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Taxes and Transport Externalities

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TAXES AND TRANSPORT EXTERNALITIES[1]

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Abstract

The paper reviews the role of taxation in controlling transport externalities. It argues that the design of transport taxes should take into account pre-existing tax distortions in the economy and looks at the implications of restrictions on the transport instruments at the disposal of the policy maker. The relevance of equity considerations for transport pricing is also explored.

Introduction

Data for the European Union show that passenger kilometers driven by car were two and a half times larger in 1999 than in 1970, bringing the share of car to 79% (versus 74% in 1970). In the US car transport accounted for an even larger share of total pkm (84% in 1998). In the case of freight transport 75% of total tkm (excl. short sea shipping and air) in the EU in 1999 was transported by road, and 30% in the US (European Commission, 2001). The large share of the car and truck mode in their respective transport markets reflects their qualities such as flexibility and comfort. However, when households and firms decide whether or not to make a trip, when to make the trip and by which mode and route, they take into account only their own costs and benefits. The resulting traffic demand is too high in comparison with the social optimum, it is

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concentrated too much at particular times of day and the share of the different modes is suboptimal. This is because each additional transport user also generates costs to other transport users and to society in general, which he does not or only partially take into account in his decision process. The costs that are not taken into account are external costs. The main marginal external costs of transport use are congestion, accidents, environmental costs and road damage externalities (in the case of heavy vehicles). Most of these externalities are characterized by a feedback effect: the level of the externality itself affects the behavior of the economic agents. This is most evident in the case of congestion and accidents. Time costs affect the demand for passenger and freight transport. Similarly, accident risks influence transport demand, modal choice, route choice, driving behavior and so on. Feedback effects are also present for air pollution and noise, since these will lead to aversive or mitigating behavior.

The government can make use of several instruments to tackle these externalities. Generally speaking, one can make a distinction between pricing, regulation and infrastructure policy. This last category is very broad. It includes, for example, the expansion of the physical or virtual capacity of the infrastructure, but also spatial planning. One instrument does not preclude the use of others. They are often complementary. In this paper we focus on the role that can be played by pricing.

The structure of the paper is as follows. First, we briefly discuss the characteristics of the marginal external costs of transport. Next, we turn to the theoretical prescriptions for pricing. The rules are quite simple in a first best world in which the policy maker can make use of perfect instruments and when there are no distortions in the rest of the economy. They become more complicated when account is taken of features of the real world. First we consider how the rules change if there are distortionary taxes in the rest of the economy. Next we consider how theory can be implemented in the real world. Very often there are restrictions on the instruments the government can use. We explore the implications of these for the optimal tax rules. Finally, we briefly discuss some dimensions of political acceptability.

External costs of transport

The marginal external costs of transport use correspond to the costs caused by an additional transport user that are not borne by the user himself but by others. Transport use causes four main categories of externalities: congestion, accidents, environmental costs (including air pollution, global warming and noise) and road damage externalities. These costs consist not only of costs in the monetary sense, but also of, for example, time losses, pollution, noise and so on.

The marginal external congestion costs are present whenever an additional vehicle in the transport network reduces the speed of the other transport users. A lower speed has several effects. It affects the operating costs of the other transport users, and their time costs. Their time costs increase not only directly because of lower speed, but also indirectly due to schedule adjustment.

The marginal environmental costs include the costs imposed by the emission of air pollutants and noise on society in general and on future generations (in the case of air pollution and global warming).

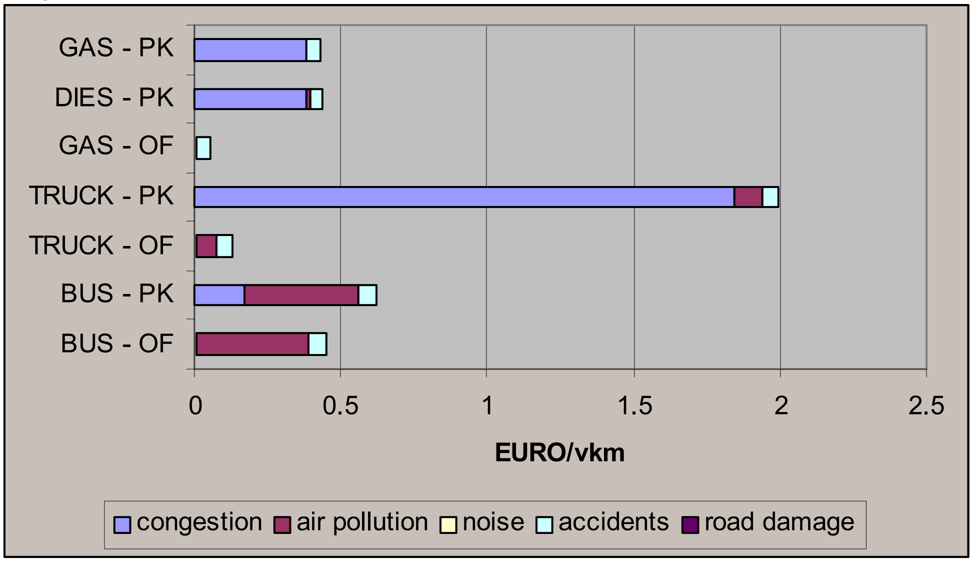
The marginal external accident costs are not straightforward to define. When an additional vehicle joins the traffic flow, it causes three types of costs to society. First, the transport user himself is exposed to an accident risk. The social costs of this consist of his own utility loss due to the accident risk (which is internal), the so-called pure economic costs associated with the accident risk (net output loss, medical costs, police costs etc.), and possibly also the utility loss of relatives and friends. Secondly, the additional transport user may have an impact on the accident risk of the other infrastructure users and therefore on the associated costs for society and these other users. Thirdly, other transport users will adapt their behavior when confronted with a changed traffic situation. These avoidance costs should also be taken into account. How much of these three types of costs is external depends on the liability and compensation rules that are in vigor, on the type of insurance pricing, etc.

The external road damage costs are discussed extensively in Newbery (1988) and Small et al. (1989). They arise when the passage of heavy vehicles causes damage to the road surface. Two types can be distinguished: the increased repair cost of the road, borne by the road infrastructure provider, and the increased vehicle operating costs for the other road users. Under a number of conditions Newbery shows that the second type of road damage costs are negligible in all reasonable cases.

The different externalities are not independent. For example, a reduction in speed will have an impact on air pollution and accident risk. But the externalities are not perfectly correlated. Therefore different instruments will be needed to tackle them. Nevertheless, when designing the policy instruments account should be taken of the interactions between the externalities.

A number of studies have tried to determine the marginal external costs of (mainly road) transport use. A selection of recent studies include Small and Kazimi (1995), Delucchi (2000), Friedrich and Bickel (2001), Mayeres and Van Dender (2001) and Beuthe et al. (2002). The relative importance of the different externalities is highly situation dependent. The marginal external costs vary widely in respect of the network considered, the volume of traffic and the vehicle type. As an illustration Figure 1 gives the marginal external costs that are expected to be generated by interregional road transport in Belgium in 2005. It shows that in this particular case congestion is the dominant external cost category in the peak period. In the off-peak period air pollution costs account for the largest share for diesel vehicles. This is due to their relatively high emission of particulate matter which is associated with high health costs. For other vehicle types accident costs are the most important in the off-peak period. It should be noted that the marginal external cost calculations are still subject to many uncertainties. Research in this area is continuing and is expected to improve the quality of the estimates.

Figure 1: Marginal external costs of interregional road transport in Belgium in 2005 (business as usual scenario)



PK = peak, OF = off peak, GAS = gasoline car, DIES = diesel car
Source: Mayeres and Van Dender (2001)

Towards better transport pricing

First best

The initial analyses in the transport economics literature of optimal pricing of transport were conducted in the first best framework. The first best pricing solution in the presence of negative externalities can be traced back to Pigou (1920): given the appropriate convexity conditions, an efficient allocation of resources can be obtained by setting the price of a good for consumption or production according to the marginal costs incurred by society. This way the generator of the externality is confronted with the damage his consumption or production imposes on others.

In the transport economics literature the first best approach is discussed in partial equilibrium models. The main interest is in urban transport and the determination of optimal tolls in the presence of congestion. The optimal pricing rules are derived by maximizing the net social benefits for trips over a road. The result can be summarized as follows: the price of the trip must equal its short run marginal social costs. To make each transport user face the marginal social costs of his trip, it is necessary to levy a toll equal to the difference between the marginal social cost and the average cost that is already borne by the user.

In practice the necessary conditions for the first best rules to be valid are not satisfied. The first best analysis assumes that the government is concerned with the sole objective of controlling the (congestion) externality and that it can make use of perfect instruments. Externality taxes are analyzed without taking into account the existence of implementation constraints or the presence of distortionary taxes. In reality these conditions do not hold.

The implications of pre-existing distortionary taxes

Controlling externalities is not the only objective of the policy-maker. He also provides public goods and services – that have to be financed – and has distributional objectives. In the first best models it is assumed that the government can make use of non-distortionary taxes in order to achieve these objectives. A tax is non-distortionary if and only if individuals can do nothing to change the tax they have to pay. Taxes for which this is not the case are distortionary. Distortionary taxes are not efficient: if the government could replace them by non-distortionary taxes it could gather the same revenue while at the same time increasing welfare. The assumption that the policy maker can make use of non-distortionary taxes is not realistic. In practice the government has to use labor taxes, capital taxes, indirect taxes etc. Therefore one has to develop a tax system such that the government's objectives (revenue raising, distributional objectives and tackling the externalities) can be realized at the lowest cost. Since transport taxes do not only have an impact on external costs but also raise revenue and have an impact on distribution, they should be considered within the broader framework of the general tax system.

Economic theory tells us what the optimal tax structure should look like in this case. Bovenberg and Goulder (2002) give an excellent overview of the theory of environmental taxation. Mayeres and Proost (1997) derive optimal tax rules for passenger and freight transport in the presence of externalities with a feedback effect, in an economy with non-identical individuals. It is assumed that the government can make use of indirect taxes on the consumption of all commodities (including transport), a tax on intermediate inputs in production and of a uniform transfer to households. For simplicity we assume that only transport generates externalities. Transport is used both by households and firms.

The indirect tax on the consumption of transport goods then consists of two components. The first component is aimed at revenue raising. The second component corrects for the external effects. If there are no other restrictions on tax instruments, this second part is present only for goods causing externalities, in our case transport goods[3]. Distributional considerations play a role in both components.

The first component is related to revenue raising. It makes a trade-off between efficiency and equity considerations. This can be illustrated best for a special case, namely if the demand for all commodities does not depend on the price of other commodities. Assume that the government wants to reduce inequality and gives a higher weight to lower income groups. In that case this component of the tax will be lower the more sensitive transport demand is to price changes (efficiency) and if the transport good is consumed proportionally more by lower income groups (equity).
In the more general case when cross-price elasticities are non-zero, efficiency requires that the tax is higher for those goods which are more complementary with leisure. This is important in the transport pricing debate. People travel for different purposes. In general a distinction can be made between leisure and commuting trips. If it is possible to tax these trips differently, theory suggests that one should tax leisure trips, which are complementary with leisure, more than commuting trips, which are complementary with labor. The implications of this for pricing have been investigated for the special case that commuting is a strict complement to labor by Parry and Bento (2001), Calthrop (2001) and Van Dender (2001), each using a different model of the transport market and making different assumptions about the available policy instruments. In a model with two transport modes that simultaneously use a congestible single link network in order to produce leisure and commuting trips, Van Dender (2001) shows that the welfare cost of uniform taxation on the two trip purposes could be important, especially if the labor income tax is constrained to be fixed at the reference level and if that reference level is high.

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[3] This is the so-called additivity property (Sandmo, 1975). Cremer et al. (1999) show that this property depends on the assumptions made about the feasible tax instruments.

The second component of the tax on the consumption of transport goods corrects for external effects. It differs from the first best Pigouvian tax in several respects. It consists of three parts:

a) a weighted average of the costs that congestion, environmental effects and safety effects cause to households, corrected by the marginal cost of public funds.
The marginal cost of public funds is the cost for society of raising one unit of government revenue. If the government has to resort to distortionary taxes, it costs more than one EURO to raise one EURO of government revenue. In that case the marginal cost of public funds is larger than one, whereas it equals one in the first best case. This implies that this part of the tax becomes lower than the weighted average of the marginal external costs for the households. The intuition behind this is as follows. The government has several objectives. A higher marginal cost of public funds implies that the budgetary objective gets a higher priority and the tackling of externalities becomes less important. In order to get as much income as possible the externality component for transport should not be set too high. This would result in too large a reduction in the demand for transport and too little tax revenue.
Equity considerations play a role in the externality correcting part of the tax. Several consumer groups give a different value to a reduction in the externalities. For example, empirical studies have shown that the value of a marginal time saving in transport or of a reduction in air pollution increases as income rises. If only efficiency considerations matter, the valuation by different income groups gets the same weight. If the government gives more importance to reducing inequality, the valuation by the lower income groups gets a higher weight than that of higher income groups. As a consequence, this part of the tax will become smaller if the lower income groups have a smaller valuation for the reduction in the externalities and if they get a higher weight.

b) the marginal external costs for the firms, related to congestion, air pollution and accidents

c) the effect of the transport externalities on net government tax revenue: the external costs of transport typically influence government tax revenue. For example, an increase in congestion will imply that less people will travel by car. This results in a reduction in fuel tax income. This is an additional cost of congestion. Simulations indicate that this component is relatively small in comparison with the direct effects on households and firms.

Theory also shows that if production exhibits constant returns to scale, it is not optimal to tax intermediate inputs in production that do not give rise to externalities. However, the tax on the input of transport should be positive to correct for the externality. The structure of this externality tax is similar to that of the externality correcting part of the indirect tax on consumption.

Implementing the theoretical recommendations

Empirical evidence shows that there is a large gap between current pricing policies and the recommendations from economic theory (see, for example, the overview in De Borger and Proost (2001)). The existing taxes are not differentiated in terms of time and place of travel, nor do they reflect the difference in air pollution costs between vehicle types, etc. In this section we briefly discuss the implications of the theoretical findings for transport policy.

Transport use causes different types of externalities, each with its own characteristics. The theoretical analysis presented above assumes that one can make use of an ideal tax instrument which can address all types of externalities simultaneously, and which can therefore be differentiated perfectly according to time and place of travel, emission and noise characteristics of vehicles, axle weight, driving style etc. Of course this is not a realistic assumption. In practice one has to use a combination of different instruments, each of which is geared towards solving one particular problem. Moreover, also in this framework the perfect instruments do not exist and there will be efficiency losses with respect to the theoretical optimum. The instruments have to be designed carefully in order to minimize these efficiency losses. In what follows we will discuss the potential of alternative pricing instruments for tackling each of the four main transport externalities. We limit our discussion to road and rail transport.

As in the previous section, we focus on pricing instruments. However, this does not mean that other types of instruments are not important. The case for complementing pricing by other instruments (provision of infrastructure, regulation etc.) is strengthened by the existence of constraints on the pricing instruments.

Congestion

One could choose to control congestion by using existing tax instruments. However, as is argued below, this is not the best strategy. More innovative instruments are called for.

Taxes on vehicle ownership, though they could play a role in raising government revenue, are not well suited for controlling congestion since they are not related to vehicle use. Nor do fuel taxes allow for an appropriate differentiation according to time and place of travel, since fuel consumption is only imperfectly related to the external congestion costs. Moreover, fuel taxes can be avoided by fueling abroad (in small countries) or by switching to more fuel efficient vehicles which makes them even less attractive for a role as congestion solvers (Parry and Small (2001)). The switch to more efficient vehicles may also cause an excessive reduction in transport related fuel use from the social point of view. It may have a beneficial effect on the environment, but at much higher costs than alternative measures. Kilometer taxes perform better, but can be expected to have only a limited impact on the spatial and temporal distribution of traffic, if they are not a function of the timing and location of travel.
Higher subsidies to public transport are often proposed as a, politically more acceptable, alternative for controlling congestion[4]. Theory shows that higher public transport subsidies may have a role to play as a second-best instrument if private transport cannot be priced correctly. However, progress in road pricing technology does not make this a very realistic assumption. Moreover, the potential of the subsidies depends on whether they can be expected to have a large impact on modal split. Since the cross-price elasticity between public and private transport is quite small, the impact on modal split will be relatively small. One also has to take into account that financing public transport subsidies may involve large welfare costs in an economy with distortionary taxes. Parking fees[5] are another example of second-best pricing instrument. They are also plagued by the problem that they can be related only crudely to the level of congestion on the network.

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[4] Subsidies can be motivated also because of equity considerations (see our discussion below) or because of economies of density which arise when public transport companies increase frequency in response to higher transport demand, thereby reducing costs for existing public transport users.

[5] Parking charges also pop up in the transport pricing debate for another reason. Currently a large group of car users are not charged for the resource costs of parking. Studies show that making them pay these costs may have important welfare effects (Calthrop et al. (2000)).

The conclusion we can draw from this discussion is that congestion is addressed best by a type of road pricing. Several types of road pricing can be envisaged. The easiest and cheapest to implement are systems such as pay lanes, area licensing and cordon pricing. In the first system one of several highway lanes is tolled while the other lanes are not. It can improve efficiency by sorting drivers according to their value of time. Area licensing requires a license to drive in certain areas, possibly at certain times of day. Highway vignettes for trucks are an example of this system, though usually not incorporating a time restriction. In urban areas area licensing usually concerns highly congested zones, which makes it more efficient in tackling congestion. With cordon pricing all vehicles entering the area within the cordon are charged a toll which could be differentiated according to time of day.
More sophisticated systems include a form of electronic road pricing, using automatic vehicle identification or smart-cards. The disadvantage of the first system is that it can be considered as an obstacle to individual privacy. This problem is overcome in the case of smart-cards. Systems using electronic road pricing offer more possibilities to charge a price in function of the traffic situation, and therefore allow to come closer to the theoretically optimal situation.

Due to political and technological reasons it is likely that the reform of transport prices will be implemented gradually. In the short run road pricing will most likely involve only parts of the network, rather than the whole network. This entails efficiency losses. When setting the second-best tolls on the tolled lanes or links in the network one needs to take into account the fact that other lanes/links remain untolled, in order to minimize the efficiency losses. Quite a number of studies have analyzed second-best tolls when there are restrictions on the tolling instrument. A good overview is given in Lindsey and Verhoef (2001). De Borger and Proost (2001) use the TRENEN model to determine the relative efficiency of various pricing measures for different cities (Brussels, Amsterdam, London, Dublin) and countries (Belgium, Ireland). It is shown that by increasing fuel prices one cannot achieve a lot. The welfare gain ranges from 5.7% to 21% of the first best outcome, depending on the severity of the congestion problem. In urban areas cordon pricing in combination with parking charges achieves up to 77% of the first best outcome. The potential of these measures depends on the size of the area, the number of cordons and the extent to which parking is underpriced. For non-urban transport in Belgium optimal highway tolls in combination with optimal public transport prices can achieve more than 80% of the first best welfare gain. Similar results are obtained by Parry (2000) who compares the efficiency of various instruments for congestion control. The efficiency gains that can be obtained by transit fare subsidies, gasoline taxes and single lane tolls are shown to be very limited in comparison with a congestion tax. He also finds that, although with heterogeneous transport users the optimal congestion tax requires a different toll on fast and slow lanes in order to sort out drivers with different values of time, the additional benefit of a differentiated toll over a toll that is uniform across lanes turns out to be relatively small.

Environmental externalities

A kilometer tax that can be differentiated in terms of pollution characteristics performs relatively well in tackling the environmental externalities of transport use. So does the fuel tax for certain types of emissions that are directly related to fuel consumption, such as CO_2, since the fuel tax can be differentiated according to the fuel used and its quality. However, it cannot make a distinction between different vehicle types. Taxes on vehicle ownership can play a role since they can be differentiated according to vehicle type. They are easy to implement and a good source of government revenue. Mayeres and Proost (2001a) argue that since fuel taxes do not allow to make a distinction according to who uses the fuel (cars versus trucks, vehicles with different emission technology, use for professional versus private purposes) and since fuel tourism occurs, especially in small countries, there is a role for vehicle ownership taxes. De Borger (2001) derives optimal rules for the taxation of car ownership and car use in the presence of externalities. His analysis shows that, when there are no restrictions on tax instruments, fixed taxes mainly play a role in raising revenue, rather than correcting for external costs. However, when there are restrictions on tax instruments, the fixed tax structure becomes crucial to respond to external cost differences between vehicle types. The tax differential between two vehicle types is then shown to be a complex function of the relationship between variable taxes and marginal external costs and of the various price elasticities that determine the budgetary implications of tax adjustments. Fullerton and West (2000) investigate the extent to which the optimal Pigouvian pollution tax can be mimicked by a tax on fuel and on car characteristics such as engine size, vintage, or the absence of pollution control equipment. They find that 71% of the welfare gain under the Pigouvian tax can be realized with a combined tax on size, fuel and vintage; 62% is obtainable via a fuel tax alone.

Safety

Reducing accident externalities relies first of all on the use of liability and compensation rules. With risk aversion, insurance comes into play. A careful design of insurance premia is probably the most efficient pricing instrument to internalize the external cost of accidents (see, for example, Boyer and Dionne (1987)). This requires a sophisticated structure of premia with full differentiation according to risk category and incorporating all variable accident cost components.

Road damage externalities

Road damage caused by vehicles depends on the vehicle weight per axle. The introduction of a kilometer charge that is a function of the number of equivalent standard axle loads of a heavy vehicle is efficient in reducing this type of externality. A tax that is closely linked to the road damage caused by vehicles would give truckers an incentive to reduce axle weights (see Small et al. (1989)). Fuel taxes are less appropriate in this case since they give truckers the opposite incentive, given that fuel use increases with the number of axles.

Political acceptability

Although economists have been advocating better transport pricing for a long time, the number of schemes that have been implemented in practice is very limited (see Small and Gomez-Ibanez, 1998). Public resistance to these new pricing schemes is large. The uncertainty about the distributional impacts of the pricing reforms is one of the main impediments to their implementation.

A number of studies have analyzed the distributional impacts of transport price reforms[6]. A prerequisite for the evaluation of the equity impacts is that transport instruments are not considered in isolation, but that the rest of the tax system is also taken into account. This implies the use of a general equilibrium approach is more appropriate for the evaluation than a partial equilibrium approach. The simulation results of Mayeres and Proost (1997, 2001b) and Mayeres (2001) show that equity considerations do not have a large impact on the ranking of transport instruments. For example, road pricing continues to be preferred to the fuel tax and higher subsidies to public transport. However, when society becomes more inequality averse, this has a significant impact on the choice of the revenue preserving strategies. While in the pure efficiency case the revenues of peak road pricing are best used to reduce the labor income tax, an increase in social security transfers is preferred with higher degrees of inequality aversion. An important implication of the analysis is that the revenue-preserving strategies cannot be ignored in the design of transport policies and that they can play a significant role in enhancing their political acceptability.

Conclusion

Economic analysis shows that significant welfare gains can be obtained by changing transport prices such that they are a better reflection of the marginal social costs of transport. Since transport demand is expected to grow further, the need for better transport pricing will only be increased in the future. This paper has explored some dimensions related to the implementation of the theoretical recommendations in the real world. It argues that the design of new pricing schemes should take into account

[6] see for example, Small (1983), Arnott et al. (1994), Mayeres and Proost (1997, 2001b) and Mayeres (2001)). A recent review of the key issues in this literature is given by Richardson and Chang-Hee (1998).

the existence of other distortions in the economy and of constraints on the available policy instruments. These pricing schemes currently are not very popular. Careful design of the revenue recycling strategies could help to improve their political acceptability.

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