-20 years on average. In short, such a programme would be highly complex.

This is why it is of some interest to explore the possibilities of a fully downstream decentralisation of permit markets within the transportation sector. The analysis is performed separately for private vehicles and for the freight industry, due to significant differences in economic behaviour between them.

## 2 TRADABLE FUEL RIGHTS FOR PRIVATE VEHICLES

Here is described a proposal of “tradable fuel consumption rights” for motorists (based with some alterations on Raux and Marlot 2005). This idea has some connections with the more general one of “domestic tradable quotas”[5] which would encompass all fossil fuel consumption of households, thus including e.g. home heating. However, application of quotas to every category of household energy consumption needs careful investigation and assessment of each one, and this is done here for private transport.

In the case of France, private cars account for approximately three-fifth of automotive fuel sales (gasoline and diesel oil), the rest being consumed by light and heavy goods vehicles. The issues of obligation liability, allocation of rights, exchange mechanism, monitoring, implementation (phasing in) and equity are tackled successively.

[5] This idea was firstly developed by David Fleming (http://www.dtqs.org/ Accessed in December 2008).

## 2.1 Obligation liability

Motorists as consumers of fuel and hence emitters of $CO_2$ would be liable for the obligation to return the fuel rights to the regulating authority.

A consumer who purchases motor vehicle fuel (which will necessarily be burnt) would have to transfer the corresponding rights to the regulating authority. These rights would then be cancelled. The right corresponds to an authorisation to emit the $CO_2$ equivalent of a litre of fuel[6]. These rights may be held initially by the agent or purchased in the permit market.

## 2.2 Allocation of rights

Different options are available for allocation of fuel rights and these refer to different views of equity. One option could be to allocate free fuel rights on a per capita basis. For instance, in the case of France, and starting in year 1, the rights allocation would be of the order of 27 billion litres of diesel or petrol used by private cars in France for 2005, or per capita – child or adult living in France– rights amounting to 450 litres per year. Based on an average vehicle consumption of 8 litres per 100 km, that would work out at 5,600 km of travel solo driving per year, but 22,400 km for a family of four. Car-pooling would therefore leave families some room for manoeuvre depending on their size. The rate by which rights allocations would be reduced each year would be announced several decades ahead and periodically adjusted by a regulatory authority independent of the government in office.

The rights would remain valid for an unlimited period, which may lead to hoarding and speculation. However, the $CO_2$ -equivalent value of quotas held by an agent could be reduced in the following year in accordance with the rate of the reduction in free rights allocations decided by the regulating authority.

## 2.3 Exchange mechanism

In order to consume more fuel than his/her free allocation, a consumer would have to purchase additional rights on the market. On the other hand, a consumer who does not use all his/her allocated rights could sell them. This possibility of selling unused rights provides an additional incentive for modifying one's behaviour, particularly for persons who can do so at low cost.

However, given the huge number of potential participants, the exchange would not be bilateral, but rather centralised through a stock exchange which would yield the daily value of fuel right. Practically, participants would buy and sell rights through intermediates like their usual bank operator or buy them at the petrol pump (see below). This means perfect information for participants about the current price of the fuel right. Since transactions would be fully authorised on the market, this would minimise the risk of a black market.

For acceptability reasons the management of fuel rights would not be left entirely to the market: rights would be sold at a price fixed by the authority and at which the authority would

[6] Currently in France, 2.4 kg CO2 for a litre of gasoline and 2.6 kg CO2 for a litre of diesel. Strictly speaking, this value should vary according to the type of fuel: diesel fuel contains more carbon than gasoline, gasoline with ETBE can have different emissions than gasoline without ETBE. A conversion factor would apply for each kind of fuel. For the purpose of simplicity of exposition and evaluation in this paper we have assumed that one right unit corresponds to one litre of any fuel.

buy back unused rights. This implies that the authority would adjust this price on a yearly basis.

## 2.4 Monitoring, verification and penalties

The sale and purchase of rights would be supervised at a national level by a regulatory authority. In order to reduce administrative costs and enforce a reliable monitoring, fuel rights transactions will have to be validated as close as possible to the time of fuel purchase, that is to say when the motorist buys fuel at the pump. The rights, awarded annually, would be held on a chipcard which records rights debit and credit operations. This could be either a smart card compatible with the automatic teller machines (ATM) that are already installed at petrol stations or a modification of credit smartcards currently used in these ATM. Rights could therefore be debited (or purchased at the current rate) when buying fuel. It would also be possible to purchase or resell permits in banks, using ATM bank distributors or over the Internet.

## 2.5 A combined taxation and marketable rights system

It would be socially unacceptable to apply suddenly the fuel rights system to all motorists. So the implementation of the fuel rights market should be progressive and would coexist with a $CO_2$ taxation system. Moreover, taking part in the fuel rights system should be voluntary. Lastly, since rights transactions would be monitored when buying fuel at the pump the administrative barrier between the two systems of taxation and fuel rights cannot be impenetrable.

A solution is to set up the "safety valve" referred to in section 1 above (in fact a "$CO_2$ tax"), which would be paid both by fuel consumers who wish to stay outside the rights market, and those who are taking part in it but have used up their allocation and are either unable or unwilling to purchase permits. This tax would therefore constitute a price ceiling of permits on the market and would have to be adjusted with reference to the country's international commitments to reduce emissions.

If the rights are allocated on a per capita basis, people not willing to cope with this system could immediately sell their rights. However if they buy fuel they would be liable to pay the "$CO_2$ tax".

To sum up, the current fuel excise taxation system will be supplemented by the coexistence of two schemes: the rights market on a voluntary basis on the one hand, the extension of fuel taxation with a "$CO_2$ tax" for those not wishing to take part in the rights market on the other hand. These two systems will be the alternative proposed to motorists: the incentive to adopt the fuel rights system will be effective if the price of fuel right stays lower than the $CO_2$ tax.

## 2.6 Equity issues

An assessment of such a system of marketable fuel rights has been performed in the case of France. In this application (see Raux and Marlot 2005) rights were supposed to be allocated to car owners.

Two main points can be stressed from this assessment. First, the comparison between taxation and permits involves the fiscal gain in the case of the tax (to the detriment of the motorists as a group) and the fiscal loss for the central government in the case of fuel rights because of the

free allocation. Second, in the case of fuel rights, residential location plays a fundamental role: the main winners are households living in the city centre or the suburbs who, on average, sell rights (they can save fuel therefore save rights more easily by reducing their vehicle-kilometres travelled) while the households living in periurban areas are on average the largest purchasers.

The free allocation on an equal per capita basis penalises high income households more than others: data from 1997 (Hivert 1999) show that the average mileage per vehicle owned increases fairly steadily with income, from slightly more than 12,000 km for the lowest income brackets (less than 11.4 thousand euros per year) to almost 16,000 km for the highest income brackets (more than 61 thousand euros per year).

Lastly, the initial free allocation avoids imposing an excessive burden on consumers, particularly the least well off. The average annual consumption of cars varies from slightly more than 900 litres (for the lowest incomes) to 1300 or 1400 litres (for the highest incomes), while the proportion of mileage that is covered on home-to-work trips varies between 24% (for the lowest incomes) and 30 or even 39% for the highest income groups. These figures show that "necessary" travel would generally not be affected, at least in the first years of the scheme with a high level of free allocation. However, this average data should not conceal a possible existence of situations of fragility, for example the "rural poor" who have no alternative but the car: such situations would require ad hoc compensation.

While a fuel rights scheme would increase the acceptance of a policy aiming at reduction of fuel use, when compared with an additional tax, the equity issue remains of paramount importance. The design of free permits allocation obviously governs the scheme acceptability.

## 2.7 Concluding comments

This system has the advantage of simplicity, as the unit of exchange is the right for each litre of fuel that is consumed. The amounts consumed or exchanged are monitored when fuel is purchased, and all persons who purchase fuel for a private use can participate in the market: monitoring is therefore straightforward as it only involves fuel purchases. The possibility of freely exchanging permits will discourage any tendency for a black market to develop.

The free allocation of emission rights creates a rent which is distributed between the individuals (if rights are allocated free on an equal per capita basis). In addition, the consumers of fuel are strongly encouraged to reduce their consumption as they can make a real and tangible profit from selling their unused permits.

The cost of implementation of the administrative system is estimated at the most between 3 and 4 euros per individual chipcard, if created from scratch (by analogy with the current implementation of national health chipcard "Vitale" in France). However, one can feel that big fuel retailing companies will develop quickly such a system in the framework of their ongoing loyalty schemes in order to attract customers, with a reasonable expectation of very moderate additional costs.

Overall this scheme is designed in a way that allows a domestic implementation, that is to say a State regulating private cars fuel consumption in order to comply with its own commitments regarding CO2 emissions[7]. In this scheme foreign drivers would not benefit from the fuel

[7] In order to attribute national responsibilities UNFCCC greenhouse gases inventories per country are based upon fuel sales within the country, excluding fuels used in ships or aircrafts for international transport.

rights free allocation of the country they visit and would have to buy rights or more probably pay the "CO2 tax" on automotive fuel.

However, a domestic implementation raises the issue of coordination with neighbouring countries, because of the potential of cross border fuelling (i.e. "tank tourism" by a driver residing in one country and travelling to another one in order to fuel the vehicle): the driver behaviour results from a trade-off of the price difference between the two countries and the distance travelled (Rietveld et al 2001; Banfi et al 2005). In case of no coordination between neighbouring countries, an obvious limit would be put on a government trying to control more strongly fuel consumption. Yet it should be underlined that this problem is not specific to quotas approach but also concerns the tax approach.

# 3 TRADABLE FUEL RIGHTS FOR FREIGHT TRANSPORTATION

As previously explained, environmental effectiveness and economic efficiency pleads to target directly the consumption of fossil fuels: other targets such as tonne-kilometres, vehicle-kilometres, load rate or empty journeys would require expensive information for the regulator and would be source of efficiency loss.

Here again the design of $CO_2$ emissions rights for freight transportation implies identification of agents holding these quotas and elaboration of an allocation method. Then issues of geographic and sector-based coverage of the scheme are discussed, followed by monitoring and transaction costs issues. Based on this discussion a final proposal is presented, followed by concluding remarks on potential environmental and border effects.

## 3.1 Rights holders, obligations and allocation

Which entities will hold, exchange and have to return the rights for the generated emissions? And, consequently, which agents will have to bear the emissions reduction burden? These questions are due to the fact that freight transport activity, and its consequences regarding $CO_2$ emissions, are the output of a whole set of decisions taken by agents, i.e. shippers and carriers, with sometimes divergent economic logic and unequal capacities of negotiation.

The targeting of fuel consumption naturally results in putting the incentives on the carriers. However, current operation of the logistic chain leaves them only limited margin for manoeuvre. Shippers, because of their requirements in terms of delivery schedules, logistic constraints and required services, impose a framework with which the carriers must comply. Is it possible to involve the agents upstream of the logistic chain, in order to guarantee the effectiveness of the incentives?

For a firm carrying goods on its own the problem does not seem insurmountable, given the integration of decisions within the firm. The firm will optimise its activity, including its industrial and geographical structure of production and distribution. For for-hire carriers, the question is a little more complex given the current situation of vassalage of the carrier vis-à-vis the shipper. It would be appreciable to work out a system which makes it possible to share out efforts of reduction between shippers and carriers, taking into account their respective margin for manoeuvre.

One way to involve the shippers in the responsibility of fuel consumption is to devise a relevant mechanism of fuel rights allocation to them. Two main types of initial allocation,

namely auction or free allocation can be proposed. The first has the advantage of avoiding complex computations, which require sometimes expensive information to obtain. It also avoids involving the authorities in a difficult negotiation with the agents, by letting the market arbitrate.

The auction of permits offers other advantages, vis-à-vis the method of free allocation mostly used, that of "grandfather rights". This last method which allocates rights in proportion of the past activity, gives a premium to "bad pupils": those who use old and polluting technologies would get, other things being equal, more quotas than others. Moreover, this method of free allocation encourages the entities to delay their actions of pollution reduction, since they can anticipate the implementation of such a system, whose preparation takes several years in general: for instance in anticipation carriers could use "dirty" trucks in order to get a higher allocation. Lastly, the auctioning of the initial allocation also makes it possible to treat new entities entering the sector on an equal basis with the existing firms.

However, this auctioning is to be perceived as an additional tax, which would undermine its acceptability. This is why the possibility of a free allocation is explored. Several free allocation methods were tested by in-depth interviews with a sample of carriers and shippers (N=20). These methods included "benchmarking" allocation either to the carriers or to the shippers (with reference to the average ratio of total $CO_2$ emissions per tonne-kilometre of the freight transport sector), and a "grand-fathering" allocation to the shipper, based on their past individual ratio of $CO_2$ emissions per tonne-kilometre.

Many objections were raised by the interviewees. The feedback, from the carriers toward the shipper, of the information on consumption and vehicle-kilometres seems particularly difficult: the audits considered would be thus particularly expensive (even if they remain limited to the firms which would voluntarily adhere to the system). The standard of allocation according to an average ratio of fuel quota per tonne-kilometre, even individualised by firm, appeared non-relevant and was disputed. The reporting character of this information and the fact of creating rent by this mechanism of free allocation, would make possible some fraudulent behaviour by collusion between carriers and shippers: even if they remained a minority, that would undermine the credibility of the mechanism.

As a whole, these drawbacks and the complexity of this mechanism of allocation justified the reserve of the majority of the shippers and even the opposition of some of them.

So it seems relevant to avoid free allocation to shippers. However, some free allocation could be considered for transport operators, at least in the first years of the scheme, in order to improve its acceptability. For road hauliers this free allocation could be a "lump sum" allocation per vehicle in order to avoid complicated computations. For rail and river operators, which are far less numerous, this could be a grand-fathering allocation as it is planned for air carriers in the current project of the European Commission (see above).

### 3.2 Sector-based and geographic coverage

The effective implementation of such a market for the freight transportation sector should be made on the level of the European Union at least, for obvious reasons of harmonisation of competition between the transport operators of the various Member States. That would imply in particular that the principle of a free allocation or not and, if a free allocation is adopted, the choice of the method of allocation and the computation of the allocations are decided at the level of the Union.

The environmental effectiveness implies to cover all freight transport modes, namely road, rail, river, maritime and air transport modes. In Europe currently in rail transport fuel taxes are much lower than for road, inland and maritime shipping as well as air transport are not submitted to any fuel taxation. These differences should obviously be taken into account when considering distribution of free permits.

This effectiveness also implies to cover the other transport sectors, and in particular the private cars, whether by a fuel rights market (see above) or by a $CO_2$ fuel tax (for the sectors or agents not included in the fuel rights market).

It would be socially unacceptable to go suddenly from a system of taxation to a complete fuel rights system. The two systems must thus coexist, while creating a financial incentive to adhere to the permits system.

As for personal transport, a "$CO_2$ tax" would apply to the freight transport operators not wishing to take part in the fuel rights market. It would also apply as a "full discharge" payment to the participants to the rights market who exhausted their initial allocation and could not, or would not, buy rights on the market. The entrance into the fuel rights market would be thus on a voluntary basis.

The geographic coverage on the level of the European Union would make it possible to cover all the intra-European international freight transport, including by air, river and sea. However, international air and maritime transport is not yet covered by the Kyoto protocol. Regarding intra-European international air transport, the European Commission proposes its integration in the existing ETS (see above).

### 3.3 Monitoring and transaction costs

The system effectiveness relies on the possibilities of checking the emissions and managing the fuel rights market, without the transaction costs becoming prohibitive.

As seen above free allocation methods for shippers imply important costs of information retrieval and risks of fraudulent deviance of the system, which justified their dismissal. The suppression of a free allocation option removes these costs of information and controlling fraud.

Regarding the transactions, the transfers of quotas between shippers and carriers would be part of their contractual relationship, as currently with the fulfilment of the transport services. These contractual relations are already the subject of legal and regulatory provisions, without need for intrusion of the authorities into the commercial relationship: there will be thus no extra administrative cost from this point of view. In the same way, the exchanges of permits on the market would not be bilateral but would pass through a stock market: thus there would be no search cost for a partner for the exchange.

The monitoring would thus be reduced to the transfer of quotas to the regulating authority at the time of fuel purchase. The purchases of fuel for trucks are done either at the pump or out of a tank on the carrier's site. For the purchases from the pump, and particularly with the pumps reserved for the heavy trucks, the driver generally uses a magnetic or chip card. These cards and the ATM distributors should have their software modified in order to manage the debit of rights in proportion to the fuel bought. The participation of the carrier firm to the fuel rights market would suppose an exclusive use of chip cards when fuelling at the pump. In relation to supplies at the tank, the invoice of the fuel supplier should include the debit of rights to the carrier firm (or invoicing them if the firm does not take part in the fuel rights market). On the whole, the risks of fraud are particularly reduced.

## 3.4 Final proposal

The tradable fuel rights would be thus based on quotas of $CO_2$ calculated from the carbon contained in the fuel (mainly diesel oil for trucks) consumed by any freight vehicle user, i.e. a for-hire carrier or a shipper performing its own transport. Obligation would be made to the user to return to the regulating authority the corresponding rights, which would then be cancelled.

In principle there should be no free allocation to shippers. However, in case of full integration in the ETS shippers holding ETS quotas could use them for transport.

A free allocation could be devised for transport operators in order to improve the acceptability of the scheme. Given the European scale, the principle of a free allocation or not and, if a free allocation is adopted, the choice of the method of allocation and the calculation of the allocations would be decided on the level of the European Union.

The for-hire carrier (or the transport organiser) would negotiate with the shipper in order to get (or be paid for) fuel rights in view of the achievement of transport operation. Carriers holding unused rights (after having transferred the required quantity referred to above to the regulating authority) could then sell them to the fuel rights market.

All freight transport modes would be covered, i.e. road, rail, river, maritime and air modes. The geographical coverage would be on the level of the European Union at least.

Monitoring of quotas to be transferred to the regulating authority would occur at the time of fuel purchase, either at the pump or when filling a tank on the carrier's site.

The entrance into the fuel rights market would be on a voluntary basis. A "$CO_2$ tax" would apply to the fuel consumers not wishing to take part in the fuel rights market. Participants to the rights market who have exhausted their initial allocation could buy additional rights on the market or pay the $CO_2$ tax as a "full discharge" payment. Other transport sectors or agents not included in the fuel rights market (eventually the private cars, depending on the extension of fuel rights market to them, see above) would be covered at least by a $CO_2$ tax.

## 3.5 Potential environmental and border effects

Regarding the possibility of controlling the growth of road freight transport and hence its $CO_2$ emissions, several counteracting forces are at work, to mention the main ones: for some goods, their value is so high that the variations of transport costs under consideration will have hardly any influence on the distribution practices; the logic of financial optimisation of inventory ("holding costs") tends to "zero stock" and "just-in-time" deliveries: this logic mainly outclasses the transport-environment optimisation logic; moreover, the growing specialisation of the production lines in the factories results in multiplying the exchanges between the production sites and thus the kilometres travelled by intermediate goods.

These insights show that different sectors of the economy would have differing responses to a $CO_2$ tax and an emission trading system. However at the macro level observation shows that the sensitivity of behaviours to the fuel price is not null, given the recent developments in oil price. For instance the total fuel deliveries in France, after a first decline in 2000, are falling since 2002 (SESP 2006) and this evolution is well correlated with that of the fuel price. This sensitivity affects the private cars in addition to the heavy goods vehicles: the total diesel oil consumption for the latter has not grown since 1999.

The sector-based and geographic coverage and the mechanism considered make it possible to claim that there would be no discrimination with regards to the market of fuel rights between the firms of the 27 Member States of the European Union, whether they are shippers or carriers.

A legitimate interrogation remains, that of the possible competition of carriers external to the European Union. In fact, the carriage of goods is less prone to economic distortions than the other branches of industry: freight will always have to be loaded in locations within the EU in order to be distributed for use in other locations within the EU, whether processing industries or final goods delivery locations. The only notable incidence would come from carriers being able to load fuel outside the European Union, thus not subjected to $CO_2$ taxation or fuel rights, and then carry out a transport within the EU. This competition could be significant in the border countries, since trucks can have a cruising range of 1,500 to 3,000 kilometres on a single tank (CEC 2002). This issue would require some kind of coordination with neighbouring countries.

## 3.6 Concluding comments

Shippers using own-account transport have a direct incentive to minimise their fuel consumption, since they would have to return rights in direct proportion to the fuel consumed by their vehicles. Conversely, shippers using for-hire carriage are not directly subject to this restriction. This said, there are two factors that could influence the behaviour of these shippers. Firstly, should they fail to make allowances for this constraint on carriers, there is the risk the latter may gradually disappear, which would mean that the economic balance would tip towards transport operators who managed to survive: this alone might persuade reluctant shippers to compromise. The second factor is the increasing trend towards the inclusion of environmental aspects into corporate activity reports to shareholders and the public. This would give shippers an incentive to gear their activity to reducing shipment-related emissions.

For their part, hauliers and organisers of third-party transport could save the rights they negotiate on different orders from shippers. If they have made efforts to minimise their own fuel consumption, for example by grouping loads and reducing vehicle-kilometres or specific vehicle consumption, they would pocket the difference. In the same way, regarding railroad combined transport, the fuel consumption for the road transport haul to a rail terminal would be debited to combined transport organisers when they provide the transport service (as well as any diesel consumed on a rail transport leg). Lastly, rail transport operators would receive rights allocations, most of which they could sell on depending on the degree of electrification of the network (and the share of nuclear or non-fossil energy used to generate their electrical power).

Regarding the articulation with world international freight transport by air and sea (international bunkers not currently covered by the Kyoto Protocol), the inclusion of air transport in the European ETS is already on tracks, as seen above. When it comes to maritime transport, the same approach might be adopted by the European Commission as stated in the “climate package” adopted in December 2008. If no agreement is reached with the International Maritime Organisation by 2011, the Commission should make a proposal to include international maritime emissions with the aim of its entry into force by 2013. These initiatives are first steps towards the inclusion of international transport in a worldwide emission trading scheme.

# 4 POTENTIAL PITFALLS AND IMPLEMENTATION ISSUES

Europe's experience with the ETS helps to identify the pitfalls to be avoided: this section shows how the above proposals can respond to these concerns. Second, the issue of the co-ordinated launch of these different markets is discussed.

## 4.1 Pitfalls to avoid in the light of the European Emissions Trading Scheme

The experience gained from the first phase of the European ETS (2005-2007) has been instructive in many respects: much criticism has been levelled at the ETS in particular (cf. Open Europe 2007) and at emissions trading markets in general with respect to their ability to meet the challenge of curbing greenhouse gas emissions.

A first criticism often encountered is that this "market" never actually worked in the first place, as can be seen from the collapse in the permit price of $CO_2$ per tonne in 2006. This happened from the point when Member States first began to declare their actual emissions, which turned out to be lower than the initial allocations. Furthermore, when it became clear that the allowances held in this first phase would not be valid for the second phase (2008-2012) the market price plummeted again. It can be argued that all of this shows that the market played its equilibrium price setting role perfectly given the surfeit of, by then, worthless allowances.

The over-generous allocation of allowances which precipitated the collapse of the market price can be put down to Member States, since most of them clearly sought to favour their own industries: the latter captured the decision-making process after intensive lobbying (Godard 2005).

One possible way of counteracting these effects would be to centralise decisions on allocations at the European Union level, reversing the subsidiarity principle. That is why, should there be a market with free allocation of fuel rights for freight transport, not only the principle but also the calculation method of the free allowance should be centralised. However, there are grounds for fearing that centralising these decisions in Brussels may not make them immune to intensive lobbying by industry organisations or to a degree of opacity in the European decision-making process.

Lastly, another criticism, the costs of administering and declaring emissions is high for small emitters, i.e. structures managing only a few stationary installations affected (for example, a boiler in a hospital). It may legitimately be said that these failings stem essentially from the principle and method of free allocation currently adopted in the ETS. The above proposals on fuel rights are aimed at avoiding these failings.

In the case of fuel rights for drivers, the principle of a fixed free allocation is proposed. As it is a fixed allocation, it avoids the need for complicated calculations that are costly to administer on an individualised basis. The simplicity of the allocation principle proposed and the transparency of the calculation as well as the fact that it applies to the entire population, reduces any risk of government decision-making being captured by private interest groups.

For freight transport, it is proposed that there be no free allocation to shippers, which eliminates any reason to lobby for allocations and the adverse consequences that might have. This is in line with the developments agreed in the last EU "climate package" of December 2008 regarding the ETS. According to this agreement, for the power sector full auctioning should be the rule from 2013 onwards, while for other sectors covered by the ETS a

transitional system should be foreseen in order to reach no free allocation in 2027. However, regarding road freight vehicles, in view of increasing the scheme acceptability fuel rights could be allocated as a fixed allowance free of charge per vehicle. In order to reduce the risks of escalating allocations if Member States pursue a "free rider" policy, the flat-rate allocation method should be regulated in detail at the European Union level.

As a general rule, the principle of fixed, cost-free allocations, which avoid complicated calculations, sharply reduces the administrative costs of these schemes. There would still be the costs of monitoring emissions and managing fuel rights transactions, which the proposals above have sought to keep as low as possible.

One last and more general problem is the volatility of the price of $CO_2$ which has been observed on the European market. This volatility is compounded by uncertainty about the configuration the ETS will take after 2012. Price volatility runs directly counter to the need for a clear and continuing long-term signal on $CO_2$ prices which can steer the required investment decisions in the right direction to achieve significant reductions in emissions over several decades. It can be addressed by the "safety valve" proposed previously. This said, whatever the incentive instruments used, tax or permits, a strong political willpower must emerge if a long-term signal is to be sent.

### 4.2 Phased implementation, coordination between transport sectors

Fuel rights would come as a mark-up on the current fuel excise taxes which are moreover different according to fuel categories. There is a debate on whether these taxes already compensate for $CO_2$ damage and this question is not settled here. In any case current excise tax could be adjusted accordingly when setting up fuel rights.

Fuel rights markets in the transport sector could be phased in. The fact that a new market is implemented does not mean that it will gain the support of all of the stakeholders overnight. Operations on rights transfer – for instance, debiting procedures at the pump – will require physical modifications which inevitably take time. This said, the necessary modifications might well happen quickly as fuel distributors will wish to attract customers who want to participate in the rights market.

If stakeholders are free to enter the market, the incentive for them to do so will implicitly be the existence of a "$CO_2$ tax", provided that the latter, driven by governments, remains higher than the price of fuel rights on the market. The other role of the "$CO_2$ tax" is to ensure fair treatment while avoiding ways out of emission reduction requirements.

For political and practical reasons, the different fuel rights markets could be introduced separately, i.e. on different dates for the freight transport and private car sectors. Of course, for a complete coverage, public transport operators should be included in the scheme for passenger transportation, along with private car owners. These operators would have to return fuel rights in proportion of the fuel they consume to transport their passengers. However, they could get a free allocation, at least in the first years of the scheme, which would be granted by the local or regional governments as part of their transport policy and their liability of $CO_2$ emissions in their administrative area of competence (see the discussion on this last issue in section 1).

The crucial point is that as soon as at least one of the markets is implemented a general "$CO_2$ tax" is established for all of the agents not yet concerned. To ensure the acceptability of these measures, the tax should be reasonably low to begin with, with increases to be phased in over

several years announced in advance. This will mean that the different markets will have to be established within a short timeframe.

Last, the previous proposals have left open the issue of a single market for quotas trading, that is to say the same price of a $CO_2$ tonne for the different sectors, whether transport or not.

## 5 CONCLUSIONS

Decentralised permit markets in the transport sector have a potential to be more effective in making this sector share the burden of reducing $CO_2$ emissions since agents are more sensitive to quantitative signals than price signals in this area. Moreover, operation of the current European ETS and projects of trading schemes in other regions in the world indicate ways of international coordination and potential for inclusion of international (freight and air) transport in these schemes.

Permit markets also allow the separation of issues relating to economic efficiency and equity of emissions reduction schemes. In terms of $CO_2$ emissions reductions, the free allocation of fuel consumption rights to households is a pragmatic response to concerns about fairness. Moreover, given the current high levels of fuel taxes for example in Europe, this type of allocation would make a programme of rationing fuel by quantity rather than price more acceptable.

In addition, the free allocation would provide a strong incentive to reduce fossil fuel consumption because of the tangible advantages to be gained by anyone who cuts their consumption to a level below their initial rights allocation.

However this makes the issue of equity more obvious, especially regarding the distribution of free rights to households. Preliminary analyses on French data show encouraging results regarding the progressive character of the distribution effect but that needs to be more fully explored.

Whether implementing a domestic tradable fuel rights scheme for personal travel or an European wide scheme for freight transport, border effects will need a thorough examination. It should be underlined that this is not specific to permits schemes but also applies to taxation schemes.

The basic objection to the implementation of decentralised fuel rights markets in the transport sector is that the costs of implementation would be much too high for the desired results given the very large number of actors concerned. The proposals set out above, for both private vehicle users and freight transport are intended to reduce these costs as much as possible: they avoid complex calculations of allocations. The only remaining costs are the costs of monitoring emissions and managing fuel rights transactions: both are achieved by electronic procedures at least cost when purchasing “at the pump”.

As a first guess, the administrative cost of operating fuel rights markets would be higher than simply extending current taxes on fuel. That may be the price to be paid for an effective involvement of the transport sector in the effort to reduce emissions.

However accurate assessment of these costs still remains to be done, e.g. management and monitoring of quota accounts, and that is a first direction for future research. The second direction is to empirically evaluate the acceptability of using quotas rather than tax schemes and compare the cost-efficiency of both schemes.

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## 7 REFERENCES

Banfi, S., Filippini, M., Hunt, L. C. (2005) Fuel tourism in border regions: The case of Switzerland, *Energy Economics*, Volume 27, Issue 5, September 2005, 689-707.

Baumol, W., Oates, W. (1988) *The theory of environmental policy*. Cambridge University Press, Cambridge, 299p.

Brons, M., Nijkamp, P., Pels, E., Rietveld, P. (2006) *A Meta-analysis of the Price Elasticity of Gasoline Demand. A System of Equations Approach*, Tinbergen Institute Discussion Paper, TI 2006-106/3.

CEC (2002) *Proposal for a Council Directive amending Directive 92/81/EEC and Directive 92/82/EEC to introduce special tax arrangements for diesel fuel used for commercial purposes and to align the excise duties on petrol and diesel fuel. COM(2002) 410 final*, Brussels, Commission of the European Communities, November 2002.

CEC (2006) *Proposal for a Directive of the European Parliament and of the Council of 20 December 2006 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community COM(2006) 818*, Commission of the European Communities, Brussels.

Coase, R. (1960), The problem of Social Cost. *Journal of Law and Economics*, 3: 1-44.

Dales, J.H. (1968), Land, water and ownership. *Canadian Journal of Economics*, 1: 797-804.

Foster, V., Hahn, R. (1995) Designing more efficient markets: lessons from Los Angeles Smog Control. *Journal of Law and Economics*, 38:19-48.

German, J. (2006) Reducing Vehicle Emissions Through Cap-and-Trade Schemes. In Sperling, D. and Cannon J., S. (eds) *Driving Climate Change. Cutting Carbon from Transportation*. Elsevier, 2006, pp. 89-105.

Godard, O. (2000) L'expérience américaine des permis négociables. *Économie Internationale* 82: 13-43.

Godard, O. (2005), Politique de l'effet de serre - Une évaluation du plan français de quotas de $CO_2$, *Revue française d'économie*, XIX(4), 147-186.

Goodwin, P.B. (1988) *Evidence on car and public transport demand elasticities 1980-1988*, TSU Ref 427, Oxford, June 1988.

Graham, D. J., Glaister, S. (2002) The Demand for Automobile Fuel. A Survey of Elasticities. *Journal of Transport Economics and Policy*, Volume 36, Part 1, January 2002, 1-26.

Hahn, R., Hester, G. (1989) Marketable permits: lessons for theory and practice. *Ecology Law Quarterly*, 16: 361-406.

Hivert, L. (1999) *Le parc automobile des ménages. Etude en fin d'année 1997*. Rapport de convention INRETS-ADEME. INRETS, Arcueil, Juin 1999.

Lyons, A., Chatterjee, K. (eds) (2002) *Transport Lessons from the Fuel Tax Protests of 2000*. Ashgate, Aldershot.

Montgomery, W.D. (1972) Markets and licenses and efficient pollution control programs. *Journal of Economic Theory*, 5: 395-418.

Nordhaus, R. R., Danish K. W. (2003) *Designing a mandatory greenhouse gas reduction program for the U.S.* Pew Centre on Global Climate Change. Arlington, VA. May 2003, 66 p.

Nordhaus, W.D. (2006) After Kyoto: Alternative Mechanisms to Control Global Warming. *American Economic Review*, vol. 96, no. 2 (May), 2006, 31-34.

OECD (1997) *Putting Markets to Work. The Design and Use of Marketable Permits and Obligations.* Organisation for Economic Cooperation and Development, Public Management Occasional Paper 19, Paris.

OECD (1998) *Lessons from Existing Trading Systems for International Greenhouse Gas Emissions Trading*. Organisation for Economic Cooperation and Development, Environment Directorate. Paris.

OECD (2001) *Domestic Transferable Permits for Environmental Management. Design and Implementation*. Organisation for Economic Cooperation and Development, Paris.

OECD (2007) *Cutting Transport $CO_2$ Emissions. What Progress?* OECD-ECMT, Paris.

Open Europe (2007) *Europe's dirty secret: Why the EU Emissions Trading Scheme isn't working*. Open Europe, London, August 2007, 57 p.

Parry, I.W.H., Walls, M., Harrington, W. (2007) *Automobile Externalities and Policies*. Discussion Paper 06-26. Resources For the Future, Washington, 37 p.

Raux, C. (2004) The use of transferable permits in transport policy. *Transportation Research Part D*. Vol 9/3, 185-197.

Raux, C., Marlot, G. (2005) A System of Tradable $CO_2$ Permits Applied to Fuel Consumption by Motorists. *Transport Policy*, 12 (2005) 255-265.

Rietveld, P., Bruinsma, F. R., van Vuuren, D. J. (2001) Spatial graduation of fuel taxes; consequences for cross-border and domestic fuelling, *Transportation Research Part A*: Policy and Practice, Volume 35, Issue 5, 433-457.

Roberts, M. J., Spence, M. (1976) Effluent charges and licenses under uncertainty. *Journal of Public Economics*, vol. 5(3-4), 193-208

Salon, D., Sperling, D. (2008) *City Carbon Budgets: A Policy Mechanism to Reduce Vehicle Travel and Greenhouse Gas Emission*. OECD / ITF, 2008, 17 p.

SESP (2006) *Les comptes des transports en 2005* (tome 1). http://www.statistiques.equipement.gouv.fr/

Stavins, R. (1995) Transaction costs and tradable permits. *Journal of Environmental Economics and Management*, 29: 133-148.

Stern, N. (2006) *Stern Review on Economics of Climate Change. Executive Summary*. http://www.hm-treasury.gov.uk/media/4/3/Executive_Summary.pdf

Weitzman, M.L. (1974) Price vs. Quantities. *The Review of Economic Studies*, Vol. 41, No. 4 (Oct. 1974), 477-491.

Winkelman, S., Hargrave, T., Vanderlan, C. (2000) *Transportation and Domestic Greenhouse Gas Emission Trading*. Center for Clean Air Policy. April 2000, 32 p.