ROAD TRANSPORT EXTERNALITIES AND ECONOMIC POLICIES: A SURVEY

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ABSTRACT

Road transport imposes negative externalities on society. These externalities include environmental and road damage, accidents, congestion, and oil dependence. The cost of these externalities to society is in general not reflected in the current market prices in the road transport sector.

An efficient mobility model for the future must take into account the true costs of transport and its regulatory framework will need to create incentives for people to make sustainable transport choices. This paper discusses the use of economic instruments to correct road transport externalities, but gives relatively more weight to the problem of carbon emissions from road transport, as this is particularly challenging, given its global and long-term nature.

Economics offers two types of instruments for addressing the problem of transport externalities: command-and-control and incentive-based policies.

Command-and-control policies are government regulations which force consumers and producers to change their behaviour. Incentive-based policies function within a new or an altered market.

Governments have many effective economic instruments to create a sustainable road transport model. These instruments can be used separately or together, but their implementation will be necessary in the nearest future.

Keywords: Road transport externalities. Corrective charges. Cap-and-trade. Scrappage schemes. Subsidies.

INTRODUCTION

Road transport plays an essential role in today's world economy. For example, in 2004 the road share of passenger-kilometres was 89 per cent for the USA and 85 per cent for the EU-25 (Eurostat, 2007, Table 5.24, p.103). In 2003 the road share of tonne-kilometres was 33.4 per cent for the USA and 72 per cent for the EU-25 (Eurostat, 2007, Table 5.1).

An efficient equilibrium is defined as a situation in which marginal social costs are equal to marginal social benefits. Externalities are a form of market failure, which means that the market is incapable of reaching an efficient equilibrium.

From an economic point of view, policies to reduce negative externalities can be divided in two groups: command-and-control (CAC) and incentive based (IB). IB mechanisms can be further categorised into price controls and quantity controls.

A CAC policy is essentially a regulation, or a "command", which needs to be "controlled" or enforced. When there is an externality, the regulator (or government) can impose a maximum level of the activity causing it, or a restriction over the behaviour of economic agents, or characteristics of products. CAC measures give rise to predictable outcomes and are relatively easy to implement, enforce, and understand (Button, 1990). However, they are inflexible and they do not provide incentives to go beyond the mandatory standard (Button, 1990). Every time a change is envisaged, the measure needs to be revised, thus leading to an additional bureaucratic burden.

IB policies, on the other hand, provide economic incentives to the targeted agents and act to directly alter private utility or private benefit from a given behavioural response.

Consequently, they are crucial instruments to induce behavioural change. They essentially correct market failures by equating social costs and benefits.

Although the idea of corrective instruments to equate marginal social costs with marginal social benefits is attractive in theory, there are three problems associated with the implementation of such instruments in the transport sector.[1] The first problem is that the marginal external cost imposed by vehicles is not easy to measure. Even when the marginal physical damage can be assessed, monetisation is not always straightforward. Hence, typically, it is virtually impossible to implement first best policies.[2] The second problem relates to the fact that any new instrument will usually be introduced in a system characterised by pre-existing corrective instruments and regulations. As a consequence, the interaction between new and existing instruments may lead to over-charging (thus, double-internalising the externality) and therefore to inefficient outcomes that reduce welfare (Zatti, 2004). The third problem is that even in the case where marginal external costs could be perfectly measured and first best policies implemented in the road transport sector, there would be no guarantee of an efficient outcome due to distortions in other (related) sectors in the economy, which are not priced according to marginal cost. For example, inefficiencies caused by adverse selection in the insurance sector, will affect the efficiency of the road transport sector. Another important example of a related sector is the labour market, which does not typically operate perfectly, mainly due to the presence of distortionary labour taxes (Verhoef, 2000, p.328).

Bearing that caveat in mind, this paper reviews road transport economic policies. There is consensus in the literature that the most important negative externalities from road transport include accidents, road damage, environmental damage, congestion and oil dependence (Newbery, 1990; Parry et al., 2007; Small and Verhoef, 2007; Maibach et al., 2008). In the sections that follow we survey policies to tackle climate change and to a lesser extent, congestion, with the objective of providing some assessment on their success or failure and concluding with some specific recommendations for policy makers. Before moving on to that, however, we present a brief theoretical section, with some basic concepts and comparisons.

1 The problems are common to other areas of the economy as well.
2 At most, it might be possible to impose an ex-ante expected first-best policy.

A BRIEF THEORETICAL OVERVIEW

Command-and control vs Incentive based policies

The main advantage of IB (both price and quantity control) instruments over CAC ones is their cost effectiveness. Economic agents (producers or consumers) with low costs of abatement will find it relatively easier to reduce their level of externality than to buy permits or pay taxes, whilst those with high costs of abatement will prefer to buy permits or pay taxes. The cost of reducing the externality is thus minimised compared to the more direct regulatory approach of setting standards (Baumol and Oates, 1988, Chapters 6 and 8). Having said that, the magnitude of these cost savings varies greatly across specific cases (Newell and Stavins, 2003, p.46). Tietenberg (1985, in Newell and Stavins, 2003) compares the costs of air pollution control across ten different examples and finds ratios ranging from 1.1 to 22.[3]

Another advantage of IB instruments over CAC is that they lead to self-revelation of private information through the choice made by regulated consumers or producers; and they exploit the market's capability of private information aggregation (Hepburn, 2006, p.228). This makes IB instruments more efficient to CAC measures when the information basis is not complete and cannot be inferred by the regulator. The advantage of IB instruments over CAC is particularly marked when the regulated entities are not homogeneous[4] and their optimal response is not uniform (Hepburn, 2006, p.228-229), or when there are time and spatial variations in problems (European Commission, 1995).

However, IB mechanisms can lead to market failures and blunt miss of objectives. This can happen, as explained in Section 1, when incentives are not correctly calibrated due to difficulties in determining the marginal external cost (and therefore of efficient level of activity), the system already having corrective instruments and regulations in place (whose effects will be added to the new IB instrument's), and the presence of distortions in other (related) sectors in the economy. In these cases, the effectiveness of the instruments in meeting the targets may be impaired. Transaction and implementation costs may also be higher for IB mechanisms than for CAC, due to the need of advanced monitoring systems (European Commission, 1995). However, costs are likely to decrease as technology progresses.

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3 Newell and Stavins (2003) attempt to fill the niche in research on the relationship between the nature and magnitude of the heterogeneity in abatement costs and the potential cost savings from IB instruments. The develop an analytical framework linking cost savings from IB instruments relative to CAC and different sources of heterogeneity in abatement costs, including the slope of the marginal cost curve, baseline emissions and firm size.

4 Permit trading provisions may, however, solve the cost heterogeneity problem.

Finally, CAC may be preferable to IB instruments when there are no informational asymmetries, there is little risk of government failure, and the regulated entities are required to respond in the same way. An instance when CAC would be advisable is when the optimal level of an externality, for example a certain polluting activity, is zero. The activity in this case should simply be banned (Hepburn, 2006). This happens when after reducing emissions by 100 per cent the marginal social benefit is higher than the marginal social cost. Obvious cases of this are bans on the use of dichlorodiphenyltrichloroethane (DDT) as a pesticide and asbestos in construction, which were implemented by many countries in the 1980s.

Incentive based: Quantity vs Price control under asymmetric information

A cap-and-trade system guarantees a quantity of externality or activity producing the externality, regardless of the abatement costs. A tax, on the assumption that polluters (either consumers or producers) are cost minimisers, guarantees that the marginal abatement cost will be equated to the tax, regardless of the resulting quantity of the externality or activity producing the externality (Baumol and Oates, Chapter 5).

Under perfect information a system of Pigouvian taxes and a system of marketable permits are equivalent and yield the same efficient outcome. In general 'it is neither easier nor harder to name the right prices than the right quantities because in principle exactly the same information is needed to correctly specify either' (Weitzman 1974, p.478).[5] If the optimal number of permits is issued by the regulator, their price will be bid up on the free market to precisely the level of the Pigouvian tax. At that point, it makes no difference to the polluter whether he pays a tax equal to his marginal external cost to the authorities, or whether he pays that same amount to buy permits that will allow him to produce the same level of externality and marginal external cost (Baumol and Oates, 1988, Chapter 5).

In an imperfect information setting, the conclusions are very different. Lack of enough relevant information on the part of the regulator is a crucial factor that can lead to regulatory failure under price as well as under quantity control mechanisms.

The source of uncertainty can lie in the marginal abatement cost curve or in the marginal social benefit curve. When there is perfect information regarding marginal abatement costs but lack of information regarding marginal social benefits, the policy, either taxes or permits, will not be optimal. The cost of the error, however, will be the same under either policy (Weitzman, 1974, in Baumol and Oates, 1988) and so in the presence of uncertainty with

5 It should be noted, however, that in the case of road transport most pollutants with local or regional impacts, exhibit a marginal damage curve which is approximately flat. In such cases, the optimal tax will be the same, regardless of the shape of the demand (or marginal social benefit) curve. Under these assumptions estimating the efficient tax requires less information than estimating the efficient quantity.

respect to marginal social benefits it makes no difference to choose one or the other. The reason for this is that the resulting permit price, after the regulator has determined what he thinks is the optimal quantity, and the resulting quantity, after the regulator has determined what he thinks is the optimal tax, depend exclusively on marginal abatement costs and are independent from marginal social benefits.

When there is imperfect information regarding marginal abatement costs, the outcome will be inefficient. In this case, the cost of the error under a permit or tax system may be different.

In general, both permits and taxes will yield inefficient outcomes. When the assumed marginal abatement costs are lower than the actual ones, the reduction of the externality under a cap-and-trade system will not be enough, and the reduction of the externality under a tax will be excessive. The opposite holds when the assumed marginal abatement costs are higher than the actual ones (Baumol and Oates, Chapter 5).

The inefficiency arising from lack of information on marginal abatements costs under permits and taxes depends on the relative slopes of the marginal abatement cost and marginal social benefit functions. An important result from Weitzman (1974), digested in Baumol and Oates (Chapter 5) is that:

- When the marginal social benefit and the marginal abatement cost curves are linear and the absolute values of their slopes are equal, the magnitude of the distortion caused by cap-and-trade and a tax will be identical (p.67).
- The steeper the slope of the marginal social benefit curve, the less severe the magnitude of the distortion caused by a cap-and-trade system will be, compared to that of a tax (p.64).
- The steeper the slope of the marginal abatement cost curve, the more severe the magnitude of the distortion caused by a cap-and-trade system will be, compared to that of tax (p.66).

Finally, when the slope of the marginal benefit and marginal cost curves are both uncertain, quantity control will in general be preferred, since ‘prices can be a disastrous choice of instrument far more often than quantities can’ (Weitzman, 1974).

Taxation leads to price stability, while permits may lead to price fluctuations. The volatility associated with permits will add up to the intrinsic uncertainty over returns in technology development, and may reduce investment incentives by risk-averse firms (Gallagher et al., 2007, p.18). Risk-aversion therefore may play a role in instrument selection. All else being equal, when the regulated entities are risk-averse, price control tends to be preferred to quantity control. In fact, the volatility of cap-and-trade systems may be avoided through taxation (Baldursson and von der Fehr, 2004 in Hepburn, 2006).

Other considerations that go beyond pure economic theory are also relevant in instrument selection. For example, regardless of any efficiency criteria, permits tend to be more costly in regulatory terms, in the sense that they require an institutional setting, definition of property rights and initial allocation, and enforcement procedures (Helm, 2005, p.212). Taxes, on the other hand, require relatively lower monitoring and enforcement expenditures (Gallagher et al., 2007). In general, policy is not designed to follow economic principles but rather to maximise votes (Helm 2005, p.213).

Hybrid instruments also constitute an alternative. These combine price and quantity instruments. An example is a cap-and-trade scheme with a price ceiling or price floor. The government commits to selling or buying permits at a certain price when the market price hits the ceiling or the floor (Hepburn, 2006, p.230). Finally, a multiple instrument package can also be implemented (Hepburn, 2006, p.231). Such a package can include permits, taxes, subsidies and regulations. The danger in this case, in terms of efficiency, is the double-charging or double-penalising of an externality, as its reduction in that case would be excessive.

Aldy et al. (2008) discuss the design of CO_2 taxes at the domestic and international level and the choice of taxes versus permits. They find a strong case for taxes on uncertainty, fiscal, and distributional grounds, especially if permits are grandfathered. First, taxes provide certainty with respect to the price for emissions, and therefore the marginal abatement costs, whilst permits fix quantity but not price, which fluctuates with market conditions, and hence, the uncertainty is larger. Second, unlike permits distributed for free, taxes offer revenues to the government, helping a healthier fiscal balance. These revenues can then be used to reduce distortionary taxes in the economy, thus increasing efficiency. Third, governments can use revenues from CO_2 taxes or auctioned permits to benefit lower income groups, thus reducing any initial regressive effects. They point out that the main disadvantage of taxes is that if they were implemented at an international level, individual countries could reduce other taxes, even taxes on sources of other GHSs, to offset the burden. To solve this problem they propose a CO_2 tax which takes into account pre-existing energy taxes or subsidies.

COMMAND-AND-CONTROL IN ROAD TRANSPORT

CAC policies are not efficient from an economic point of view: even in a context of perfect information when the regulation or standard is set at the optimal level, the target is not achieved at minimum cost and, worse yet, the social costs could exceed the potential benefits (thus replacing market failure with government failure). Despite being inefficient policy instruments, they are the most widely-used ones to regulate environmental and other externalities. In many cases, however, the choice of instrument is justified by the severity of the problem, with the extreme case of lethal fumes being the prototype example.

The transport sector is no exception, and throughout the world there is a plethora of examples of CAC policies targeting different transport externalities. In this section, some of these examples are briefly described and discussed, mainly to illustrate how the regulations were set and to give an idea of their success or failure.

Fuel standards

These are standards that countries impose on vehicle fuels. The most notable example is the ban on lead in petrol, which has been implemented virtually all over the world as of 2010, mainly due to its effects on children's brains. Other pollutants which have been reduced or phased out include benzene and sulphur dioxide.

Much less common, at least for the time being, are regulations on CO_2 emissions from fuel. One exception is the Low Carbon Fuel Standard, introduced by the state of California in 2007. The Low Carbon Fuel Standard requires fuel providers to reduce greenhouse gas (GHG) emissions of the fuel they sell. The programme intends to achieve a 10 per cent reduction in the carbon intensity of transport fuels by 2020 (Farrell and Sperling, 2007).

Vehicle standards

Vehicle standards regulate vehicle fuel efficiency, tailpipe emissions and safety. The main systems of **vehicle emission standards** are those from the US and the EU, although countries such as Australia, China, Japan, Switzerland, South Korea and Taiwan have also implemented some type of fuel economy or CO_2 standard (Clerides and Zachariadis, 2008, p.2658).

In the US, for example, the Corporate Average Fuel Economy (CAFE) was introduced in 1975 and is still in place as of 2010. The purpose of CAFE is to reduce energy consumption by increasing the fuel economy of cars and vans.

Although consumers may regard CAFE as a good policy (all else being equal, they spend less on fuel to drive the same distance, or they spend the same and drive more), CAFE has been seen as an inefficient CAC policy for two reasons: (a) it encourages excess investment in fuel efficiency and distorts the mix of large and small vehicles (Godek, 1997, p.495) and (b) it is less cost effective than fuel taxes at reducing petrol consumption because by lowering fuel costs per km driven it increases (rather than reduces) vehicle use (Kleit, 2004; Austin and Dinan, 2005; West and Williams, 2005; Parry, 2007, in Fischer et al., 2007).

In the EU in 2008, the European Parliament voted to adopt a regulation with mandatory reductions of emissions of CO_2 to reach an objective of 130 grams of CO_2 per km for the average new car fleet by the year 2012. This will be achieved through improvements in vehicle motor technology and by other technological improvements, such as fuel-efficient tyres and air conditioning, traffic management and eco-driving, and by an increased use of biofuels. The decision was taken because previous targets to reduce CO_2 emissions had relied on voluntary commitments from car manufacturers, improvements in consumer information and the option of individual countries implementing fiscal measures, all of which had failed.

Clerides and Zachariadis (2008) explore the impacts of fuel standards (and also of fuel taxes) on new car fuel economy in Australia, Canada, the European Union, Japan and the US, in the period 1975-2003. They find that fuel standards contribute to fuel economy improvements in the US, Europe and Japan. They also find that new car fuel economy becomes less sensitive to fuel prices after the implementation of standards (p.2671) and show that in Europe and Japan the impact of a fuel economy standard on new car fuel consumption has usually been more pronounced than that of an increase in fuel prices (p.2671).

Although fuel economy standards have had impacts on fuel economy, Aldy et al. (2008, p.496) argue that standards for the average fuel economy of vehicles in a manufacturer's sales fleet do not encourage mitigation outside the automobile industry, or downstream sequestration activities, or reduction in road user mileage. Portney et al. (2003) conclude that fuel taxes (or carbon taxes) and tradeable permits would make more efficient tools for reducing fuel consumption and GHG emissions. One way of making fuel standards slightly more efficient, they suggest, would be to provide some flexibility by making fuel economy credits transferable between car and van fleets and between different manufacturers (p.216).

Other CAC policies in the road transport sector

Other CAC policies include restrictions on vehicle circulation, vehicle ownership, parking, and emissions in certain areas or on certain days. In London, for example, there is a 'Low Emission Zone', which was implemented in February 2008 and covers most of Greater London, broadly defined as the area inside the M25 motorway. The main objective of the scheme is to deter the most polluting diesel vehicles from driving inside Greater London.

Restrictions to circulation are another CAC policy, which has been widely implemented in towns and cities throughout the world. It is very common to see pedestrianisation of streets, which are closed to traffic at all or some times of the day. It is also common to see streets where only public transport and taxis can circulate. Many (historic) towns in Europe have such types of areas.

Another type of road space rationing has been to restrict certain license plates from circulating. Such a policy can be found in cities like Athens and Mexico City, where cars with even (odd) number plates are allowed to drive on even (odd) days only. The problem with this type of policy is that even if the final number of vehicles using the road as a result of this type of policy were optimal from an economic point of view, there is no guarantee that the most efficient trips, with the highest marginal benefit (made by those drivers with the highest willingness to pay) would be the ones taking place (Verhoef et al., 1995, p.141). In Mexico City the restrictions led to an increase in the total number of vehicles in circulation as well as a change in composition towards high-emissions vehicles (Davis, 2008), as many households bought an additional car to be able to drive on any day of the week and the amount of driving increased (Eskeland and Feyzioglu, 1997).

Another way of controlling vehicle use is through restrictions on vehicle ownership. The only example of a direct quantity control of this sort is the Vehicle Quota System (VQS), a policy implemented in Singapore in 1990 and still in place today.

Prospective vehicle owners are required to purchase a Certificate of Entitlement (COE), which is a licence that lasts ten years. The government sets a quota on COEs for different vehicle categories a year in advance and the allocation of COEs is done through open auction. When a person submits a bid (something which is done electronically) the current successful price is known and the person can adjust his bid. As the number of bids usually exceeds the set quota, there are usually unsuccessful bidders.

Since there are bids this policy can be seen as an incentive based rather than a command-and-control one. However, the COEs are not tradeable, so the policy cannot be classified under the cap-and-trade umbrella. It falls into a grey area.

It is also worth mentioning parking restrictions. These can indirectly reduce traffic levels, and in doing so reduce most traffic externalities. Verhoef et al. (1995) show that under strict assumptions (each individual drives the same distance, congestion is equally spread over the urban road network, the regulator has full control over all parking space available, every car is parked in a publicly managed parking space, and all cars are parked for the same length of time) quantitative restrictions on parking can achieve the optimal volume of traffic in terms of marginal congestion costs and marginal parking costs,[6] just as they would with an IB policy. However, they point out that there would be no guarantee that the most valuable trips would be the ones realised. They also note that under quantity restrictions on parking, a market for parking permits could develop spontaneously, as drivers would try to secure parking for the most valuable trips.

Finally, reducing the number of parking spaces available, could result in more congestion, as more drivers would spend time looking for an available parking slot (Arnott and Rowse, 1999, Arnott and Inci, 2006).

6 This result can probably be extended to other externalities.

INCENTIVE BASED POLICIES: TRADEABLE PERMITS IN ROAD TRANSPORT

An IB policy based on quantity control is a system of marketable (transferable or tradeable) permits, credits, allowances or rights in which the regulator determines a cap or *aggregate* quantity of emissions, pollution or waste and leaves their allocation amongst the polluters to be determined by the market (Baumol and Oates, 1988, p.59).

There are three steps involved in implementing and maintaining a system of this sort. First, the regulator sets the quantity or aggregate quota. Second, the regulator allocates the permits, which together do not exceed the cap. There are mainly two allocation methods: grandfathering and auctioning. These can be used in their pure form or they can be combined. With grandfathering, permits are allocated for free to each polluter, according to their past (historic) emissions. With auctioning, polluters pay for the permits they wish to buy, according to the price that emerges from the auction. Third, emitters trade their permits. Usually, those with lower marginal abatement costs sell permits and those with higher abatement costs buy permits. Permit trading amongst sources establishes the market-clearing price.

The biggest tradeable permit system to have ever been implemented is the EU Emission Trading Scheme (EU ETS), implemented at European level to help achieve the Kyoto target of an 8 per cent emission reduction of GHG in the EU by 2012. The EU ETS only covers emissions of CO_2. For the first two trading periods, 2005-2007 and 2008-2012, aggregated emission caps were imposed on the most energy-intensive sectors (cement, glass, ceramics, paper, steel and iron, and power) (European Commission, 2003, Annex I), which were responsible for more than half of EU CO_2 emissions from 2005 to 2007 (European Commission, 2005, p.5). Permit allocation is made through grandfathering and combined with a very small percentage of auctioning (5 per cent and 10 per cent at most, for the first and second periods respectively).

Aviation will be included in the EU ETS from 2012 and as of 2010 there are already some discussions about the prospects of including road transport as well (UK DfT, 2007).

If a cap-and-trade system were to be implemented in the road transport sector, there would be a number of issues to consider. The UK DfT (2007), Albrecht (2001) and Grubb and Neuhoff (2006) highlight a number of points that need to be assessed and decided upon the introduction of a cap-and-trade system for CO_2 emissions (in the road transport sector). These are:

- Allocation of permits:

  - How to allocate (auctioning vs. grandfathering)
  - Whom to allocate (individual motorists, vehicle manufacturers, fuel producers)
  - How many permits to allocate (cap on emissions)
- Area of applicability of the policy (regional, national, international)
- Duration of the permit (time scale)
- Decision over whether the emission trading scheme is a stand-alone scheme, or part of a broader emission trading scheme across-sectors
- Interaction of the road transport emission trading scheme with other schemes, such as the EU ETS, and other policies, such as fuel taxation
- Credibility of the scheme continuation
- Costs and benefits for firms, road users and government
- Long-term marginal abatement costs (which in transport depend on intermodal shifts, penetration of highly fuel efficient vehicles, and behavioural change, amongst others)

Ellerman et al. (2006) point out that the main challenges in the introduction of emission trading schemes in the transport sector come from the fact that emission sources are small, dispersed and mobile, hence difficult and costly to monitor, and from the fact that the transport sector is already highly regulated.

Auctioning vs grandfathering

The way in which permits are allocated to the relevant parties is important. The two ends of the spectrum are grandfathering and auctioning.

Auctioning creates revenues for the government, which can be redistributed in the form of, for example, tax cuts (Cramton and Kerr, 1999, p.256). Hence, the use of auctioning has the potential to correct distributional impacts. Revenues from auctioning permits to fuel producers could also be channelled into investments in transport infrastructure, public transport, R&D of cleaner technologies, etc. However, it has been argued that individuals or entities with greater financial power are in a better position to buy as many permits as they require during the auctioning phase, thus threatening equity (although upper regulatory limits could be imposed to prevent this effect) (Watters and Tight, 2007, p.6). Finally, auctioning provides more transparency and clearer long-term price signals compared to grandfathering. Periodic auctions could improve price stability and the management of uncertainty (Hepburn et al., 2006, p.147).

Auctioning is to be preferred to grandfathering also from a dynamic perspective in relation to the incentives it creates. Theoretically, auctioning enhances incentives for innovation. This is due to the fact that innovation ultimately leads to a decrease in demand for permits, and consequently a decrease in prices of permits. This reduces the scarcity rents which belong to the industry under a grandfathering scheme, but do not under auctioning (Cramton and Kerr, 2002).

In addition, grandfathering may lead to perverse dynamic incentives in emissions reduction.

The case for free allocation of permits is mainly due to the fact that it minimises problems of social and political acceptability (Raux and Marlot, 2005). Also, in some instances, free allocation may be administratively less costly. If an emission trading scheme were to be implemented amongst motorists, free allocation would allow at least a certain amount of fuel to be consumed at no additional cost (Raux and Marlot, 2005). Even taking into account the opportunity cost for a motorist of not selling the permit, this opportunity cost would be the lost revenue but would not be an "additional" cost on top of what he paid for fuel previously. Auctioning permits to such a large number of individuals would not be practically feasible. Grandfathering has already been shown to involve lobbying activities to get the preferred allocation (Hepburn, 2007), and this would cause a loss of resources. Also, a grandfathering allocation of permits among drivers would involve administrative costs to collect the historic data necessary for the allocation.

Target group

The question of whom the permits should be allocated to - fuel producers, vehicle manufacturers, or individual motorists - is not easy to answer, and we shall evaluate each option separately.

If the target group were fuel producers, they would be required to hold permits to cover the total amount of emissions resulting from the fuel they sell (UK DfT, 2007). Oil refineries in the EU are currently included in the EU ETS on the basis of their direct combustion emissions, i.e. CO_2 emitted during the fuel production process. They are therefore already familiar with the EU ETS. In the UK, regulating twenty fuel producers would cover 99 per cent of fuel sales (UK DfT, 2007). This means that the administrative costs of this option would be relatively low. However, fuel producers have few tools at their disposal for reducing emissions, mainly efficiency increases in the production process and the alteration of carbon composition of petrol. The main effect of emission trading in the short run will be an increase in fuel prices, as refineries are likely to pass on at least part of the cost of emission trading permits to consumers. The likely short-term effect of the policy is a non-equitable regressive effect, similar to that of an additional tax on fuel (Watters and Tight, 2007). A tax would have the advantage of being less volatile, more easily adjustable, and requiring less monitoring. The exact burden share between refineries and final consumers of fuel would depend on supply constraints and the level of competition, amongst other factors (Millard-Ball, 2009).

By and large, the main short-term impact on emissions of upstream trading would be a reduction in fuel consumption due to an increase in fuel prices (UK DfT, 2007). Short-term responses by motorists would be a reduction in the amount of travel and adoption of a more responsible travel behaviour (such as for example, eco-driving, using public transport, walking or cycling, etc). In the long run, demand may lean more towards more fuel-efficient vehicles (UK DfT, 2007). Demand for vehicle travel is relatively inelastic, especially in the short term. Consequently, if the trading system was part of a multi-sector system (like the EU ETS), the transport sector would tend to purchase credits rather than reduce emissions itself. Hence, upstream trading would miss out on the potential for numerous low-cost transport abatement measures (Millard-Ball, 2008).

Another emission trading scheme option in the road transport sector would target vehicle manufacturers. Under such an arrangement, manufacturers would be required to purchase permits for emissions imputed to their vehicles (UK DfT, 2007; Millard-Ball, 2008). It would be difficult to retroactively cover all vehicles in circulation but it would certainly be possible to cover all new vehicles sold. The disadvantage with this approach is that it could potentially boost the second-hand market, increase second-hand car prices, prolong the life of fuel inefficient vehicles, and hit the new vehicle market.

Finally, the inclusion of individual motorists into the cap-and-trade scheme could occur under different formats:

- Motorists could be required to use permits against the purchase of fuel. Permits could be allocated for free by the regulator or auctioned. Individuals could then trade their permits. Bank operators or petrol stations could act as intermediaries in the purchase and sale of permits (Raux and Marlot, 2005). This would make this option similar to allocation to fuel producers (UK DfT, 2007). A problem with this option could be cross-border refuelling, unless and entire region adopted such a system.
- Motorists could be required to use permits against the purchase of a vehicle. The number of automobiles would be capped and vehicle ownership permits would be traded (Millard-Ball, 2008).
- Motorists could be required to use and trade parking permits or vehicle kilometres travelled allowances, or tradeable driving day rights.
- Motorists could be endowed with personal carbon quotas or domestic tradeable quotas to cover their entire carbon footprints, including personal transport emissions (Millard-Ball, 2008).

Although trading at individual motorist level could be extremely costly to implement and monitor it would also have a couple of advantages. First of all, the maximum efficiency of an economic incentive instrument is achieved when it operates at the most decentralised level (Raux and Marlot, 2005). Second, a large number of consumers would yield a large and liquid market for permits (Watters and Tight, 2007). In the short run the system would probably act as a disincentive on car usage. In the long run, it would act as an incentive to purchase low-emission vehicles. Finally, if permits were freely allocated in equal amount to motorists, the system would be perceived as equitable and politically acceptable (Watters and Tight, 2007).

Other considerations

If the road transport sector in Europe were included in the EU ETS drivers would probably become net buyers of permits, at least in the short-run. This would be likely to happen unless permit prices were so high that alternative technologies became attractive, or unless additional requirements were imposed. It should be stressed that motorists, fuel producers or car manufacturers becoming net buyers is a desirable characteristic of economic instruments and not an imperfection. Reductions would be made where the marginal abatement costs are lower, which would be in other sectors of the economy[7], rather than the road transport sector. If the regulator's objective were to guarantee a certain level of emission reduction from road transport, then a separate scheme (perhaps linked in some way) to the EU ETS would need to be designed.

Finally, transaction costs could potentially be very large and erode part of the benefits from carbon trading. This would apply to any of the three target groups (fuel producers, car manufacturers and individual motorists and hauliers).

INCENTIVE BASED POLICIES: FISCAL INSTRUMENTS IN ROAD TRANSPORT

Governments use taxes for two reasons: either to generate revenues and to redistribute part of the revenues to achieve a "fairer" distribution of resources in society and provide goods or services that the market by itself would not provide (such as for example, defence) or to correct market failures. The first type of taxes are distortive taxes, the second type are corrective taxes. What the two types of taxation have in common is that they act as incentives (or disincentives) on behaviour, by increasing the marginal cost of certain activities. What they differ on is that the first type of taxes is introduced in an otherwise efficient economy. Their introduction generates a deadweight loss, by 'inserting a wedge between marginal cost and price' (Cramton and Kerr, 2002, p.339). The second type of taxes, on the other hand, is introduced in an otherwise inefficient economy, in order to correct the distortions and change behaviour so as to restore efficiency.

Taxes in road transport can be introduced as either IB instruments to influence travellers' behaviour in such a way as to induce a given response that reduces or corrects market

7 However, Parry (2007) argues that the benefits from auctioned (rather than grandfathered) permits (and also taxes) to reduce road transport emissions are larger than the costs when account is taken of (a) their impact on reducing other road transport externalities such as accidents, congestion, local air pollution and oil dependence and (b) interactions with the broader fiscal system such as the use of revenues to reduce distortionary labour taxes.

failures, or as revenue raising instruments. The effectiveness of taxes as corrective instruments depends on the strength of the link between the externality they are targeting and the tax itself. If this link is weak, then drivers, polluters, or road users may respond in an inefficient way (Crawford and Smith, 1995, p.40).

Taxes and charges on road transport are used extensively throughout the developing and developed world. In what follows, we collate evidence of different types of road transport taxes and charges applied in different countries, their relative differences and, to the extent which is possible within a review, their impact.

Taxes on purchase and ownership of a vehicle

These taxes include registration taxes and annual vehicle excise duties. All European countries levy a value added tax (VAT) on the purchase of new motor vehicles, just as they do on purchases of most goods and services.[8] VAT rates vary between 15 per cent and 25 per cent, with Denmark, Hungary and Sweden at the higher end. Most countries also levy a registration tax, based on the pre-tax price, fuel consumption, cylinder capacity, CO_2 emissions and/or other emissions, and vehicle length (European Automobile Manufacturers' Association, 2009, p.1).[9]

The case of Singapore is worth highlighting, as it has very high ownership taxes. On top of the COE described above, motorists need to pay the Additional Registration Fee (ARF). The ARF is an *ad valorem* duty on a vehicle's open market value[10] payable by buyers of new motor vehicles, in addition to an administrative fee, referred to as the Basic Registration Fee. The ARF rate was raised through the 1970s, reaching 125 per cent in 1978 and 150 per cent in 1980 (Santos et al., 2004). However, as the ARF rate rose, it also discouraged existing vehicle owners from replacing their cars and encouraged new car buyers to buy used cars. Concerned with a stock of aging vehicles, when the applicable ARF rate was raised to 100 per cent in 1975, the government introduced a Preferential Additional Registration Fee (PARF) to counterbalance the disincentives on vehicle renewal. The purchaser of a new vehicle paid a substantially lower PARF rate if he de-registered an old vehicle (i.e. by exporting or scrapping it) of the same engine category at the time of his new purchase. Since 1997, the PARF has been amended to a system where the applicable discount is a function

[8] VAT is not a 'corrective' tax, but a typical revenue raising tax governments impose on the purchase of virtually all goods and services.

9 Bulgaria, the Czech Republic, Estonia, Germany, Lithuania, Luxemburg, Slovakia, Sweden and the UK do not have any registration tax (European Automobile Manufacturers' Association, 2009, p.1).

10 The open market value is essentially similar to Cost plus Insurance and Freight (CIF). It includes purchase price, freight, insurance and all other charges incidental to the sale and delivery of the car to Singapore.

of the age of the vehicle to be de-registered. Vehicles older than ten years no longer qualify for PARF treatment.

Annual ownership taxes, sometimes also called annual circulation taxes or vehicle excise duties, are levied in most countries, usually on private and commercial vehicles. In Europe, the criteria to set these taxes vary across countries. For cars these include cylinder capacity, fuel efficiency, vehicle age, gross weight, CO_2 and/or other emissions; and for commercial vehicles, which tend to be heavier and damage roads more, these depend mainly on weight and axles, although also on noise and CO_2 and/or other emissions (European Automobile Manufacturers' Association, 2009, p.2).

Ryan et al. (2009, p.373) find that annual ownership taxes, in contrast with registration taxes, show a strong impact on total new car sales in Europe. Consumers seem to be more sensitive to taxes they will pay every year for as long as they own the vehicle than to one-off registration taxes.

Taxes on usage of a vehicle

These taxes include fuel duties, which are levied in most countries, but also emission (or carbon) taxes and other charges.

Carbon tax and fuel duties

The idea of a carbon tax has frequently encountered public and political opposition, even more so than the idea of a cap-and-trade system. In 1992, 1995 and 1997 the European Commission advanced proposals for a European carbon tax (Vehmas et al., 1999, p.344). These, however, failed, due to strong opposition from industry and several member states (Richardson, 2002, p.194).

There are some countries in Europe that have implemented a carbon tax, but the efforts have never been coordinated or agreed at EU level. These countries are Finland, which introduced a carbon tax in 1990, Sweden and Norway, in 1991, the Netherlands in 1992, Denmark in 1993 (Richardson, 2002, p.194), and Italy, in 1999.

Although most countries argue that these carbon taxes have decreased CO_2 emissions to some extent (Vehmas, 2005, p.2180) the carbon tax component of the petrol and diesel duties have not made them significantly different from those applied in other countries, as it can be seen on Figure 1.

In July 2008 British Columbia in Canada implemented a carbon tax. It started at CA$10 (£5, €6.4, $9.4)[11] per tonne of carbon dioxide equivalent (CO2e)[12] and will rise by CA$5 per year reaching CA$30 in 2012. The petrol tax will then reach 7.24 Canadian cents per litre (British Columbia Government website), equivalent to 4.6 Euro-cents, which represent a very small increase relative to the current tax component of 22 Euro-cents shown on Figure 1.

Although fuel taxes are in place in most countries, they vary widely from one to another. In fact, no other product seems to be subject to such divergent treatment (Gupta and Mahler, 1995, p.101).

Figure 1 shows unleaded petrol taxes and prices for OECD countries during the third quarter of 2008 in € per litre.

As it can be easily seen from Figure 1, Mexico and the US have remarkably low petrol taxes, when compared to the rest of the OECD countries. Unsurprisingly there is not that much difference in the pre-tax price across countries, except, as expected, for Mexico. There is, however, considerable variation regarding taxes.

11 The average exchange rate in the period Jan-Dec 2008 was CA$1= £0.51= €0.64 = $0.94 (IMF Exchange Rate Query Tool).

12 Using a stoichiometric conversion factor of 44/12 = 3.6667, this is equivalent to CA$ 2.23 per tonne of carbon.

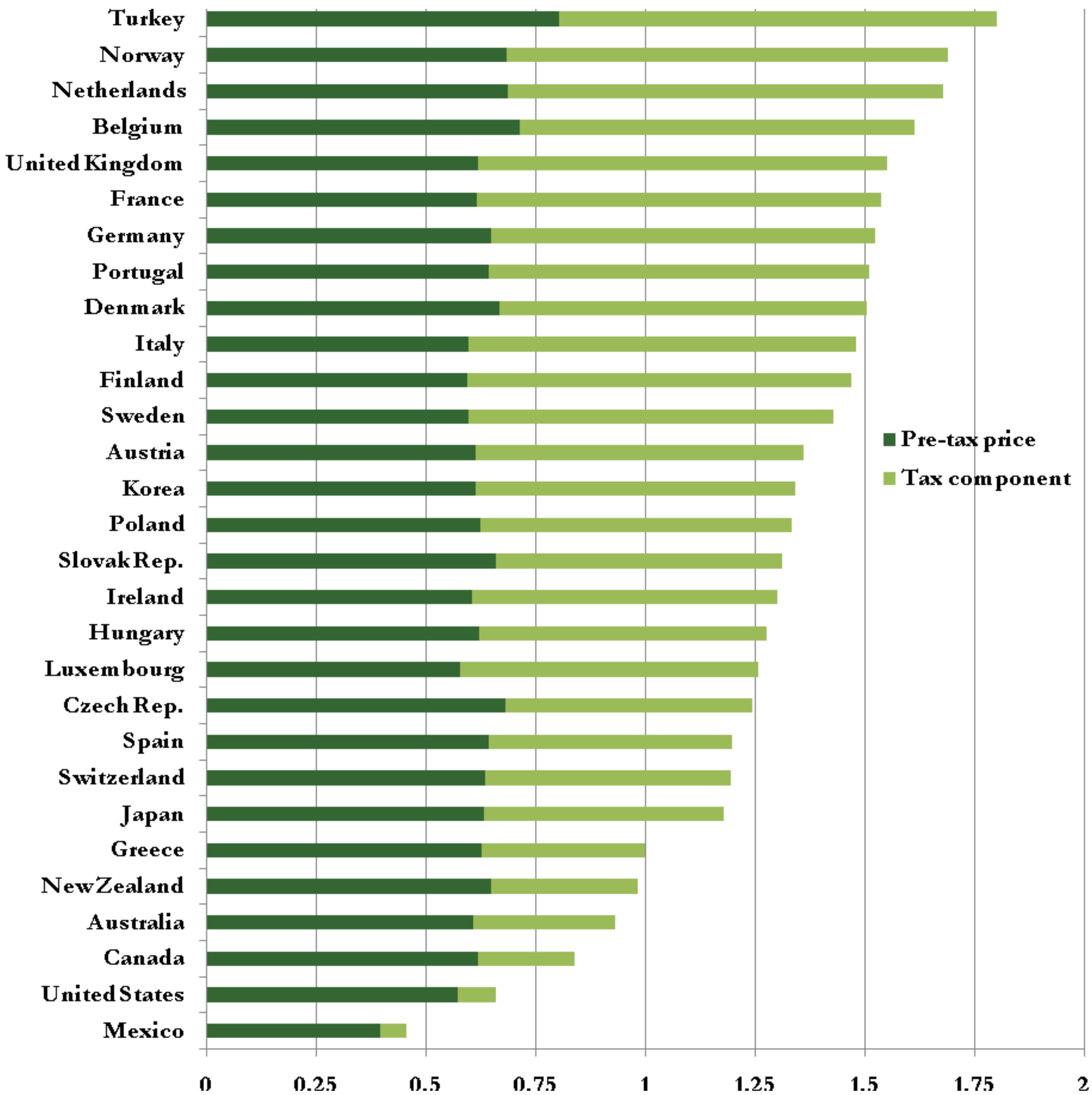

Figure 1 – Unleaded petrol taxes and prices for OECD, € per litre (3rd quarter 2008)*

Source: International Energy Agency (International Energy Agency, 2008), Figure 8, p.xxxiv

*or latest available

Note: Tax includes both fuel duty and VAT (or equivalent sales tax). In some countries, like in the US, both federal and state taxes apply. In these cases, the graph shows state and federal taxes as weighted averages, based on petrol sold in all states (International Energy Agency, 2008, p.296).[13]

13 An average fuel tax in the US of 8.6 Euro-cents per litre of unleaded petrol for the third quarter of 2008 is equivalent to 50 cents per gallon.

Parry and Small (2005) develop a model that estimates the optimal fuel tax and they calibrate such a model for the US and the UK. The externalities they include are damage from CO_2 emissions and air pollution, congestion and accidents. They conclude that for the year 2000 the optimal petrol tax in the US would have been $1.01 per US gallon (26 cents, 28 Euro-cents, 17 pence per litre)[14], more than twice the actual rate for that year, and the optimal petrol tax in the UK would have been $1.34 per US gallon (35 cents, 38 Euro-cents, 23 pence per litre), slightly less than half the rate for that year (p.1283).

Newbery (2005, Table 7.3, p.217) finds that the external costs of road damage,[15] air pollution, global warming, water pollution and noise in the UK in 2000 amounted to 36 pence per litre of petrol.[16] Since the fuel duty in the UK for the year 2000 was 48.8 pence per litre (UK DfT, 2008, Table 3.3, p.53) it can be concluded that the fuel duty more than covered those externalities.

Both Parry and Small (2005) and Newbery (2005) conclude that the UK had a fuel duty that more than covered the environmental costs of petrol. The numbers could be easily updated to 2010 and the same conclusions would be reached.

It is worth keeping in mind that in the UK, and probably in other countries with comparable fuel tax rates, the global warming externality seems to have *already* been internalised, which would make substantial increases in tax rates inefficient from an economic point of view. CO_2 emissions from road transport in these countries are probably lower than they would have been had no such high taxes been in place (Sterner, 2007), but they still seem to be too high to meet the various commitments that different governments have adhered to. The only way to defend higher fuel tax rates would be to use a much higher shadow price of carbon.

Similarly, Jin (2010) finds that the petrol tax in Canada, which is the third lowest of all OECD countries, should not be raised on efficiency grounds. The main reasons are the following: (a) there is no cost of oil dependency, (b) the fuel duty in Canada is over twice as high as the fuel duty in the US, (c) the average fuel economy is higher in Canada than in the US. Also, due to the pre-tax petrol price as well as the fuel duty being higher in Canada than in the US, the petrol tax in Canada is less effective at reducing distance-related externalities. Raising the fuel tax would cause overcharging of fuel-related externalities.

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14 The average exchange rate in the period Jan-Dec 2000 was $1 = €1.08 = £0.66 (IMF Exchange Rate Query Tool).

15 Newbery (2005) points out that the damage per litre of fuel varies across vehicle types and ages, and although the vehicle excise duty can be fine-tuned to allow for those differences, fuel duties cannot.

16 Note that Newbery (2005) excludes accidents and congestion from these calculations.

Congestion charges

Although congestion charging has been advocated by transport economists for many decades its implementation has been limited. The main barriers are typically public and political opposition, linked to equity concerns. As a result, there are only a few examples of congestion charging as of 2010. These include the Norwegian toll rings, the London Congestion charge, the Stockholm congestion tax, and the Singaporean Electronic Road Pricing. Additional non-urban examples include toll highways in various countries and high occupancy toll lanes in the US.

The Norwegian toll rings are often cited in the road pricing literature as examples of congestion charging, although they were designed to generate revenues to finance infrastructure. Since the original aim of these toll rings was not to reduce traffic levels and congestion, the decrease in demand for car travel has been low, with estimates varying from zero to 10 per cent reduction at most. Similarly there have been no significant changes in private car occupancy rates or demand for public transport (Ramjerdi et al., 2004).

There are also a number of toll highways around the world. Although the only objective of many of these schemes is to generate revenue, some also aim at relieving congestion. Examples include the M6 Toll in England, the 407 Express Toll Route (ETR) in Toronto and a number of roads in major Australian cities, such as for example, City Link in Melbourne and the Westlink M7 Toll Road in Sydney. In all these cases the toll highways are privately owned or managed. Drivers have the option of choosing between the toll road with lower journey times and the publicly provided alternative with higher journey times.

High Occupancy Toll (HOT) lanes in the US are lanes where tolls are applied on low occupancy vehicles wanting to use lanes which are free to use for high occupancy vehicles (HOV). High occupancy is usually defined as vehicles with two or more occupants.

The State Route 91 (SR-91) Express Lanes, which opened in December 1995, were the first practical example of congestion pricing in the US (Sullivan and El Harake, 1998). As of 2010 there are an additional seven HOT lane projects in operation in the US, which have been partly funded by the Value Pricing Pilot program or by its predecessor, the Congestion Pricing Pilot Program. Projects include segments of the I-15 in San Diego, California (implemented in 1996), the I-25 in Denver, Colorado (implemented in 2006), the I-394 in Minneapolis, Minnesota (implemented in 2005), the Katy Freeway (I-10) and the US 290 in Houston, Texas (implemented in 1998 and 2000 respectively), the I-15 in Salt Lake City, in Utah (implemented in 2006), and the SR 167 in King County, Seattle, Washington (implemented in 2008). The individual designs vary, and tolls range from 50 cents to $9. In some cases tolls apply in the morning peak, in others in the afternoon peak, and in others they change in real time with traffic demand. In this case, drivers are informed of the toll rate changes through variable message signs located in advance of the entry points. An advantage of HOT lanes over other congestion charging systems is that with HOT lanes drivers ‘can choose between meeting the vehicle occupancy requirement or paying the toll in order to use the HOV lane’ (DeCorla-Souza, 2004, p.288).

In September 1998 Electronic Road Pricing (ERP) replaced the Area Licensing Scheme in Singapore, a paper permit based congestion charge, which had been implemented in 1975. With ERP charges apply per-passage. Vehicles are charged automatically on an electronic card, which is inserted in an In-vehicle Unit, each time the vehicle crosses a gantry. Charges vary with vehicle type, time of day and location of the gantry. This makes the system the most fine-tuned road pricing scheme in the world to date.

The London congestion charge, introduced in February 2003, applies in a relatively small area of central London, which was originally 8 mi^2 (21 km^2), extended to 15 mi^2 (39 km^2) in 2007, and set to shrink back to what it was originally, in or after 2010. All vehicles entering, leaving, driving or parking on a public road inside the Charging Zone between 7:00 a.m. and 6:00 p.m. Monday to Friday, excluding public holidays, must pay the congestion charge. This was initially £5, but in July 2005 it was increased to £8 per day.

The congestion tax in Stockholm was implemented in August 2007. It is a cordon toll system, with a cordon that surrounds the entire Stockholm City, which has a total area of roughly 13.7 mi^2 (35.5 km^2). Each passage into or out of the area surrounded by the cordon costs SEK 10, 15 or 20 (roughly between £0.8 and £1.7 or €0.9 and €1.8)[17] depending on the time of day. The accumulated passages made by any vehicle during a particular day are aggregated and the vehicle owner is liable for either the sum of the charges or SEK 60, whichever is lower.

CONCLUSIONS

Given that the market fails in the presence of externalities, corrective instruments may be used in order to increase efficiency. The two types of intervention which have been suggested in economics, and reviewed in this survey for the case of road transport, are command-and-control (CAC) and incentive-based (IB). IB can be further categorised into price controls and quantity controls.

The main advantage of IB policies over CAC ones is their cost effectiveness. Road users and fuel and vehicle producers with low costs of externality abatement tend to reduce the amount of externalities generated by them while those with high costs of abatement choose to buy permits or pay taxes.

17 The average exchange rate in the period Jan-May 2009 was SEK 1 = 8 pence = 9 Euro-cents (IMF Exchange Rate Query Tool).

A number of CAC and IB policies have been reviewed and the following conclusions have been reached:

CAC policies are not efficient as even in a perfect information scenario when the standard is set at the optimal level, the target is not achieved at the minimum cost. Notwithstanding this, CAC are the most commonly implemented type of measure.

Regulations, however, are an adequate instrument for regulating fuel quality, perhaps complemented with a duty differential or a facility for trading credits. This approach was successful in phasing out leaded petrol in many countries, including the US and those in Europe, as well as in reducing the sulphur content of petrol and other harmful emissions.

For regulating CO_2 emissions, **a carbon tax, or at least a fuel tax, would be better suited as an instrument**. Fuel economy standards for vehicles, not too dissimilar from CO_2 caps per km, reduce fuel consumption but also cause a rebound effect, as vehicles drive longer distances on fewer fuel.

The Low Emission Zone (LEZ) in London is a CAC policy. However, its cost effectiveness may not be as poor as that of other CAC instruments, mainly because it is being phased-in. In reality, the vehicles affected by the regulation are few, as the increasing standards, required for circulation inside the LEZ, kick in years after the EU-standards, on which they are based, come into effect.

Bans on vehicle circulation, of the types imposed in Athens and Mexico City, have caused an increase in driving and emissions, as families bought second hand, less efficient cars, in order to have both odd and even licence plates and be able to drive every day of the week.

Parking restrictions do not ensure that the most efficient trips will be the ones realised, and they may increase congestion when drivers look for scarce parking spaces.

IB policies do not impose any choices, but rather leave consumers and producers to make decisions according to their costs and benefits, preferences and constraints.

The main candidate for a permit system in the road transport sector is CO_2 emissions. One important difficulty is that emission sources in road transport are small, dispersed, and mobile, which makes enforcement difficult. This obstacle could, however, be overcome by implementing a system that would work at the pump (and in that case it would essentially be similar to a fuel tax) or one at upstream level, designed either for fuel producers or car manufacturers.

Taxes and charges have been widely implemented in the road transport sector around the world, both in developed and developing countries. Their effectiveness as corrective instruments, however, depends on the link between the externality they are targeting and the tax or charge itself.

Vehicle purchase and ownership taxes do not influence travel behaviour, which is easier to change with congestion charges and fuel duties.

Congestion, which varies with vehicle type, road and time of day, is best targeted with a congestion charge than with a fuel tax. A fuel tax may reduce demand for travel, but may not reduce it (enough) during congested periods. Examples of congestion charging are limited, with only three urban schemes, the ones in Singapore, London and Stockholm, and a few High Occupancy Toll lanes in the US. The most fine-tuned system is the Electronic Road Pricing scheme in Singapore, which charges different rates to different vehicle types, at different locations and times of day.

The variation in fuel duties across countries is large. Although these were originally introduced as revenue-raising instruments, they are now also increasingly being regarded as corrective taxes to internalise road transport externalities.

Virtually all countries have mechanisms in place for collecting fuel duties. Thus, in addition to being fairly effective and internalising the global warming externality, a carbon tax on motor fuels, or at least blunter fuel duties, have the advantage of already being place. In addition, they are easy to monitor and enforce, inexpensive to collect, and guarantee some level of price stability. **Permits are more costly in regulatory terms, in the sense that they require an institutional setting, definition of property rights and initial allocation, as well as enforcement procedures.** On top of that, there are likely t be substantial transaction costs, which could potentially erode part of the benefits from trading. Having said all that, there seems to be some preference, both from politicians and from consumers and producers, for tradeable permits. This is evident in the trends regarding initiatives to tackle climate change.

The EU ETS was designed and implemented after proposals for a European carbon tax failed in the 1990s. In the US there are currently proposals for cap-and-trade systems, rather than carbon taxes, let alone substantial increases in fuel taxes.

Since cap-and-trade systems seem to be better accepted, perhaps in the hope that they will be grandfathered following insistent lobbying from affected parties, the time may have come to start thinking globally on how to design and implement new systems that will be compatible with each other. Better yet, would be a unified carbon market. This would entail international agreements on country-level quotas and long and costly negotiations, but may finally result in the world-wide institution of a truly global carbon market.

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