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Introduction

Road Pricing: Is It Needed, Is It Possible, Is It Inevitable?

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The introduction of cordon charges in large European cities such as London and the pressing budget constraints for infrastructure construction and maintenance (e.g., in Germany) have spurred a renewed interest in the issue of transport pricing. Recent special issues or collection of papers can be found in Schade and Schlag (2003), in Santos (2004), in Transport Policy vol. 15, issue 5 (2005) and vol. 13, issue 2 (2006) or in de Palma, Lindsey and Proost (forthcoming), inter alia.

This special issue contains a selection papers presented at the 2nd Kuhmo conference in July 2005, which was held in Kuhmo, Finland.

What is the contribution of this issue to the on-going debate on road pricing? The papers can be subdivided into two categories: a) theoretical papers and b) policy and applied research papers.

A striking characteristic of the literature on road pricing is that the degree of consensus among economist on its beneficial social effects seems to be inversely proportional to its acceptance among the general public and the politicians. Social efficiency and political acceptability instead of going hand-in-hand appear to be moving in opposite directions. Three papers - by Amihai Glazer and Esko Niskanen (2006), Andreas Kopp (2006) and Edoardo Marcucci, Marco Marini, and Davide Ticchi (2006) – discuss, at a theoretical level, the reasons why this might occur. The first two papers add the concept of “fairness”, a term including both the concepts of “equity” and “justice”, to the concept of social efficiency, while the third paper deals with the issue of political acceptability of road pricing policies.

Amihai Glazer and Esko Niskanen explain the opposition to road pricing schemes through the interpretation road users might have when a congestion toll is perceived as a

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punishment for the damage a user causes on others. In this sense, road pricing is perceived by the road user as “unfair” or “unjust”. The argument assumes that when a user suffers from congestion, he believes that he has already undergone some punishment and thus considers unfair or unjust the payment of an additional toll. Consequently, a person views a congestion toll as unjust if the toll exceeds the difference between the congestion externality a road user generates on others and the uncompensated externality he suffers from others. (Some users may also misunderstand or ignore the concept of externality or user-pay principle). By exploring the implications of such a view and by illustrating how to determine the toll satisfying this criterion of justice it is shown that the socially optimal toll violates this criterion. The authors illustrate how the fair or “just” toll varies with the parameters of the model and discuss the implications of alternative definitions of justice as well as potential extensions of the basic model considered.

Andreas Kopp studies the conflict between allocative efficiency and fairness arising from an optimal decentralized provision of infrastructure services. The author discusses the most prominent principles of fairness, arguing that the reward principle could be considered as the most relevant fairness principle for the discussion of distributional effects of pricing rules. Applying this fairness notion, no conflict of compatibility between allocative efficiency arises in a benchmark case with strong congestion and optimal marginal cost prices, whereas a genuine distributional conflict results in the case of relatively low levels of congestion and heterogeneous users, with the implication of the non-coverage of fixed costs and revenues deriving from imposition of efficient prices.

The paper by Edoardo Marcucci, Marco Marini, and Davide Ticchi use the citizen-candidate game framework to analyse the issue of the political acceptability of road pricing policies. The paper asserts that road pricing policies are never applied when there is no redistribution of the resources generated in favour of other modes of transport (public transport) or when the congestion of these types of transport is relatively high. The results suggest that the efficiency of the redistribution of resources from road to the alternative types of transport (public transport) as well as the fraction of the population that uses the road transport provide key factors in explaining the adoption of road pricing schemes.

The opening paper of the applied and policy oriented group of papers is written by Robin Lindsey. It provides an up-to-date survey of the recent developments and current policy issues in road pricing in the US and Canada. This contribution complements the mostly European perspective of the remaining papers. Although it is difficult to make a comparison between the two continents, it is the author’s opinion that the US and Canada are in a relative delay with respect to Europe and Singapore as for the practical implementation of road pricing schemes. At the same time, however, both countries have demonstrated quite a sustained interest in road pricing considering it an appropriate instrument both for reducing congestion as well as for generating revenues. The interest in road pricing schemes is testified for the US by the funding of the Value Pricing Pilot Program aimed at pricing demonstration projects and for Canada by the undergoing examinations of road charging in order to finance both the construction of new roads as well as the maintenance of old ones.

The paper by André de Palma, Kiarash Motamedi, Nathalie Picard, and Paul Waddell follows the strong and growing interest in the development and use of large-scale planning models. It describes the first step of a project aiming at the integration of
UrbanSim, a dynamic micro-simulation land use model, and METROPOLIS, a dynamic traffic model. Such integration, novel in many respects, allows for the treatment of two type of endogeneity in residential location choices: the interdependency between residential location and housing prices as well as the interdependency between residential location and travel times for work and other purposes trips. Such modelling effort allows a more comprehensive long-run (as well as short-run) evaluation of the impact of the road pricing policies since the distribution of commercial and residential activities are treated as endogenous.

Stef Proost, Saskia Van der Loo, André de Palma, and Robin Lindsey approach the issue of road pricing at a more micro level. For this purpose, they analyse a proposal to build a new tunnel under the Scheldt river, near the centre of Antwerp in order to relieve traffic congestion on the ring road and in an existing tunnel. They use a new CBA-economic model, MOLINO, which is briefly summarized. Three tolling schemes on the new infrastructure are compared with the tolling of the existing tunnel without building a new infrastructure. The comparison among the different options is carried out using the MOLINO model, recently developed as part of the European-Union funded REVENUE project. The two tunnels are regarded as imperfect substitutes in a multi-year accounting framework where emissions, accidents, noise externalities, and road damage, revenues accruing to the national and regional governments from existing transport user charges are considered along with the salvage value of the new tunnel.

Pricing measures provide an important tool to influence user behaviour. The available ones are numerous and very diversified. The pricing design depends on the objectives pursued and it is therefore important to predict the most likely responses induced by these forms of intervention. Different people have different options to change transport behaviour and this implies different reactions to different pricing schemes. The extant literature on this aspect is somewhat scarce.

Barry Ubbels and Erik Verhoef carried out an empirical research though a questionnaire among Dutch car owners on the impact of road pricing on road users’ behaviour. The results indicate that road pricing may have considerable effects, and that much depends on the design of the measure. In terms of trips adjusted, the effectiveness of the measures is in the range of 6% to 15% for all purposes. The effect in terms of kilometres is somewhat smaller. There are considerable differences between trip purposes, with commuting generally being least sensitive when the charge is time independent. The effect of revenue use is obvious in most cases, the measures with revenues allocated to lower income users have generally more impact. Although the decision whether or not to implement a price measure remains a political one, it is clear that the effects depend very much on the type and structure of the measure proposed.

The paper by Bernhard Wieland describes a recent and important innovation in European pricing measures: the use of a satellite based tolling system for heavy goods vehicles (HGVs) in Germany. The Author describes the political and economic background of the introduction of the HGV-toll by sketching the history of the implementation process, describing the major structural elements of the toll, and discussing current problems and possible future developments. It is interesting that the major reason for the HGV-toll acceptance seems to have been the existence of a “grand coalition” of actors supporting it including politicians, truckers, environmentalists, the general public, and especially car owners. Each actor had his own motivation in mind while the media concentrated their reporting more on the technical and managerial problems of Toll Collect, the company in charge of the system, rather than on the
economic and social issues linked to it. In conclusion, the author argues in favour of the need to find a binding political mechanisms with respect to the use of the revenues of the toll. Even if it is known from the economic theory of second best that allocating these revenues to road building must not necessarily be the first best option, acceptance might however increase if citizens can be convinced that the toll is not “just another tax.”

Finally, Alessandra Libardo, Silvio Nocera, and Dario Trabucco discuss the merits of pricing for a peculiar purpose: tackling the problems posed and the damages provoked in the lagoon of Venice by the waves originating from boat traffic. Given that most of the traffic is freight transportation the authors concentrate on suggestions pertaining to the re-organization of freight operations and distribution in Venice. The innovative aspect of this paper consists in the adaptation of the road pricing logic to a particularly complex environment where mobility through water canals determines specific forms of externality requiring complex control systems. The pricing has the objective of modifying the status quo of the organization of the freight movement in the lagoon, with the aim of introducing the pressure of competition between the operators, who nowadays actually operate in a rather captive market system characterised by little efficiency.

Acknowledgments

We would like to thank all the participants and researchers who were in Kuhmo, who contributed to the “Kuhmo spirit”, made the 2nd Kuhmo conference a success and contributed directly or indirectly to this special issue. Our special thanks go to Esko and Anita Niskanen who acted as local organising committee and planned all the aspects and details of the conference including the chamber music, and the magnificent Finnish dinner preceded by a lovely smoke sauna and swim in a lake. We also thank the personnel of the Kuhmo Arts Centre for their readiness to help us in technical and other problems.

References

When users of congested roads may view tolls as unjust

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Abstract

Though congestion tolls can increase social welfare, the public often opposes them. One explanation for the opposition is that a road user views a congestion toll as punishment for the damage he causes others. Since a user suffers from congestion, he believes that he has already suffered some punishment and therefore it is unfair or unjust to impose a toll in addition. We assume that a person views a congestion toll as unjust if the toll exceeds the difference between the congestion externality a road user generates on others and the uncompensated externality he suffers from others. We explore the implications of such a view. We illustrate how to determine the toll that satisfies this criterion of justice and how the socially optimal toll violates the criterion. We examine how the just toll varies with the parameters of the model. We discuss the implications of alternative definitions of justice and possible extensions of the basic model considered.

Keywords: Congestion tolls; Unjust tolls; Social optimum.

1. Introduction

Though congestion tolls can increase social welfare, the public often opposes them. A common explanation in the literature for political opposition to congestion tolls is that users of the road suffer a loss of utility. A well-known policy implication of this literature is that redistribution of the toll revenue to users (for example, through reducing other taxes or through investments in capacity) would increase political support for congestion tolls.

The public may also object to road pricing when they view a congestion toll as a punishment or as a penalty. The so-called double-payment argument reflects the view. This view was well summarized in a report to the European Commission: “Road users are the true victims of congestion and have to pay for it by longer and longer commuting times. Why should they pay twice for being stuck in queues?” (Harsman, et

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al., 2000). The double-payment argument or view appears to explain much political opposition to congestion tolls. Though inconsistent with determination of the toll that would maximize social welfare (as it is presented in economic literature), it provides a powerful argument for political debate (capable of affecting people’s emotions and of echoing their views about fairness, etc). If, however, the externality an individual road user generates were much larger than the congestion he suffers, even road users and their representatives might see the double-payment argument as having little moral force, and the public might find it fair to charge some toll. The literature has not evaluated this possibility or hypothesis. We do.

We thus explore implications of assuming that a road user views a congestion toll as a punishment or as a penalty. This leads us to consider such issues as fairness, equity and justice. (We use, following the literature, “fairness” as a general term that covers both “equity” and “justice.”) The formulation of justice discussed in this paper reflects justice as viewed by consumers rather than by government as a social optimizer (or by the authors of this paper). That is, we focus on positive statements, aiming to explore the implications of certain attitudes of consumers, rather than making normative statements suggesting a just toll as an optimal policy.

The paper can be seen as consisting of two parts. First, Sections 3-6 review literature which deals with these issues, discuss the concepts of equity and justice as defined in this paper, and summarize behavioural assumptions. Second, Sections 7-12 illustrate the concepts in terms of a simple economic model of road congestion, derive a just toll and compare it to the socially optimal toll, explore how the just toll may depend on different parameters of the model and on alternative ways of defining justice, and discuss extensions of the model and analysis.

2. Literature

Considerations of fairness appear in all ethnographically or historically recorded societies (Brown, 1999). Biological evidence that people care about fairness is provided by Camerer (2003): subjects whose brains were imaged while presented with an unfair offer showed greater activity in the bilateral anterior insula of the brain, revealing that such an offer created negative emotions. Experimental studies by economists also suggest that fairness considerations are important determinants of human behaviour (see the survey by Fehr and Schmidt, 2003). Even monkeys appear to react with anger to inequitable reward distributions (Brosnan and de Waal, 2003).

Considerations of justice explain some attitudes of the public toward reforms and toward compensation. The psychologists Baron and Jurney (1993) report that some subjects opposed reforms that they recognized would improve matters. Subjects justified such resistance by noting that the reform would harm some group (despite helping many others), that a choice would be taken away, or that costs and benefits would be distributed unfairly. In a study on attitudes toward penalties and compensation in tort law, Baron and Ritov (1993) find that penalties were independent of their deterrent effect on behaviour, that penalties were greater when paid directly to the victim than when paid to the government, and that many people assign compensation not in terms of the injury but, in terms of setting the balance right between the injurer and the victim. For a recent discussion of equity as applied to transportation, including a survey of the literature, see Raux and Souche (2004).
3. Three kinds of justice

The examination of the issues related to fairness, equity and justice goes back to Aristotle, who distinguished three kinds of justice:

1. Compensatory justice, which concerns compensating the victims of wrongdoing;
2. Distributive justice, which concerns assigning benefits and burdens; and
3. Retributive justice, which concerns punishing of crimes or harm caused others.

All three approaches are relevant when considering congestion tolls. In the context of congestion pricing, compensatory justice and distributive justice (equity) have been extensively studied by economists; retributive justice has not.

In principle, we can consider these justice issues from the viewpoint of a social optimizer (social-welfare maximizing government) or from the viewpoint of a road user. In this paper, we focus on the user; that is, we explore how a person’s views on these issues affect his behaviour and choices and the implications of all this.

4. Consumer’s evaluation of a congestion toll

The findings reported in Sections 2 and 3 are consistent with the idea that in evaluating a policy, people look not only at the effects of the policy on their own utility, but also whether it is consistent with their views about fairness – both in terms of its effects on different people (distributive justice) and as a punishment or penalty (retributive justice).

We assume that a person, when evaluating (or voting for) a policy, here a congestion toll, is influenced by (at least) three kinds of issues or factors:

1. Utility maximization, through comparing a consumer’s own position before and after a policy or toll is introduced;
2. Equity, which reflects a person’s concern of how a policy or toll differentially affects different people; and
3. Justice, which involves comparing the penalty a person pays to the damage he causes and has suffered.

These three factors, or behavioural drivers, broadly correspond to the three kinds of justice identified in Section 3. (Consequently, we henceforth also call distributive justice as equity, and retributive justice simply as justice.) These factors typically work in parallel, and thus a consumer’s overall evaluation results from their joint impact. Which argument has most weight in any particular case is an empirical question.

It may be natural to assume that when deciding whether to drive, a person typically cares only about his own utility. That is, a person does not normally make equity and justice related considerations or comparisons on a daily basis when deciding whether to drive (and so ignores the externality he creates). In this paper we consider those occasions (which are less common) when a person is evaluating (considering whether to vote for) a toll. Also in this context, we can assume that each road user knows that the toll reduces his utility (assuming the revenues are not returned to users), and that he cares about this. (The economics literature widely discusses how the utility of road users
declines if the toll revenue is not returned to them.) Therefore, if the toll revenue is not returned to a user, a utility-maximizing user would prefer (vote for) a zero toll. However, when evaluating a congestion toll, people may also care about fairness (social) aspects more generally, both in terms of distributive justice or equity and in terms of retributive justice.

5. Justice compared to equity

Equity, or distributive justice, concerns how a policy, here a road toll, differentially affects different people. One definition would call an allocation equitable if continuing users of the road enjoy at least as high a utility as when the toll is zero, or if their reduction of utility is within certain “acceptable” limits. As the term equity suggests, particular attention is paid to the effects of the toll on different consumers.

Justice, or retributive justice, concerns penalizing or punishing people who harm others. In the case of road travel, the harm is the congestion externality that road users cause each other. In normal situations considered in this paper, a road user both generates an externality on other users (increasing their travel time) and suffers an uncompensated externality generated by other users. (In Section 12, however, we briefly discuss asymmetric externalities.) We then define justice in terms of the damage a person causes others compared the damage he suffers from others: a just toll equals the difference between these two. Our conception of justice thus compares the toll to the congestion externality a road user generates on others and to the uncompensated externality he suffers from others.¹

Equity thus assumes that a person may be concerned not only with his own utility (or with the utility of his own group), but also with the effect of a toll on the utility of other groups. Consideration of equity leads to a cost-benefit type of comparison of the pre-toll and after-toll situations.

Essential to justice – and in contrast to equity as we define these two terms – is that a just toll and just allocation is based not on comparisons of utility, but on comparisons of damages caused and suffered, independently of the comparison of the pre-toll and after-toll situations. (However, in Section 10 we discuss implications of expanding our basic definition of justice to allow for utility comparison.)

The rest of this paper focuses on retributive justice, and the implications of people’s concern about this. While for equity considerations it would be necessary to assume different types of people using a road, for our considerations of retributive justice we can assume that all users are identical. However, in Section 12 we discuss situations where different road users are involved.

¹ A related consideration may affect the views of consumers toward taxes which control externalities. A person may oppose such a tax because he dislikes the reminder that he hurt others. In contrast, taxes not aimed at controlling what is viewed as bad behaviour may be subject to less opposition. A voter may prefer a tax on labour over a tax on pollution because working is not considered evil. Similarly, a property tax is not viewed as a punishing wrongdoing (there is nothing wrong with owning property), and so a voter may have no emotional objection to a property tax. Nor is a parking fee associated with punishment. This reasoning suggests that since going to work is viewed as good behaviour, taxes on commuters will be viewed more favourably than are taxes on other types of trips.
6. Consumers and retributive justice

To summarize the discussion above, the key assumptions behind our conception of (retributive) justice are that:

1. A person who views a toll as a punishment or penalty may ask whether the punishment is fair or just. 2
2. A person recognizes that his travel can increase the congestion others suffer, and thus in principle can view some toll that aims to correct that damage as just.
3. A person compares the damage he causes others with the damage others cause him.
4. A person views a toll that equals the difference between the damage he causes and the damage he suffers from other as just and hence acceptable.

Thus, while our conception of justice has an individual viewing a congestion toll as penalizing a person (including himself) for the damage he causes others, the individual may within certain limits see the punishment as just. More particularly, he thinks that the amount of the penalty should be reduced by the damage the person himself already suffered. When viewing a congestion toll as punishment, a person may, depending on the conditions, regard the punishment as just or unjust, and hence acceptable or unacceptable.

7. Model of road congestion

Following the standard analysis of congestion, let a road user both suffer a congestion externality from others, and create one on others. Let \( q \) be the number of road users and let the cost of travel per person be \( C(q) \). The marginal social cost of a person’s travel is \( d[C(q)q]/dq = C(q) + qC'(q) \). 3 that is, the sum of the cost he incurs or pays, \( C(q) \), and the externality he generates, \( qC'(q) \). Denoting the cost of travel when no-one else travels by \( C(0) \), a user’s damage from congestion is \( C(q) - C(0) \). For the moment, we simplify by letting \( C(0) = 0 \).

Denote by \( D(q) \) the marginal willingness to pay for a trip, and let \( t \) be the congestion toll. Then in equilibrium \( D(q) = C(q) + t \). Figure 1 illustrates the situation. The social optimum number of trips is \( q_{opt} \); this would be the equilibrium if each person fully allowed for the externality he generates \( q_{opt} \). Alternatively, \( q_{opt} \) can be supported as an equilibrium by the socially optimal toll \( t_{opt} \). And, \( q' \) is the equilibrium number of users when a person ignores the externality he creates and when the toll is zero.

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2 Of course, consumers may have different views of what is the penalty. One view is that the penalty consists of the decline in consumer surplus. If, however, each user makes only one trip, then the decline in consumer surplus is the same as the increase in the consumer’s cost of travel. Accordingly, another view is that the penalty consists of the increase in the user's cost of travel following imposition of the toll.

3 Our analysis ignores people who respond to the toll by ceasing to make the trip. These people cause no congestion, and thus should not be punished. But yet they suffer from the congestion, equal to the consumer surplus they would enjoy were traffic free-flowing. Consideration of these people would make a toll which is just even smaller. One way of extending the model to consider such people is to look at the aggregate externality users generate, and compare that to the aggregate loss of utility of users from imposition of the toll.
C(q) + qC'(q) = marginal social cost

qC'(q) = damage user causes

C(q) – C(0) = a user’s suffering

D(q)

$t_{opt} = \text{socially optimal toll}$

$t_{just} = \text{just toll}$

$t_{opt} = qC'(q)$ evaluated at $q^{opt}$ i.e. where $C(q) + qC'(q) = D(q)$

$t_{just} = qC'(q) - C(q)$ evaluated at $q^{just}$ i.e. where $qC'(q) = D(q)$

Figure 1: The socially optimal toll and the just toll.

8. Just congestion toll

Since the analysis is interesting only if the toll is positive, we assume the damage a user causes exceeds the damage he suffers. Given the assumptions of our model (in Sections 6 and 7), the damage a user causes exceeds the damage he suffers if $qC'(q) > C(q)$, or if $C'(q) > C(q)/q$. For a convex function, which gets steeper as we move to the right, the inequality is satisfied. Since we can assume that the average cost curve is convex, this means that in normal cases a positive just toll can be determined. In Figure 1, the convexity property of the cost function is assumed to hold for all $q > 0$. Here we can view $q^{just}$ as a just solution, and as an equilibrium which is supported by toll $t^{just}$, i.e. the maximum just toll.

We can also think that, in principle, $q^{just}$ could be realized as an equilibrium if a consumer, as a behavioural assumption when deciding whether to drive, cared about the difference between the damage he generates on others and the damage he suffers from others. That is, rather than fully allowing for the externality he generates (fully internalizing this in his behaviour), which would lead to the social optimum $q^{opt}$ as the equilibrium, a person may care only about the difference between the externality he generates and the damage he himself suffers from others.

Figure 1 shows that, under the conditions stated above, the just toll is always smaller than the toll which maximizes social welfare. Also, given that revenues from the toll are not returned to a consumer, a user’s utility under the just toll is greater than under the socially optimal toll.
9. Effect of free-flow speed

We defined in Section 7 the damage that a user suffers from others as $C(q)-C(0)$, where $C(0)$ is travel time under free-flow conditions. In many practical cases free-flow speed will be determined by a speed limit: the lower the speed limit the higher is travel time $C(0)$. This suggests that the lower is the speed limit, the smaller is the damage a person suffers from others. This would mean, other things equal, that under a wider set of conditions the damage a person suffers is smaller than the damage he causes. (In Figure 1, the larger is $C(0)$, the smaller is $C(q)-C(0)$ for any $q>0$. For $q=0$ the difference is nil anyway.) This in turn would mean that a given toll could more likely be viewed as just. (In London the speed limit may have been low, and therefore the congestion toll may have been viewed as just.)

10. Effect of alternative definitions of justice

Since a toll reduces travel, thereby reducing congestion and travel time, the increase in a user’s cost (cost including the toll) is less than the level of the toll. This raises the question whether a user would allow this reduction in costs in his criterion for justice, and what would be the implications of this. A user who did consider the reduction in travel time would be willing to accept a higher toll as a just toll the higher his cost of travel would be in the absence of the toll. Indeed, the model of Section 7, when appropriately incorporating the comparison between utility before and after the toll, implies that the toll viewed as just would be higher when a user recognizes the reduction in travel time induced by a toll than when he does not.

11. Justice and quantitative restraints on travel

The conception of justice as defined here applies to a policy that aims to correct a person’s behaviour i.e. in our case reduce the congestion externality his behaviour generates. More specifically, it only applies to pricing policy with tolls or fees as relevant instruments. In particular, justice issues as considered here do not arise in the context of quantitative restraints on travel. This may partly explain why quantitative restraints are more often implemented than road tolls.

12. Extensions

So far we considered situations where all road users are identical. The analysis argued that a primary consideration in acceptance of congestion tolls is whether the generators of the externality are also its victims. When they are, as in the analysis above, a corrective tax can be viewed as adding insult to injury. But if users differ, in the sense that one group causes more damage than the other, then even those who generate the damage may view a corrective tax as just.
12.1 Multi-passenger vehicles

The externality generated by a vehicle is independent of the number of passengers in the vehicle. The standard (economic) approach to congestion tolls would therefore give no discount to car pools. In contrast, the justice approach would consider that the congestion externality per vehicle is higher the more passengers in it, and so would call for a discount, that is a smaller congestion toll, on vehicles with multiple occupants. Here a large group (single-occupant cars) generates damage to a small group (car pools).

12.2 Controlling other externalities

Other examples of asymmetric externalities can occur with cigarette smokers, with electric utilities generating pollution transported elsewhere, with upstream cities which pollute downstream cities, and with trucks which slow down other vehicles because trucks poorly negotiate urban roads or steep inclines. In these cases, typically, a small group hurts a large group (while the large group little hurts the small group).

13. Conclusion

The practice of economics can be frustrating: economists offer well-founded advice, which policymakers ignore. The advice might be ignored for many reasons: voters and policymakers don’t understand the analysis; special interests oppose the proposal; the policy would redistribute income in undesirable ways; government is too busy with other issues; the policy has effects which the economist ignored; voters and policymakers use considerations other than the effects of policy on the profits of firms or on the utility of consumers. This paper considered the last explanation.

Considerations of morality or of justice often enter political discourse. Prohibitions on torture, prostitution, or abortion clearly fall into this category. So do some “sin taxes,” such as those on alcohol. We believe that voters and elected officials may view congestion tolls in a similar way: they are designed not only to affect behaviour, but also to punish people for inflicting damage. The interesting complication is that the people who cause the damage are also the people who suffer the damage, and so road users may believe that they already bear some punishment. We formalized this argument, describing the congestion toll that meets a reasonable criterion of fairness or of justice. This toll, though positive, is less than the standard socially optimal toll. Considerations of justice do not therefore preclude the imposition of a congestion toll, but they do cause the public to oppose the high tolls that standard economic analysis recommends.

And considerations of justice can suggest the design of tolls which will make them more acceptable. The general principle is that the toll should be lower the greater the damage a person suffers from congestion: inner-city residents living near congested areas should be charged a lower toll than are commuters; the toll on a car with multiple passengers should be lower than on a single-occupant car; trucks, which are inherently slow-moving even with no congestion, should be charged a higher toll than are fast-moving cars.
Notation

C(q) - Cost of travel time to each user
D(q) - Marginal value of trip
t - Congestion toll
q - Number of users

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Harsman, B. et al. (2000) "Ways and means to increase the acceptance of urban road pricing." Final Report of Project PRIMA.
Fairness, efficiency and the simultaneity of pricing and infrastructure capacity choice

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Abstract

The primary objective of infrastructure pricing in normative economics and policy discussions is economic efficiency. This focus has led to the proposal that charges for infrastructure use should be based on all internal and external marginal costs associated with the use of infrastructure services. Distributional considerations, of the “fairness” of infrastructure pricing often played a supplementary role to help the acceptance of infrastructure charging.

This paper sets out a simple framework for a quasi-market for infrastructure services with the perspective of simultaneously determining efficient prices and levels of infrastructure investment. It is shown that, depending on the intensity of infrastructure use, revenues generated by efficient prices do not in all cases cover the full costs of the services. Efficient cost recovery requires an additional fixed charge. Such a combination of a fixed charge and an efficient price per unit of service implies a distributional conflict if users differ substantially in their demand for infrastructure services. It is shown that methods to allocate fixed costs resolve this conflict applying standard norms of distributional justice and being compatible with a bargaining equilibrium among heterogeneous infrastructure users.

Keywords: Infrastructure pricing; Infrastructure investment; Cost recovery; Fairness.

1. Introduction

This paper discusses the conflict between allocative efficiency and “fairness” that arises from an optimal decentralized provision of infrastructure services. Pricing of infrastructure services and the notion of “fairness” is narrower than in current policy discussions (Commission of the European Communities, 1998). The paper starts out by focussing on the problem of efficiently providing infrastructure services for high levels of congestion and a homogeneous population of prospective users (Starrett, 1988, for

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example). It will be shown that with high levels of congestion, optimal prices for infrastructure services cover full costs. Congestion costs are represented as a disutility due to crowding. This contrasts with the standard literature on pricing and infrastructure investment, where congestion costs are included in a generalised cost function, making strong assumptions about its functional form (Mohring and Harwitz, 1962; Small, 1992; see the review in Verhoef, forthcoming). In contrast, with no or relatively low levels of congestion, optimal prices imply deficits in the provision of these services.

To pin down ideas on fairness, prominent principles of fairness will be discussed (for a review, see Moulin, 2003). One of these principles, the reward principle, will be argued to be the most important fairness principle in the discussion of the distributional effects of pricing rules. Applying the fairness notion of the reward principle, no conflict of compatibility between allocative efficiency and distributive justice arises in the benchmark case with strong congestion and optimal marginal cost prices. A genuine distributional conflict results in the cases of relatively low levels of congestion, with the implication of the non-coverage of fixed costs by the revenues from efficient prices, and heterogeneous users with respect to their demands for infrastructure services.

The paper concludes with a characterization of the allocation of fixed costs that satisfies widely supported axioms of fairness (Mirman and Taubman, 1982), and which can be interpreted as the outcome of an n-person cooperative bargaining game (Harsanyi, 1979) as well as an application of the Rawlsian theory of justice (Rawls, 1988).

2. The basic framework

In accordance with the public finance characterization of transport infrastructure goods, we focus on the fact that transport infrastructure in general and highways in particular have high fixed costs and relatively low costs that vary with the level of usage. Moreover, due to the indivisibility of infrastructure goods there is an under-utilization of the good and crowding at high levels of usage. Considering construction, maintenance and congestion costs due to crowding, the collection of users is confronted with decreasing average costs for low levels of usage due to the dominance of the fixed costs and with increasing costs per user for high levels of usage due to the dominance of the congestion costs. Due to the invisibility there is also a very low elasticity of substitution with other infrastructure objects, if this exists at all. These characteristics imply that private markets do not in general lead to optimal allocations, or that government interventions have the potential to lead to a higher degree of welfare for the collective of users. In implementing reforms of the provision of transport infrastructure services, income distribution effects seem to have had at least as strong a resonance politically as arguments concerning the efficiency of the transport sector. One of the reasons why infrastructure pricing is perceived to be unjust lies in the disconnection between the provision of services and payment brought about by tax financing. Some of the users seem to have interpreted this as receiving a free good.

To set out the analytical framework for the analysis of the distribution effects of highway pricing, we start with a very simple framework where income distribution is not an issue. A population of n users all have the same preferences for the consumption of infrastructure services and a private consumption good.
We start by defining the following variables:

\[ c \equiv \text{consumption good (actual consumption minus initial endowment), the consumption good is perfectly divisible} \]

\[ \eta \equiv \text{individual use of the transport infrastructure good} \]

\[ n \equiv \text{number of individuals, treated as a continuous variable} \]

\[ U \equiv \text{utility of individual (all equal)} \]

\[ \Gamma \equiv \text{costs of infrastructure provision} \]

\[ n^*\eta \equiv G, \text{total use of the public consumption good} \]

The identity of the preferences is expressed by assuming that all users have the same utility function.

We disregard the production sector: All individuals are equipped with a certain amount of consumption goods and decide on how much of private consumption they would like to give up for using the infrastructure. This disregard of the production sector for the private good means that we implicitly assume that the private sector is perfectly competitive.\(^1\) Focussing on the allocation aspects in this section, all individuals are equal in terms of the initial endowment with the private consumption good \(c\).

### 2.1 Utility

Given that individuals are assumed to be homogeneous, all have the same utility function:

\[ U = U(c, \eta, n\eta) = U(c, \eta, G) \]

\[ U_c \geq 0, U_\eta \geq 0, U_{c\eta} \leq 0 \]

(1)

All consumers, or the representative consumer, have binary preference orderings which are complete, transitive and continuous. The utility function is then a continuous, real-value function. It increases digressively with the private consumption good, and with the individual use of infrastructure, which might be the number of trips or the number of kilometres travelled. \(G\) denotes the total use of the infrastructure. The higher the total use the more individuals suffer from congestion costs. That is, an increase of \(G\) reduces utility. The second row of (1) denotes first derivatives of the utility function.

---

\(^1\) Otherwise the pricing of infrastructure services might have to consider second best pricing, taking account of the degree of monopoly in the private sector.
2.2 Costs

Costs of the facility increase with its total use, the “capacity”. We assume that costs increase with the capacity. At this stage it is not necessary to restrict admissible forms of the function, i.e. decreasing, constant or increasing average costs.

\[
\Gamma = \Gamma (n \eta) = \Gamma (G) \\
\Gamma_G \geq 0
\]  
(2)

3. The planner's problem with homogeneous users

The planner seeks to maximize the utility of the individuals. As all individuals are identical, this amounts to maximizing the utility of a “representative agent”. With perfect knowledge of the preferences of the infrastructure users, he will simultaneously optimise the supply of services and cost recovery through the revenues generated by pricing. The constraint he faces is the total availability of resources. The planner cannot spend more on infrastructure than the total amount of consumption goods the individuals do not want to use for private consumption. He or she then faces the following budget constraint:

\[
n(\bar{c} - c) - \Gamma (n \eta) = 0
\]  
(3)

To find out how much of the endowments should go into private consumption and how much should be used for infrastructure, the planner solves a constrained optimization problem. She or he maximizes individual utility under the budget constraint:

\[
\max L = U(c, \eta, n \eta) + \lambda [n(\bar{c} - c) - \Gamma (n \eta)]
\]  
(4)

That is, the planner determines the optimal level of consumption, the optimal number of users of the facility and the optimal number of trips.

4. Optimal solutions for pricing and capacity

First-order conditions for the optimal solution:

\[
\frac{\partial L}{\partial c} = \frac{\partial U}{\partial c} - \lambda n = 0,
\]  
(5)

which implies

\[
\lambda = \frac{1}{n} \frac{\partial U}{\partial c}
\]  
(6)
\( \lambda \) indicates what the social availability of one more unit of the consumption good means to the welfare of all users.

\[
\frac{\partial L}{\partial \eta} = \frac{\partial U}{\partial \eta} + n \frac{\partial U}{\partial G} - \lambda \frac{\partial \Gamma}{\partial G} n = 0
\] (7)

The first term on the right-hand side shows the increase in utility of having one more use of the infrastructure. The second term indicates the disutility of all the other members of society doing the same, with the consequence of increasing congestion. The sum of these effects should be equal to the marginal costs of all of the (equal) individuals taking the same decision, multiplied by the factor that transforms costs in terms of the consumption good into terms of utility.

Dividing by the expression for \( \lambda \) and \( n \) we obtain from (7):

\[
\frac{\partial U / \partial \eta}{\partial U / \partial c} + n \frac{\partial U / \partial G}{\partial U / \partial c} - \frac{\partial \Gamma}{\partial G} = 0, \text{ or } (8)
\]

\[
\frac{\partial U / \partial \eta}{\partial U / \partial c} \bigg|_{(a)} = \frac{\partial \Gamma}{\partial G} - n \frac{\partial U / \partial G}{\partial U / \partial c} \bigg|_{(b)}
\]

The absolute value of (a) is identical to the Marginal Rate of Substitution between private consumption and use of the infrastructure facility. It indicates how much of private consumption individuals are prepared to give up to have one more unit of infrastructure use in equilibrium. It is equivalent to the willingness to pay for a unit of infrastructure use and is in a well-defined sense the "efficiency price". (b) is negative and indicates an individual's utility loss due to congestion if another individual increases the use of the facility by one unit: \((-n)\) times this expression is then what the latter should pay to compensate all the other users for the increase in congestion. The first term on the right-hand side of (9) is the marginal cost of operating the facility due to the increase in infrastructure use by one unit.

Marginal operation costs plus the compensations for the disutility of increased congestion add up to the efficiency price.
That this just covers the total costs of the facility can be seen from the planner's answer to the question of how many users should be admitted to the facility. Given that he knows already the optimal quantity of demand per user, this amounts to determining the capacity.

Differentiating (4) with respect to \( n \), we have

\[
\frac{\partial L}{\partial n} = \eta \frac{\partial U}{\partial G} - \lambda (\bar{c} - c) - \frac{\partial \Gamma}{\partial G} \eta = 0. \tag{10}
\]

Dividing by the expression for \( \lambda \) according to equation (6) we obtain

\[
n \frac{\partial U}{\partial G} (\bar{c} - c) - \frac{\partial \Gamma}{\partial G} \eta = 0 \tag{11}
\]

Multiplying both sides of the equation by \( n \) leads to

\[
n \frac{\partial U}{\partial G} (\bar{c} - c) n - \frac{\partial \Gamma}{\partial G} G = 0 \tag{12}
\]

Minus \( n(\bar{c} - c) \) is equal to \( \Gamma \). That is

\[
\Gamma = -n \frac{\partial U}{\partial G} \frac{\partial G}{\partial (c)} + \frac{\partial \Gamma}{\partial G} G = 0 \tag{13}
\]
The right-hand side of (13) shows the total payments by the users of the infrastructure. (c) is the total payment by all users for causing congestion, (d) is the total payment for the marginal operation costs of all users. The right-hand side of (13) is exactly equal to the efficiency price of using one more unit (trip, hour of driving), which is equal to the right-hand side of (9), times the total use of the infrastructure G. It also shows that if congestion is sufficiently strong, transport infrastructure can be offered like a private good. Dividing (13) by G, we have the optimality condition that the marginal congestion costs plus the marginal infrastructure costs add up to the average infrastructure costs, i.e. the costs per unit of service. This is illustrated in Figure 1, with the slope of the ray from the origin representing the average costs. As this ray is tangent to the social cost curve, it represents the social marginal costs as well. Without congestion (c) in (13) is negligible, and the optimality conditions will always be violated with the usual assumptions about the cost function of infrastructure. With constant marginal costs and fixed costs, average costs will be decreasing throughout the relevant levels of usage.

The optimality conditions can be restored by fixed transfers to the infrastructure sector. These transfers are either financed by taxes or by fixed charges. In any case, they have to be unrelated to the use of the infrastructure as well as to the characteristics of the users so as not to violate the optimality conditions. It is this required independence that leads to distributional problems in the case of the heterogeneity of agents.

5. User heterogeneity, optimality and perceptions of distributional justice

To cast the problem of distribution effects and pricing in the simplest form, we assume that two groups exist that are still identical but for their endowment with initial income. We assume that the first group has \( n_1 \) members, all equipped with an initial income of \( \bar{c}_1 \), the second group has \( n_2 \) members with an income of \( \bar{c}_2 \). To avoid any discussion of the comparability of utilities, we assume that all individuals have the same utility function.

The total use of the infrastructure has then to be redefined to

\[
G = n_1 \eta_1 + n_2 \eta_2 ,
\]

and the cost function to

\[
\Gamma = \Gamma(n_1 \eta_1 + n_2 \eta_2)
\]

The planner's problem is then changed to

\[
\max L = U(c_1, \eta_1, G) + U(c_2, \eta_2, G) + \lambda[n_1(\bar{c}_1 - c_1) + n_1(\bar{c}_1 - c_1) - \Gamma(n_1 \eta_1 + n_2 \eta_2)]
\]

By the same analytical steps as in the case of homogeneous users, we arrive at two optimality conditions, one for each group.
\[
\frac{\partial U}{\partial \eta_1} + n_1 \frac{\partial U}{\partial c_1} - \frac{\partial \Gamma}{\partial G} = 0
\]

(17)

and

\[
\frac{\partial U}{\partial \eta_2} + n_2 \frac{\partial U}{\partial c_2} - \frac{\partial \Gamma}{\partial G} = 0
\]

(18)

The first term on the left-hand side of both equations indicates the willingness to pay of the user group members for an additional unit of infrastructure services. Despite the differences in income, these are equal because

\[
\frac{n_1}{\partial U/\partial c_1} = \frac{n_2}{\partial U/\partial c_2} = \frac{1}{\lambda}
\]

(19)

as follows from the optimal values for the consumption of the private good.

That is, the optimal social organization of infrastructure provision implies the pricing of individual units of infrastructure use according to the social marginal costs of the services. If congestion is strong enough that the social marginal cost of infrastructure increases with an increasing number of users and/or an increasing number of kilometres travelled, the infrastructure is self-financing.

6. Principles of distributive fairness

Notions of “fairness” are not, of course, universal. They refer to underlying principles which are more or less able to claim universal support. Fairness naturally, and following Aristotelian philosophy, entails the equal treatment of equals. If two persons have identical characteristics in all dimensions relevant to an allocation problem at hand, they should receive the same treatment, i.e. the same share of income, voting power or costs of a service which is commonly enjoyed.

The unequal treatment of unequals is, in contrast, a vague concept, which is open to interpretation. That is, the difficulties with the notion of “unequal treatment of unequals” result from the heterogeneity of the population that the fair distribution of surplus or costs is designed for. Four different principles are central to the discussion

(1) exogenous rights,
(2) fitness,
(3) compensation,
(4) reward.

These principles will be briefly discussed to argue that the potential conflict with the Pareto principle -- that allocations should be such that no reallocation of resources could improve the position of one party without worsening the position of another -- implies
that only the reward principle is important for the discussion of infrastructure pricing and distributive fairness.

The notion of fairness concerning exogenous rights is independent of the consumption of the relevant resources or the responsibility of the consumers in their production. A paramount instance of exogenous rights is the fairness principle of equality in the allocation of certain basic rights such as political rights, the freedom of speech, etc. The right to vote, for example, is equal for all voters regardless of their desire to vote or the rationality of the voters. Equal exogenous rights postulate equality ex ante in the sense of an equal claim to resources, regardless of the way they affect our welfare and that of others. For the provision of infrastructure services, this would imply an equal (and free) access to infrastructure that is financed by a lump sum tax, regardless of the endowments of the user or differences in individual demand.

The fitness principle postulates that resources must go to whoever potentially makes the best use of them. The fitness principle justifies an unequal allocation of resources, independently of needs, merit or rights.

Both the exogenous rights and the fitness principle are in sharp contrast to the compensation principle. The compensation principle is based on the idea that certain differences in individual characteristics are involuntary, morally unjustified and affect the distribution of a higher order characteristic that is to be equalized. This justifies unequal shares of resources in order to compensate for the involuntary difference in the primary characteristics. The compensation principle aims at an equal degree of satisfaction of consumers’ needs \textit{ex post}. For the consumption of infrastructure services, equality according to the compensation principle would require an equal sacrifice in utility terms for all users of the transport system. The compensation principle is relevant to the discussion of the fairness of pricing rules only to the extent that fiscal redistribution mechanisms are \textit{unable} to correct a socially undesirable distribution of incomes or abilities. The unequal distribution of characteristics which induce undesired inequalities of higher order characteristics should focus on the correction of the unequal distribution of primary characteristics. More specifically, if the income distribution of a society is perceived to be too unequal, the unequal income distribution should be corrected by fiscal measures and not the consequent unequal distribution of opportunities to travel.

The most important principle of fairness for the discussion of infrastructure pricing roles and distributional fairness is the reward principle. According to the reward principle, individual characteristics are morally relevant when they are viewed as voluntary and consumers are held responsible for them. They justify unequal treatment. Due to the fact that individual demands do not lead to variations in total costs of infrastructure but might reduce the per capita costs for all consumers, the application of the reward principle is not straightforward.

7. Distributional conflict of fixed fee and optimal pricing

If infrastructure users are unequal, a distributional conflict might be introduced as a result of different demands by the users of the infrastructure. More specifically, the different interests of unequal users may manifest themselves in differences in the preferred pricing rule. Assume that the users have a choice between different pricing
rules to cover the full costs of infrastructure. A first option could be to postulate that the per-km user charges should cover the full costs of the infrastructure. The optimisation of the social planner, set out in section 2, would then have to be extended by a restriction that prices have to cover the costs of the infrastructure. Such an optimisation exercise would lead to a Ramsey price of $p_0$. The consumers might be offered the choice of paying a price $(p_0 - t)$ which is lower by the amount $t$. The alternative expenditure functions would then be (cf. Willig 1978)

\[ E(p_0, n^*) = p_0 \eta, \text{ and} \]
\[ E(p, n^*) = \gamma + (p_0 - t) \eta \]

The user will prefer the pricing rule that will imply the higher indirect utility, denoted by $V$. She or he would prefer a two-part tariff to a Ramsey price if

\[ V(p_0 - t, \bar{c} - \eta) \geq V(p_0, \bar{c}) \]

For small $t$, starting from full cost prices, the consumer prefers a two-part tariff if

\[ \frac{dV}{dt} \bigg|_{t=0} = -\frac{\partial V}{\partial p} - \frac{\partial V}{\partial \bar{c}} \gamma = \frac{\partial V}{\partial \bar{c}} (\eta - \gamma) > 0 \]

As the marginal indirect utility with respect to real income is always positive, the preference for a two-part tariff follows from $(\eta - \gamma)$ being positive. The higher the equilibrium demand for infrastructure services, the more the user will prefer a two-part tariff. The smaller the equilibrium demand, the more they will prefer Ramsey pricing. To implement full cost pricing to satisfy the political demands of the low demand group would lead to an aggregate welfare loss. If marginal costs were zero, as assumed in Figure 2, the triangle BCD would represent the loss of consumer rent which would result from full cost pricing.
The solution of the conflict between equity and efficiency proposed here relies on the well-known model of allocating the costs of a jointly used resource according to the cooperative game theory concept of the Shapley value (Shapley, 1953, Shubik, 1962). In terms of the general principles stated in section (6), the solution concept rests almost entirely on the reward principle, posing the question of a fair level of contribution to the joint costs in order to deserve the service enjoyed in equilibrium.

With marginal cost pricing, the cost allocation game is about access charges for different users whose demands add in different ways to the total costs of the infrastructure. This is a standard mechanism for joint fixed cost allocation mechanisms (Young, 1994; Sharkey, 1995). They have also been applied in transport economics, as a solution to charging in cases where there are only fixed costs and price inelastic demand (Littlechild and Thomson, 1977). The cost allocation method has even been proposed as a way to calculate full cost prices for infrastructure use (Doll, 2005). However, it has not been discussed as a solution to the distributional problem of two-part tariffs. To introduce the idea of the solution concept, consider the following example. There are three classes of vehicles A, B and D requiring different infrastructure designs, leading to different fixed, annual stand-alone costs:

\[ C(i) = 60, \text{ for } i = A, B, D \]  \hspace{1cm} (24)
The capital C indicates fixed annual costs for the different coalitions, assuming technical efficiency. To compute a fair allocation, a generalised principle of marginalism is applied. Adding, for example, vehicle class B to A, or D to A, or both B and D to A leads to additional demands for the infrastructure, implying additional costs of 60.

\[ C(A) = C(AB) - C(A) = C(AD) - C(A) = C(ABD) - C(A) = 60 \]  

The solution mechanism now orders the vehicle classes to randomly identify the expected additional fixed costs, for which the individual vehicle classes are responsible. For the coalition formation process B, A, D we obtain, for example, the following values \( x_i \), with \( i = A, B, D \):

\[ x_B = C(B) = 60, x_{AB} = C(AB) - C(B) = 60, x_{AD} = C(ABD) - C(A) = 60 \]

This process is repeated for all possible sequences to form the “coalition” of all vehicle classes. This leads to the following orderings and additional fixed costs:

<table>
<thead>
<tr>
<th>Ordering</th>
<th>Class A</th>
<th>Class B</th>
<th>Class D</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABD</td>
<td>60</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>ADB</td>
<td>60</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>BAD</td>
<td>60</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>BDA</td>
<td>60</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>DAB</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>DBA</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

| Sharpley value | 50 | 50 | 20 |

That is, the fair allocation as defined by the Shapley value assigns the average of the marginal contributions to total costs in the process of the formation of the all-player coalition to the individual vehicle types. This model of a random formation of the all-player coalition mimics, in a sense, the notion of the Rawlsian theory of justice that fairness considerations are based on the expectation that the individual might end up in a socially disadvantaged position. Furthermore, it has been shown by Harsanyi that the cost allocation solution presented above generalizes the two persons bargaining game of Nash to an arbitrary number of players. That is, the notion of fairness presented here does not depend on a "public interest" view of politics, where a benevolent dictator decides on the assignment of costs following a universally accepted principle of fairness. Rather, the solution concept can be interpreted as the anticipated outcome of a bargaining process between all parties involved.

An often-raised counterargument against the Shapley value is the high level of information requirements, either for planners or bargaining partners. In the specific
context of infrastructure provision there is, however, a way of identifying types of consumers by vehicle types. In many countries, an approximate solution could be implemented by designing or re-designing a vehicle tax according to the presented cost allocation mechanism.

9. Conclusion

The paper has discussed the conflict between efficient pricing and fairness. It has been shown that the conflict arises in cases where marginal congestion costs are too low to allow for coverage of full costs by marginal cost pricing. Conventional solutions to solve the distributional problem would entail efficiency losses. The paper proposes an allocation mechanism for the fixed costs that would resolve the conflict between efficiency and distributional equity.

References

Road pricing as a citizen-candidate game

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Abstract

We construct a political economy model to analyze the political acceptability of road pricing policies. We use a citizen-candidate framework with a population composed by three groups differing for their income level. We show that road pricing policies are never applied when there is no redistribution of the resources in favour of other modes of transport or when the congestion of these types of transport is relatively high. The results suggest that the efficiency of the redistribution of resources from road to the alternative types of transport as well as the fraction of the population that uses the road transport are key factors in explaining the adoption of road pricing schemes.

Keywords: Road pricing; Political acceptability; Citizen-candidate.

1. Introduction

This paper studies the political acceptability of a road pricing policy in a context characterized by heterogeneous agents choosing between two distinct congestible infrastructures producing differentiated transport services. One service is fast and expensive (e.g., auto) while the other slow and not expensive (e.g., public transport). By assumption, public transport is slower than private transport, regardless of the modal split. The heterogeneity of agents is accounted for by assuming the existence of three groups. People are homogeneous within each group and the three groups differ for the level of income of the agents. For this reason, we call these groups rich, middle class and poor. No one group has the absolute majority of votes which, therefore, requires the combination of any pair of groups. At the same time, we assume that initially (i.e. at the

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status quo) both modes of transport are always used by at least by one income group. For the political competition, we use a citizen-candidate framework (see Osborne and Slivinski, 1996; Besley and Coate, 1997) in which there is neither uncertainty nor commitment. This in turn means that the elected candidate implements its preferred policy.

The model assumes that a road pricing can be imposed on the private mode of transport by any elected citizen-candidate with or without redistribution in favor of the public transport mode. Redistribution of revenues to car drivers is ruled out. Under these assumptions, the model provides the following results. Road pricing policies on the private mode are never imposed when there is no redistribution of raised revenues towards the public mode of transport. When such redistribution is made, it is possible to obtain equilibria with the adoption of road pricing schemes. In particular, this is the case when the congestion of the alternative mode of transport is relatively low or when the resources from road pricing allow to improve substantially the quality of the alternative mode of transport. Finally, the acceptability of road pricing policies appears to be high when a large fraction of the population does not use road transport in the status quo.

The paper is organized as follows. Section 2 presents the related literature. Section 3 defines the basic setup of the problem. Section 4 characterizes the equilibrium of the model when there is no redistribution of the road pricing revenues while Section 5 determines the properties of the equilibrium when such redistribution (in favor of public transport) is allowed. Section 6 concludes.

2. Related literature

This paper combines a recent stream of literature on integrated urban road pricing policies (see, for instance, Glazer and Niskanen, 2000 and Armelius, 2005) with a rather standard version of a citizen-candidate game (Osborne and Slivinski, 1996; Besley and Coate, 1997). The novelty of this approach relates to the analysis of the interaction between the level of the tariff proposed, the eligibility of the candidate proposing it and its political acceptability, given the income distribution and the modes of transport used by the community.
In order to locate our contribution, we can conveniently divide the literature on road pricing in three different streams, as suggested in a recent book by Arnott, Rave and Schöb (2005). In the first stream of literature, urban congestion pricing theory was developed in a first-best transport and capacity perspective. A second stream has began with the literature on second-best pricing and capacity with the aim of making congestion pricing more politically acceptable. Finally a third one, characterized by a more applied attitude, examines in detail all the relevant aspects at a micro level that can foster or hinder the adoption of a pricing scheme. Given the above framework of references on road pricing, one might locate this paper in an embryonic part of the third phase of Arnott's et al. schematization of road pricing literature. In fact, even if, among other weaknesses, the setup proposed is very aggregated with respect to agents heterogeneity (a much more advanced work, under this respect, is de Palma and Lindsey, 2004) and the analytical treatment of the two transport modes (private and public) is rather rough, nonetheless, the paper attempts to provide some new insights concerning the political acceptability of road pricing policies. Previous research has looked into the issue of political acceptability enquiring various issues such as those reported below, but has never interpreted the problem in a citizen-candidate framework.

The politico-economic and fairness considerations of adopting road pricing have recently been addressed in a paper by Oberholzer-Gee and Weck-Hannemann (2002) where the lack of citizens' support for road pricing initiatives is attributed to two factors which are the general lack of will to adopt the price system as an allocation mechanism for scarce resources (Hahn, 1989; Frey et al., 1985) and the difficulty with which the latent support for road pricing schemes translates into actual policy making (Small, 1992). This way of explaining the low practical implementation of road pricing dwells on research interpreting the scarce adoption of road pricing schemes as due to its low political acceptability (see reviews by Jones, 1995; Schlag and Teubel, 1997). Individuals might not accept road pricing due to a misperception of the negative effects as being caused by others rather than by oneself (Sheldon et al., 1993) thus contributing to a feeling of unfairness either perceived or real (Emmerink et al., 1995). Research by Baron and Jurney (1993) and Baron (1995) has shown that people are opposed to coerced reforms even though they sympathize with the intended purpose. The most important reasons for opposing road pricing have been attributed to social or moral
norms of fairness and freedom of choice. These considerations had already been raised by Borins as late as 1988 (Borins, 1988). Other issues concerning the acceptability of road pricing policies that have progressively received greater attention have to do with misunderstanding, complexity, equity/fairness, privacy issues or tax resistance (Giuliano, 1994; Goodwin, 1989; Jones, 1998; May, 1992) as well as individual specific uncertainty (Marcucci and Marini, 2003).

Implementation hinges on a political question: will it be politically feasible to impose a road pricing scheme? As it is now strongly remarked in the current literature, this question can hardly be answered in abstract and general terms (Santos and Fraser, 2005).

3. Setup

We consider a population living in a given area composed of three homogeneous groups \( \{G_k\}_{k=1,2,3} \) only differing in their income level. We denote by \( y_k \) the income level of every agent belonging to a \( k \)-th income group. Hence, we assume that \( y_1 > y_2 > y_3 \), with \( y_k^I = y_k^B \) for every \( \{i,h\} \in G_k \). Every group has mass \( \mu_k \), with \( \sum_k \mu_k = 1 \) and \( \mu_k < 0.5 \). Therefore, it follows that \( \mu_g + \mu_l > 0.5 \) for every \( \{g,l\} = 1,2,3 \).

In other words, group 1, 2 and 3 correspond to the rich, the middle class and the poor respectively, and the absolute majority of votes requires the combination of any pair of groups.

We also assume that each individual consumes one unit of transport. We denote with \( t \) the time spent for the journey and assume that this is positively related to the number (or mass) of agents \( \mu \in [0,1] \) using that mode of transport, i.e. \( \frac{dt}{d\mu} > 0 \). Hence, we denote by \( v_k(t_j(\mu_j)) \) the value of a journey made by an agent of group \( k \) when using a given \( j \)-th congestible mode of transport. The journey requires travel time \( t_j \) which depends positively on the mass \( \mu_j \) of the people using the mode of transport \( j \). The willingness to pay of the individuals is decreasing in the time spent for the journey and, therefore,

\[\text{We make no restrictive hypotheses concerning the income differences between the three groups.}\]
\[
\frac{dv_i}{dt} < 0 \text{ for every individual in } G_k. \text{ Moreover, due to the different income of the individuals of the three groups, we can simply assume that for every } j^{th} \text{ mode of transport and for every level of congestion } \mu_j: ^2
\]

(1) \[v_1(t_j(\mu_j)) > v_2(t_j(\mu_j)) > v_3(t_j(\mu_j)) \geq 0.\]

The optimization problem of an individual belonging to a given group \( k \) is:

(2) \[\max_j \sigma_k(t_j(\mu_j), p_j) = \max_j \left[ v_k(t_j(\mu_j)) - p_j \right] \]

where \( \sigma_k(t_j(\mu_j), p_j) \) denotes the net surplus of each consumer in group \( k \) using the \( j^{th} \) transport mode at its price \( p_j \). Thus, by choosing one unit of a given transport mode over a number of alternatives, all individuals aim at maximizing their own net surplus, equal to the difference between their willingness to pay for the time spent in the transport mode and its unitary price. To keep things simple, we suppose that in the area under consideration, only two substitute systems of transport exist for a given journey, a fast one (auto) \( j=f \), and a slow one (public transport) \( j=s \), with \( 0 < t_f < t_s \) and \( p_f > p_s > 0 \). Therefore, at the optimal choice, every \( i \in G_k \) will select mode \( j \) if and only if:

(3) \[\begin{cases} 
\sigma_k(t_j(\mu_j), p_j) \geq \sigma_k(t_h(\mu_h), p_h) \\
\text{and } \sigma_k(t_j(\mu_j), p_j) \geq 0
\end{cases}\]

for \( h \neq j \). At the status quo, we expect that, when affordable, rich people \( (i \in G_1) \) will always choose auto for any congestion level and poor people \( (i \in G_3) \) public transport. Therefore:

(4) \[\begin{cases} 
\sigma_1(t_j(\mu_j), p_j) \geq \sigma_1(t_i(\mu_i), p_i), \\
\sigma_3(t_j(\mu_j), p_j) \leq \sigma_3(t_i(\mu_i), p_i).
\end{cases}\]

\[ ^2 \text{The intuition behind this assumption is that for any given time spent in transport, the higher income individuals have a higher willingness to pay for the trip which originates from the higher opportunity cost of time.} \]
As far as the people of middle class are concerned \((i \in G_z)\), two status quo are conceivable. In a first one, they all prefer to use auto, and this requires that, at the given prices \(p_f\) and \(p_s\):

\[
\begin{align*}
\sigma_z(t_f(\mu_f), p_f) & \geq \sigma_z(t_s(\mu_s), p_s), \\
\text{and } \sigma_z(t_f(\mu_f), p_f) & \geq 0.
\end{align*}
\]  

(5)

In the second status quo, the sign of the first expression above is reversed, and initially the people of the middle class will, at the given prices, find optimal to select the private mode of transport.

Using the setup described above, we now consider a simple citizen-candidate game in which a road pricing scheme on the auto (with a given distribution of the raised revenues) is decided by a leader elected directly by the people of the area through a majority voting process among the menu of citizen-candidates participating to the election. The menu of candidates is endogenous and one individual runs for office if and only if, in equilibrium, the net gain of doing so - the surplus he gets if he does run, plus an exogenous benefit \(b\) - exceeds a given cost \(c\) of running for office.\(^3\) We assume the absence of any form of commitment so that the elected candidate implements its preferred policy. We also assume that voting is sincere.\(^4\)

In order to determine the political outcome of the game, we first determine the preferred road pricing policy that a candidate of group \(G_k\) would select once elected. Then, we determine which agent will be elected and the policy implemented. We analyze two possible situations. The first is when the road pricing revenues are not redistributed, while in a second situation the revenues from road pricing are redistributed in favor of the public mode of transport.

\(^3\) The existence of an exogenous benefit \(b\) of winning the election and of a fixed cost \(c\) to run for it, with \(b > c\), implies that no candidate will run for an election when there is no probability of winning. When this probability is positive, running for the election provides positive utility.

\(^4\) This assumption can be justified by noting that each individual regards himself as an atomistic subject. Therefore, he considers his vote irrelevant in conditioning the outcome of the elections. Osborne and Slivinsky (1996) assume that voting is sincere while individuals are strategic in Besley and Coate (1997).
4. Road pricing in absence of redistribution

We now consider the benchmark case in which none of the revenues raised by the road pricing are redistributed.\(^5\) We first analyze the case in which at the status quo all population of the middle class \((i \in G_2)\) initially uses the fast mode (i.e. the road). We denote by \(\bar{\tau}_k\) the road pricing under no redistribution decided by a candidate belonging to a group \(G_k\) when elected. In what follows we illustrate in detail the level of road pricing set by the running candidate of each group under the no distribution scenario.

The optimal policy of the rich \((i \in G_1)\). A rich candidate would ideally tax positively the auto only if the gain in surplus obtained by excluding the middle class, and thus reducing congestion, exceeds the cost of being tolled. In this case, the tax \(\bar{\tau}_i\) will be just equal to the difference between the surplus of one middle class member when using the auto together with the rich class and the surplus obtained by using the public mode of transport with both the middle and the poor class.\(^6\) Therefore, if

\[ v_i(t_f(\mu_i)) - v_i(t_f(\mu_i + \mu_2)) - \bar{\tau}_i > 0 \]  

(6)

it follows that

\[ \bar{\tau}_i = \sigma_2(t_f(\mu_i), p_f) - \sigma_2(t_f(\mu_2 + \mu_3), p_f) > 0. \]  

(7)

If, on the other hand, there is no gain for the rich class individuals from the switch, i.e.

\[ v_i(t_f(\mu_i)) - v_i(t_f(\mu_i + \mu_2)) - \bar{\tau}_i \leq 0 \]  

(8)

\(^5\) Such an absence of redistribution can also represent the case in which the taxation system is so inefficient that no money is offered back in any form to the tax payers.

\(^6\) Note that here the toll makes every middle class individual indifferent between auto and public transit, according to a standard Wardrop’s (1952) concept of equilibrium. In network analysis it has been standard to assume that (a) travellers behave selfishly, and (b) individual travellers are atomless, i.e. have zero mass or measure. Accordingly, the equilibrium can be conceived as a situation stable against individual deviations.
every rich candidate will optimally impose a zero road pricing \((\tilde{\tau}_i = 0)\).

The optimal policy of the middle class \((i \in G_2)\). When there is no redistribution of the revenues, there is no reason for the agents of the middle class to impose a positive road pricing as they have already optimally chosen the use of the private mode of transport \((\tilde{\tau}_2 = 0)\).

The optimal policy of the poor \((i \in G_3)\). It is clear that also for the poor there is no incentive to impose a positive road pricing given that they would obtain no advantage from it \((\tilde{\tau}_3 = 0)\).

It is easy to see that, at the second status quo, in which initially all \(i \in G_2\) use public transport, the proposed road pricing schemes is \(\tilde{\tau}_1 = \tilde{\tau}_2 = \tilde{\tau}_3 = 0\).

The next proposition makes clear that, in absence of redistribution, the political equilibrium implies a zero road pricing scheme.

**Proposition 1.** Under no redistribution of the road pricing revenues, the political equilibrium of the citizen-candidate game implies a zero road pricing scheme (i.e. \(\tau^* = 0\)) under both status quo considered.

**Proof.** When the game starts with the first status quo \((\mu_f = \mu_i + \mu_2\) and \(\mu_j = \mu_3\)) and there is no redistribution of the road pricing revenues, the proposed \(\tilde{\tau}_i\) will either be positive or equal to zero (depending on the effect of congestion on rich class's surplus), while both middle and poor citizen-candidates will prefer to impose a zero road pricing, since, in absence of redistribution, they both lose from the switch of the middle class. So, for the case in which \(\tilde{\tau}_i > 0\), no rich candidate will run for office as he would be defeated by a poor or middle class candidate. In equilibrium, a middle class or a poor candidate will run for office and win the elections. The choice on which of the two will run only depends on the relative weight of the mass \(\mu_2\) and \(\mu_3\): in fact, when the policy of different citizen candidates (belonging to different groups) coincides, the voters will always vote for their own candidate. In this case, whoever is the winner, the political equilibrium will always imply a zero road pricing \(\tau^* = 0\). Similarly, when \(\tilde{\tau}_i = 0\), the
only candidate running for the election will belong to the class with greater mass $\mu_k$, and will decide an equilibrium road pricing $\tau^* = 0$. Starting with the second status quo ($\mu_f = \mu_i$ and $\mu_s = \mu_2 + \mu_3$), all citizen-candidates will propose $\tilde{\tau}_k = 0$, so that the political equilibrium with a $\tau^* = 0$ will, again, be trivially satisfied.

Although the above result is not surprising, it helps to understand the reasons why road pricing policies, without an appropriate scheme of redistribution of the revenues obtained towards public transport, is likely not to be implemented in modern cities. In fact, without an appropriate use of the funds raised, only rich citizens may (sometimes) gain from road pricing. This occurs when the gain from the reduced congestion more than offset the increased price of road transport. All other citizens have no interest, without redistribution, to impose a toll. This in turn implies that no road pricing is the preferred policy of the majority of the population and of the elected politicians. The following section shows that the result can be different when simple forms of redistribution of the resources obtained from road pricing are implemented.

5. Road pricing in presence of redistribution

We now briefly consider a framework where all revenues raised by a road pricing scheme are redistributed in favor of the public transport through a reduction of its price $p_s$.\(^7\) At the status quo at which the middle class uses the auto ($\mu_f = \mu_i + \mu_2$ and $\mu_s = \mu_3$), a road pricing scheme on the auto decided by an elected candidate of group $G_k$, here denoted $\hat{\tau}_k$, will be as follows.

The optimal policy of the rich ($i \in G_r$). Similarly to the previous section, every rich candidate ($i \in G_r$) would ideally tax positively road users only when the gain from excluding the whole middle class from this mode of transport - in terms of reduced congestion - exceeds its increased price as due to such a pricing scheme. In this case, the

\(^7\) The effect on $p_s$ is analogous (and provides a reduced form) to the redistribution of road pricing funds in favour of public transport, which can either reduce its price or increase its quality (in turn rising the willingness to pay of its users), hence increasing their surplus.
tax $\tau_i$ will be just equal to the difference between every middle class member's surplus from being in the private mode with the rich class and the surplus by being in the public mode with the poor and the middle class, at the reduced price $p_s^1 = \left( p_s - \frac{\mu_1}{\mu_2 + \mu_3} \tilde{\tau}_1 \right)$, including the redistribution. Note that now such a marginal condition is more easily satisfied as before, because in this case the redistribution constitutes an extra incentive for the middle class to switch to the public mode of transport. Therefore, if

$$v_i(t_f(\mu_i)) - v_i(t_f(\mu_i + \mu_2)) - \tilde{\tau}_i' > 0$$

then

$$\tilde{\tau}_i' = \sigma_2(t_f(\mu_i), p_f) - \sigma_2(t_*(\mu_2 + \mu_3), p_s^1) > 0,$$

where $p_s^1 = \left( p_s - \frac{\mu_1}{\mu_2 + \mu_3} \tilde{\tau}_1 \right)$ denotes the reduced price of public transport after redistribution. However, if condition (9) is not satisfied, then the rich will find optimal to impose a zero road pricing, i.e. $\tilde{\tau}_i'' = 0$.

The optimal policy of the middle class $(i \in G_2)$. A candidate of the middle class has no interest to impose a positive tax on the auto, except when a positive gain can be made tolling the rich class and joining the poor class in the use of public transport at the reduced price generated by the redistribution of resources. Therefore, if

$$v_2(t_f(\mu_i)) - p_f < v_2(t_*(\mu_2 + \mu_3)) - p_s + \frac{\mu_1}{\mu_2 + \mu_3} \tilde{\tau}_2',$$

we have

$$\tilde{\tau}_2' = \sigma_1(t_f(\mu_i), p_f) - \sigma_1(t_*(\mu_2 + \mu_3), p_s^2) > 0,$$
where \( p_s^2 = \left( p_s - \frac{\mu_1}{\mu_2 + \mu_3} \hat{\tau}_2^s \right) \) denotes the price of public transport after redistribution.

However, if condition (11) does not hold, the middle class candidate will impose a zero road pricing \( \hat{\tau}_2^w = 0 \).

The optimal policy of the poor (i.e., \( i \in G_3 \)). A poor citizen-candidate has two possible choices. The first is to impose a very high tax on the private mode of transport (call it \( \hat{\tau}_3^p \)) up to the point where only the rich class use the auto. This happens if the gain in surplus is so high to exceed the over-congestion in public transport determined by the switch of the middle class from the auto to public transport. Notice that in this case the optimal policy of the poor is exactly the same of the middle class (when the latter wants to impose a positive road pricing), i.e., \( \hat{\tau}_3^p = \hat{\tau}_2^w \). The second possibility for the poor class candidate is to tax all auto users up to the point at which none of the middle class members switch from auto, its status quo, to public transport. We denote such a tax as \( \hat{\tau}_3^w \) and it is clear that \( \hat{\tau}_3^w < \hat{\tau}_3^p \).

Formally, if the following condition is satisfied

\[
(13) \quad v_3(t_3(\mu_2 + \mu_3)) + \frac{\mu_1}{\mu_2 + \mu_3} \hat{\tau}_3^p > v_3(t_3(\mu_3)) + \frac{\mu_1 + \mu_2}{\mu_3} \hat{\tau}_3^w
\]

thus

\[
(14) \quad \hat{\tau}_3^p = \sigma_3(t_3(\mu_3), p_f) - \sigma_3(t_3(\mu_2 + \mu_3), p_s^y) > 0
\]

with \( p_s^y = (p_s - \frac{\mu_2}{\mu_2 + \mu_3} \hat{\tau}_3^p) \). When, instead, (13) does not hold, we have

\[
(15) \quad \hat{\tau}_3^w = \sigma_2(t_3(\mu_3), p_f) - \sigma_2(t_3(\mu_3), p_s^w) > 0
\]

with \( p_s^w = (p_s - \frac{\mu_2 + \mu_3}{\mu_3} \hat{\tau}_3^w) \).

In the framework considered, various equilibria may emerge depending on the combination of the optimal policies of the three groups. To discuss what we consider
the most relevant cases, it may be convenient to consider two possible scenarios arising from the first status quo and one arising from the second status quo.

5.1 Case 1: congestion does not hurt much the poor class

Let us first assume that the congestion of public transport is not a big problem for the poor. This means that, when possible, they would always prefer to impose a road pricing at its maximum level \( \tau' \). This road taxation will be implemented whenever the middle class has the same optimal tax policy \( \tau' = \tau' \). Clearly, as before, the citizen-candidate running for office and winning the election will depend on the relative size of these two classes. Here, the preferences of the rich are irrelevant. If, instead, the middle class finds optimal a zero road pricing (i.e. \( \tau^* = 0 \)), the preferences of the rich become important for determining the equilibrium. As long as also the rich does not want a road pricing (\( \tau^* = 0 \)), this will be the policy implemented as there are two classes (middle class and rich) which prefer it. If the rich would instead prefer a positive road pricing (\( \tau^* > 0 \)), because the gains from the reduction in the congestion of the road generated by the switch of the middle class to public transport more than compensate them for the tax paid, then an equilibrium may not necessarily exist.\(^8\)

Therefore, when the middle class uses the auto at the status quo, the implementation of road pricing requires that the congestion of public transport is not too costly from the point of view of the poor and the middle class. It is clear that a positive road pricing is more likely to have the support of the population when the possibility of increasing the quality (or reducing the price) of public transport through the revenues of road pricing is substantial. We can summarize some of the above results with the following proposition.

**Proposition 2.** When the road pricing income is entirely redistributed in favor of the public mode of transport and at the status quo the middle class uses the road transport, the political equilibrium of the citizen-candidate game will imply two cases:

\(^8\) This may happen when, in a two-candidate context, there is no group that always wins.
(a) For a very low sensitivity of the poor class to congestion, if
\[ \mu_i\left[ \sigma_1(t_f(\mu_i), p_j) - \sigma_1(t_f(\mu_2 + \mu_3), p_j) \right] > \sigma_2(t_f(\mu_i), p_j) - \sigma_2(t_f(\mu_2 + \mu_3), p_j) \]
then \( \tau^* = \hat{\tau}_2^* = \hat{\tau}_3^* > 0 \).

(b) If, instead
\[ v_1(t_f(\mu_i)) - v_1(t_f(\mu_2 + \mu_3)) < (\mu_2 + \mu_3)\left[ \sigma_2(t_f(\mu_i), p_j) - \sigma_2(t_f(\mu_2 + \mu_3), p_j) \right] \]
and
\[ \mu_i\left[ \sigma_1(t_f(\mu_i), p_j) - \sigma_1(t_f(\mu_2 + \mu_3), p_j) \right] < \sigma_2(t_f(\mu_i), p_j) - \sigma_2(t_f(\mu_2 + \mu_3), p_j), \]
then \( \tau^* = \hat{\tau}_1^* = \hat{\tau}_2^* = 0 \).

Proof. See Appendix.

5.2 Case 2: congestion hurts the poor class

Under an alternative scenario, the congestion of public transport can constitute a problem for the poor class. Hence, they should prefer a low road pricing (i.e. they prefer \( \hat{\tau}_1^* \)) that is not enough to induce the middle class' agents to change their mode of transport. As we have seen above, the middle class may have two different optimal policies. However, if congestion is so costly for the poor that they prefer to give up a large redistribution of resources from the private mode to the public one, then it is reasonable to expect that the middle class' optimal policy is to use the auto without imposing a road pricing (\( \hat{\tau}_2^* = 0 \)). Under these conditions, the policy implemented is no road pricing (\( \tau^* = 0 \)) independently on the preferences of the rich. In fact, if the rich prefers no road pricing (\( \hat{\tau}_1^* = 0 \)), this policy is optimal for two classes and the winner will be a rich or a middle class candidate depending on the relative size of their class. When the rich prefers a positive road pricing (\( \hat{\tau}_1^* > 0 \)) in order to exclude the middle class from the use of the auto, the elected candidate will be the agent of the middle class as he will get the votes also of the poor. In fact, the poor prefer (by assumption) no road pricing with the middle class using the road to the alternative where public transport is
subsidized but it is congested also by the middle class. This is summarized in the following proposition.

**Proposition 3.** When the road pricing income is entirely redistributed in favor of public transport and at the status quo the middle class uses auto, for a very high sensitivity of the poor class to congestion, the political equilibrium of the citizen-candidate game will imply a zero road pricing. In particular, if:

$$v_3(t_s(\mu_1)) - v_3(t_s(\mu_2 + \mu_3)) \geq [\sigma_2(t_s(\mu_1), p_f) - \sigma_2(t_s(\mu_2 + \mu_3), p_f)] \geq \mu_1[\sigma_1(t_s(\mu_1), p_f) - \sigma_1(t_s(\mu_2 + \mu_3), p_f)],$$

then $\tau^* = \tilde{\tau}_R^* = 0$.

**Proof.** See Appendix.

5.3 Case 3: the middle class uses the public transport at the status quo

Finally, we can examine the case in which the middle class uses public transport at the status quo. In this case, the poor and the middle class have the same preferences. They both want to impose a high taxation on the use of auto since this is used by the rich class only (recall that $\tilde{\tau}'_R = \tilde{\tau}_R^*$). Therefore, a rich citizen-candidate will never be elected as he would be defeated by a middle class or a poor candidate. In equilibrium, the candidate running for office will be from the largest class between middle class and poor and the road pricing policy implemented will involve a tax rate $\tau^* = \tilde{\tau}_R = \tilde{\tau}_R'$. The adoption of a road pricing scheme in this scenario arises by the desire of the majority of agents (not using the auto) to raise revenues in order to improve their mode of transport.

The insight provided by the latter result is that a positive road pricing is likely to be implemented when a large fraction of the population uses alternative modes of transport as these individuals have the incentive to tax the use of road in order to improve the alternative types of transport.

The following proposition summarizes this result. It is so easy to grasp that does
not require a formal proof.

**Proposition 4.** When at the status quo the middle class uses public transport, the only political equilibrium of the citizen-candidate game will imply $\tau^* = \tilde{\tau}_2 = \tilde{\tau}_3 > 0$.

Finally, notice that, in general, many elements appear to be crucial for the result of an election. First, the price ratio of transport modes when compared to the speed or quality preferences of all three classes. Second, the sensitivity to congestion of the two alternative modes of transport, reflecting a number of structural features of the whole transport network. Third, the way in which the redistribution of a road pricing is assumed to affect people’s wealth.

6. Concluding remarks

In this paper, we have proposed a simple framework to explain the reasons why road pricing schemes are not so diffused around the world. We have focused on the political acceptability of such policies using a political economy model where the electoral competition takes place with citizen-candidates. We have found that the redistribution of resources obtained through road pricing policies towards other modes of transport along with less congestion is necessary (even though not sufficient) to make this policy acceptable to the majority of the population. The analysis has also highlighted that road pricing policies are more likely to be accepted by a winning coalition when the redistribution of resources obtained with this form of taxation going to the advantage of other modes of transport allows to increase substantially their quality (or, more generally, the surplus of the agents that use them) or when at the status quo a large fraction of the population does not use the auto.

References


Appendix

Proof of Proposition 2.

Rearranging expressions (11) and (12) we can rewrite expression (11) as
\[
(A1) \quad v_i(t_i(\mu_i)) - v_i(t_i(\mu_2 + \mu_3)) > (\mu_2 + \mu_3) \left[ \sigma_2(t_i(\mu_i), p_f) - \sigma_2(t_i(\mu_2 + \mu_3), p_s) \right]
\]
which is the condition implying \( \hat{\tau}_2 > 0 \). Using instead (9) and (10), we can rewrite (9) as
\[
(A2) \quad \mu_i \left[ \sigma_1(t_i(\mu_i), p_f) - \sigma_1(t_i(\mu_2 + \mu_3), p_s) \right] > \sigma_2(t_i(\mu_i), p_f) - \sigma_2(t_i(\mu_2 + \mu_3), p_s).
\]
which is the condition implying \( \hat{\tau}_1 > 0 \). Finally, using expressions (13)-(15) we obtain
\[
(A3) \quad \mu_i \left[ \sigma_1(t_i(\mu_i), p_f) - \sigma_1(t_i(\mu_2 + \mu_3), p_s) \right] > v_3(t_3(\mu_3)) - v_3(t_3(\mu_2 + \mu_3))
\]
where (A3) exactly represents the condition implying \( \hat{\tau}_3 > 0 \). Note that for a relatively low sensitivity of the poor citizens to congestion, when (A1) holds, also (A3) is satisfied. Therefore, when (A1) holds the equilibrium toll is \( \tau^* = \hat{\tau}_2 = \hat{\tau}_2 > 0 \). When, instead, neither (A1) nor (A2) hold, the equilibrium toll will be \( \tau^* = \hat{\tau}_1 = \hat{\tau}_2 = 0 \).

Proof of Proposition 3.

By rearranging conditions (11)-(12) and (13)-(15) we have that \( \hat{\tau}_2 = 0 \) and \( \hat{\tau}_1 > 0 \) are selected for
\[
\left[ \sigma_2(t_i(\mu_i), p_f) - \sigma_2(t_i(\mu_2 + \mu_3), p_s) \right] \geq \mu_i \left[ \sigma_1(t_i(\mu_i), p_f) - \sigma_1(t_i(\mu_2 + \mu_3), p_s) \right]
\]
and
\[
v_3(t_3(\mu_3)) - v_3(t_3(\mu_2 + \mu_3)) \geq \mu_i \left[ \sigma_1(t_i(\mu_i), p_f) - \sigma_1(t_i(\mu_2 + \mu_3), p_s) \right]
\]
respectively. Note that, whatever the choice of the rich citizen-candidate, the following condition
\[
\left[ v_3(t_3(\mu_3)) - v_3(t_3(\mu_2 + \mu_3)) \right] \geq \left[ \sigma_2(t_i(\mu_i), p_f) - \sigma_2(t_i(\mu_2 + \mu_3), p_s) \right]
\]
directly implies
\[ v_1(t, (\mu_1)) - v_1(t, (\mu_2 + \mu_4)) \geq (\mu_2 + \mu_4) \left[ \sigma_2(t, (\mu_4), p) - \sigma_2(t, (\mu_2 + \mu_4), p) \right] = \tilde{\tau}_1. \]

The last expression clearly shows that each poor class candidate will prefer to keep congestion low in the public transport rather than receiving a positive toll \( \tilde{\tau}_1 \) as redistributed income. Therefore, all members of the poor class will vote for the middle class candidate, and, again, the political outcome will imply a zero road pricing, \( \tau^* = \tilde{\tau}_2 = 0. \)
Recent developments and current policy issues in road pricing in the US and Canada

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Abstract

The United States and Canada lag Europe and Singapore in implementing road pricing on a large scale. But the two countries have shown interest in tolling roads as a way to curb congestion and to generate revenues. The US is funding congestion pricing demonstration projects through its Value Pricing Pilot Program, and Canada has examined new ways to charge for road use and to finance road construction and maintenance. This paper reviews the current state of road pricing and funding in the two countries. The prospects for extensive road pricing appear to be brighter in the US than in Canada.

Keywords: Road pricing; Congestion; Earmarking; US Highway Trust Fund; Fuel taxes.

1. Introduction

For over a decade the European Union has been studying the application of marginal-cost-based pricing in transportation, and has issued Green and White Papers as well as sponsored a series of research projects. The United States and Canada have not made a comparable effort. Nevertheless, the two countries are acutely aware of flaws in the way that transportation is currently priced and funded, and they have shown interest in policy reform. As far as pricing roads the US has been funding congestion pricing demonstration projects through its Value Pricing Pilot Program since 1998. And in 2001, Canada completed a thorough review of the Canada Transportation Act that addressed the case for new ways to charge for road use and to finance road construction and maintenance.

The purpose of this paper is to summarise these and other developments, and to identify both the challenges and the prospects for wide-scale implementation of road pricing in the two countries. Europe is chosen as the main reference for comparison since many readers of this journal will be Europeans, and because there are interesting similarities and differences between the two continents. The US and Canada have standards of living and systems of government that are similar to the EU. As in the EU,
financing, regulation and operation of transportation facilities are divided between multiple levels of government: federal, state (US) or provincial (Canada), regional and municipal. And the political and acceptability barriers to road pricing are broadly similar. There are also some differences. Despite heavy subsidies to North American urban transit systems, the automobile is more dominant than in Europe. Urban sprawl is greater, and traffic congestion is less concentrated in urban centres. Particularly in the US, there is less trust in government and more reliance on the private sector generally. Yet private-sector involvement in road pricing has been much less than in the EU. And neither the US nor Canada has yet established either networks of interurban toll roads or large-scale urban road pricing schemes such as those found in Europe.

The US and Canada differ in some respects. There is a stronger commitment to public funding of transport in Canada, evident also in other sectors such as education and health care. But the US federal government is more active in funding urban transport projects, and in using transport investments to pursue economic development and national security goals. The US also earmarks a majority of federal fuel tax revenues to roads, whereas Canada does not. Finally, whereas the US has not ratified the Kyoto Protocol, Canada has done so and has an onus to reduce consumption of carbon-based fuels.

The next section reviews in some detail the current state of policy and practice of road pricing in the US. Section 3 provides a parallel, but briefer, summary for Canada. Section 4 addresses some of the major issues concerning the evolution of road pricing in the two countries. Concluding remarks are offered in Section 5.

2. Road pricing in the United States

Toll roads have a long and checkered history in the US going back to the late 1700s. Private roads were widespread in the 1800s, but they rarely made money and disappeared as canals and railroads came to dominate long-distance traffic. From time to time, state and local governments found toll financing of roads attractive as a way to accelerate road construction, as a supplementary source of funding during periods of financial stringency, and as a way to raise money from immediate beneficiaries, including non-resident travelers who were not subject to local taxes.

Currently the US has several hundred tolled facilities. As of January 1, 2003, there were 8,440 km of toll roads, bridges and tunnels, of which 8,097 km comprised tolled sections of roads inside the US (about 9% of total highway mileage). Electronic toll collection was used on 229 facilities. Some facilities differentiate tolls by vehicle and other characteristics, some offer alternative means of payment, and a modest fraction feature time-of-day toll variations.

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1 See Klein and Fielding (1992) and Levinson (2002, Chap. 2).
2 According to Shoup (2005, p.553, fn 56), financial stringency may also have been a motivating factor in installing parking meters during the Great Depression.
3 US Department of Transportation (2003). The numbers reported in the text are derived by counting each section or location of road as a separate facility if it is listed separately in the US DOT (2003) tables.
Growing support for road pricing

For a number of reasons support for road pricing has been growing in the US.

Increasing severity of congestion. According to the Texas Transportation Institute (2005), in 2003 the cost of congestion-induced time delays and extra fuel consumption amounted to $63.1 billion in 85 major US urban areas. In Los Angeles, the most congested city, the annual delay per traveler was 93 hours, and average travel time during peak periods was 75% longer than travel time under free-flow conditions. These figures have grown relatively steadily since at least 1982.

Improved tolling technology. Conventional tollbooths have high administration costs and can impose long waits on drivers. But with electronic toll collection and smartcards now commonplace, and Global Position System (GPS) technology coming in, there are no significant technical barriers to direct and differentiated charges for road use.

Limitations of traditional supply and demand policies. Building new roads is constrained by tight public budgets, lack of space and environmental concerns. Public transport systems are very expensive, and ill-suited to the decentralised urban structure and diverse trip patterns that characterise most US cities. And travel-demand management strategies, though numerous, have a limited potential to control automobile use (Meyer, 1999).

Limitations of existing funding mechanisms. Road construction and maintenance in the US is funded primarily by indirect user charges rather than tolls. All 50 states have gasoline taxes. Federal funding is provided through the Highway Trust Fund (HTF), which was established in 1956 to finance the federal share of the Interstate highway network and to support other federal-aid highway projects. Revenues for the HTF are derived from taxes on fuel, tires, truck sales and heavy-vehicle use. The HTF and the primary reliance for funding on fuel and other indirect taxes have come under attack on several scores:

1. Although tax rates are linked to vehicle characteristics, a Highway Cost Allocation study (US DOT, 1997, 2000) concluded that heavy combination trucks pay only about 80% of their costs, whereas automobiles and other light vehicles cover 110%. The system therefore does not adhere to the user pays principle as far as major user groups.
2. Although the HTF was established as an earmarked fund for roads, only a portion (roughly 65%-75%) of the money is now actually spent on road projects.
3. Money in the HTF is allocated according to geographical distribution formulas that guarantee states revenues regardless of whether the revenues can be put to good use, and that inflate demand for spending.
4. Despite the popularity of fuel-inefficient Sports Utility Vehicles (SUVs), the average fuel efficiency of the vehicle fleet in the US will probably improve in the future. Coupled with the growth of alternative-fuel vehicles, this will dampen gasoline consumption. State and federal fuel tax rates are difficult to increase, and the recent hike in world oil prices is likely to make it all the harder. Maintenance

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4 Texas Transportation Institute (2005, Table 1).
5 See, for example, Orski (2005) and Roth (2005).
expenditures, meanwhile, are rising as the Interstate Highway system ages and rising traffic levels impose more wear and tear on roads of all types.

Due to these and other problems, the HTF is increasingly seen as both inappropriate and inadequate to continue as the primary highway funding mechanism.

**Value Pricing Pilot Program projects**

During the 1970s the US federal government attempted unsuccessfully to initiate congestion pricing demonstration projects in several cities. Fears of adverse impacts on businesses and the poor, and insufficient efforts to gain constituency support, were largely responsible for the failure (Elliott, 1986; Higgins, 1986). But road pricing has since gained momentum thanks to two breakthrough pieces of federal legislation: the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, and the Transportation Equity Act for the 21st Century (TEA-21) of 1998. TEA-21 authorised the Value Pricing Pilot Program (VPPP) to fund innovative road and parking pricing measures for alleviating congestion, and permitted limited tolling on Interstate highways. Table 1 lists the projects that have been funded to date.

<table>
<thead>
<tr>
<th>Project category</th>
<th>Operational</th>
<th>Under development</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 New lanes</td>
<td>2 HOT lanes</td>
<td>6 HOT lanes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 managed lanes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 queue jump</td>
</tr>
<tr>
<td>2 Previously toll-free roads</td>
<td>4 HOT lanes</td>
<td>4 conversion HOV to HOT lanes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 FAIR lanes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 cordon toll</td>
</tr>
<tr>
<td>3 Existing or new toll roads, bridges and tunnels</td>
<td>4 variable tolls</td>
<td>4 variable tolls</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 variable pricing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 discount truck tolls</td>
</tr>
<tr>
<td>4 Parking and vehicle use</td>
<td>1 car sharing</td>
<td>1 mileage-based insurance</td>
</tr>
<tr>
<td></td>
<td>1 cash-out of free parking</td>
<td>1 variabilisation of fixed auto costs</td>
</tr>
<tr>
<td></td>
<td>1 cash out of cars</td>
<td>1 financing infrastructure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 GPS-based pricing</td>
</tr>
</tbody>
</table>

All of the operational projects in the first two categories feature High-Occupancy Toll (HOT) lanes. HOT lanes are a variant of High Occupancy Vehicle (HOV) lanes that allow vehicles carrying fewer people than the HOV occupancy requirement (usually 2 or 3 people) to use the lanes if they pay a toll (or a surcharge over the existing HOV fee). General-purpose toll-free lanes run parallel to the HOT lanes.

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Table 2 provides information on the five HOT lane facilities that are currently in operation. The HOT lanes on State Route 91 (SR-91) were built in 1995 before the VPPP was launched. The lanes were privately operated until 2003 (see Section 4). Tolls vary hourly according to a schedule that depends on day of week, with a goal of maintaining free-flow conditions on the HOT lanes. A number of studies have examined how the tolls affect ridesharing, lane and departure-time choices of users.7

Table 2: Operational High Occupancy Toll (HOT) lane projects.

<table>
<thead>
<tr>
<th>Facility</th>
<th>Launch date</th>
<th>Location</th>
<th>Time variation</th>
<th>Differentiation by vehicle &amp; occupancy</th>
<th>Use of revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Route 91 (SR-91)</td>
<td>1995</td>
<td>Orange County, CA</td>
<td>Variable (scheduled)</td>
<td>HOV3+ free</td>
<td>Operations, maintenance, corridor improvements</td>
</tr>
<tr>
<td>Interstate 15 (I-15)</td>
<td>1997</td>
<td>San Diego County, CA</td>
<td>Dynamic (6 min. changes)</td>
<td>HOV2+ free</td>
<td>Express bus service &amp; operations</td>
</tr>
<tr>
<td>Interstate 10 (I-10, Katy Freeway)</td>
<td>1998</td>
<td>Houston, Texas</td>
<td>Flat $2 during peak</td>
<td>HOV3+ free SOVs prohibited on toll lanes</td>
<td>Operations</td>
</tr>
<tr>
<td>Northwest Freeway (US 290)</td>
<td>2000</td>
<td></td>
<td></td>
<td>As I-10, except lanes available only during morning peak</td>
<td></td>
</tr>
<tr>
<td>I-394</td>
<td>2005</td>
<td>Minneapolis-St. Paul</td>
<td>Dynamic (3 min. changes)</td>
<td>HOV2+ free</td>
<td>Capital costs, operations, improvements, bus transit</td>
</tr>
</tbody>
</table>


Interstate 15 (I-15) was the first facility on which pre-existing HOV lanes were converted to HOT status. By law, I-15 is required to maintain a level of service of C or better on the HOT lanes. This is accomplished by varying tolls “dynamically” as often as every six minutes. A schedule is published that shows average toll levels by time of day. The normal maximum toll is $4, but tolls may be raised up to $8 in the event of severe traffic congestion. Drivers who plan to use the HOT lanes therefore face uncertainty about how much they will pay, but they are (nearly) guaranteed a congestion-free trip. By contrast, on SR-91 the toll paid is predictable but travel time can vary with unexpected demand or capacity fluctuations.

The two HOT lane projects in Houston, Texas, carry very low traffic volumes compared to SR-91 and I-15, and the tolls remain “flat” at $2 rather than varying over time. The most recent project, I-394 in Minneapolis, involved a conversion of existing HOV lanes to HOT lanes and construction of new tolled lanes, and is therefore tallied in

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7 See, for example, Lam and Small (2001) and Brownstone and Small (2005).
both Categories 1 and 2 of Table 1. As on I-15, tolls vary dynamically with the goal of maintaining free-flow conditions on the tolled lanes.

Category 1 in Table 1 also includes managed lanes and queue jumps. The term managed lanes refers to demand management, and the concept encompasses various facility types: HOV lanes, HOT lanes, Single Occupancy Vehicle (SOV) express lanes, special use lanes and truck lanes. Queue jumps are elevated roads that allow drivers to avoid congested intersections by “jumping” over them. Being relatively cheap, queue jumps are affordable for areas with small populations.

Fast And Intertwined Regular (FAIR) lanes in Category 2 entail conversion of some freeway lanes to toll lanes, while leaving other lanes free (Decorla-Souza, 2004). Toll-lane revenues are used to give drivers on the free lanes credits that can be used either for future trips on the toll lanes or other purposes (transit, parking, etc.). FAIR lanes are designed to enhance acceptability by allocating toll revenues directly to users of the freeway in a revenue-neutral way.

One project in Category 2 features a cordon toll around Fort Myers Beach, Florida: an island community where additional roadways are not practical and where the limited number of access points makes cordon pricing viable. A cordon toll was proposed for New York City by the mayor, Michael Bloomberg, but withdrawn in the face of opposition.8

The third project category in Table 1 covers toll roads, bridges and tunnels. Unlike with HOT lanes, all lanes on these facilities are tolled. A majority involve variable (i.e. time-varying) tolls.9 The fourth and final category in Table 1 encompasses a wide range of usage and area-based pricing schemes. A common motivation underlying these schemes is that the existing system of transport prices in the US is biased in favour of auto travel in two ways. First, auto usage is underpriced or unpriced on average. For example, fuel taxes do not cover environmental and other external costs of driving. Also, 91% of commuters drive to work and 95% of auto commuters park free at work.10 Second, a large fraction of the total costs of driving are fixed charges (vehicle depreciation, insurance, registration, licensing fees, etc.) that do not vary with usage and contribute to the underpricing of driving at the margin.

The project on cashing-out free parking in Category 4 offers commuters cash, transit passes or another alternative to free parking with comparable value.11 Mileage-based insurance is being studied in the form of Pay As You Drive (PAYD) insurance premiums that are paid in proportion to distance travelled. PAYD insurance is a form of road pricing because it charges for road use. The per-kilometre premium rate can be conditioned on driver characteristics that are used for pricing insurance today, such as age, sex, and safety record. PAYD insurance is superior to “pay at the pump” insurance

8 A new proposal for a peak-period charge in Manhattan was made in November, 2005, by the city’s major business association (http://nytimes.com/2005/11/11/nyregion/11traffic.html). In an attempt to forestall further opposition, several roadways would remain free.
9 For details see DeCorla-Souza (2004, pp.295-301).
10 Shoup (2005, p.267 and Appendix B). The supply of parking in the US is also artificially inflated by minimum parking requirements, which according to Shoup (2005) are often arbitrary, vary greatly from city to city, and can be extremely onerous on developers.
11 The advantages of cashing-out free parking (especially in the US) are explained by Shoup (2005, pp.262-266). Shoup also describes (pp. 383-390) high-technology parking meters that can adjust parking rates by time of day and expected parking occupancy rates in the neighbourhood. Such meters have been installed in a few US cities, but they are far more prevalent in European cities where parking space is scarcer, and the need for efficient rationing more pressing.
proposals under which costs would vary (inappropriately for insurance purposes) with vehicle fuel efficiency, but would be independent of driver characteristics.\textsuperscript{12}

Arguably the most ambitious of the VPPP projects is Oregon’s GPS- and distance-based pricing proposal. The long run plan is to charge for all driving within the state, with charges proportional to distance traveled and varying by type of road and time of day. Travel would be monitored by GPS and payments would be paid at the pump when the vehicle is refuelled.\textsuperscript{13} State fuel taxes would be refunded. The project faces a number of stumbling blocks including the cost of installing fuel-pump infrastructure and on-board vehicle equipment, the need for a long transition period to deal with vehicles that lack GPS or odometer-based devices and that would be too costly to retrofit, the shift of burden away from fuel-inefficient vehicles, lack of agreement on whether revenues should be spent on highways or other modes, and privacy concerns related to GPS.

\textit{Summary of US developments}

The HOT lane projects have been the biggest success of the VPPP so far. A number of reasons can be offered. First, the projects have relatively small set-up and operating costs. Second, three of the projects (SR-91, I-15 and I-394) are designed to minimise congestion. This goal is readily explained and motivated to politicians and the public. It can be verified by examining loop-detector data on traffic flows and speeds, and the benefits are readily visible both to users of the lanes and those who drive on the parallel toll-free lanes just a few metres away. Third, availability of the toll-free lanes enhances acceptability by giving drivers a choice whether to pay for an essentially identical trip in terms of route. Contrary to the view that toll lanes will be used only by the rich as “Lexus Lanes”, lower-income and unemployed individuals and off-peak commuters occasionally use them when they are especially pressed for time. Fourth, revenues are earmarked, either for operations or public transport alternatives. Fifth, environmentalists have come to see congestion pricing generally, and HOT lanes in particular, as a way to improve air quality by keeping traffic moving smoothly.\textsuperscript{14}

It is of some interest that the five existing HOT lane projects differ in terms of whether the lanes are new or converted from HOV lanes, vehicle occupancy requirements, the extent of time variation of tolls, and the allocation of revenues (cf. Table 2). This suggests either that there is some flexibility in the design of successful schemes or, alternatively, that the design needs to be tailored to the particular circumstances of the facility in question. A number of other HOT lane projects are

\textsuperscript{12} Two recent theoretical studies have come out in favour of variabilisation. Edlin (2003) has determined that, by pricing congestion through a percentage tax on per-mile premiums, sizeable (and comparable) benefits would result from reductions in congestion and accident costs. Greenberg (2003) proposes a 10% federal subsidy to states, insurance companies and other companies for converting taxes and other fixed auto costs to a per-kilometre basis. He finds that the subsidy compares well with most existing policies in terms of cost-effectiveness for improving air quality and reducing traffic fatalities.

\textsuperscript{13} For details see Forkenbrock (2004) and Whitty et al. (2005).

\textsuperscript{14} A sixth possible benefit of HOT lanes is that by maintaining free-flowing conditions they actually support higher traffic throughput per lane than toll-free lanes. This has been confirmed from traffic counts on SR-91 (Poole and Orski, 2003, p.6) but the idea that congestion pricing can increase throughput in general is controversial. See, for example, postings to the Congestion Pricing Forum listserv between September 28 and October 12, 2005.
under development, and new projects are frequently being announced. One factor working in favour of HOV-to-HOT lane conversion projects is that most HOV lanes are underutilised in the US and can accommodate a large percentage increase in vehicle loads before speeds begin to deteriorate. Most other countries do not have this “slack”, and therefore cannot expect to replicate US success with HOT lanes.

The HOT lane and other VPPP projects provide several lessons that may carry over to other road-pricing initiatives. One is that new tolls are politically feasible if the locations and designs of the schemes are chosen carefully. A second is that variable and even dynamic pricing is acceptable. Focus groups were strongly opposed to dynamic pricing on I-15 before it began operation (Godbe Research & Analysis, 1997). But dynamic pricing is now accepted, and it has achieved a better balance between peak and off-peak periods. Indeed, Sullivan (2002, p.3) remarks that “There appear to be no differences in consumers' acceptance or ability to comprehend any of these current systems, regardless of their complexity.” In part, drivers may accept dynamic pricing because they value highly reliable travel times. A third lesson is that effective marketing of new schemes to the public is vital. As Berg (2003, p.38) notes:

“If value pricing is to be implemented, it has to be seen as the logical solution arrived at through public participation, not something that has been developed in isolation by ‘experts’. Just as new products are introduced with marketing campaigns, new public policies need to be ‘marketed’ to the public.”

This lesson is echoed by European experience (e.g. Schade and Schlag, 2003). The new life imparted to road pricing by the ISTEA and TEA-21 legislation has been extended with passage, in August 2005, of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) which authorises the Federal highway and transit programs for 2005-2009. In addition to continuing the VPPP, SAFETEA-LU includes existing or new programs that permit tolls to be collected for the purpose of constructing, reconstructing or rehabilitating Interstate highways. It includes a new Express Lanes Demonstration Program to permit tolling for congestion relief, emissions reductions, and building new Interstate lanes to reduce congestion. The Act also creates two commissions to assess the adequacy of the Highway Trust Fund to provide long-term transportation funding, and to consider supplementary or alternative revenue sources besides the fuel tax.

3. Road pricing in Canada

The history of toll roads in Canada broadly resembles that in the US: early enthusiasm, followed by retrenchment and sporadic implementation thereafter. During the nineteenth century many toll bridges, roads, and ferries were owned and operated by municipalities and private companies (Bryan, 1972). Most were subsequently abolished

15 Safirova et al. (2004) convincingly demonstrate this using a simulation model for Washington, D.C.
by provincial governments. Currently, there are only 19 operational tolled facilities comprising 385 km of toll roads in Canada, compared to over 8,000 km in the US.\textsuperscript{18}

Ownership, operations and institutional structures of the facilities vary considerably. A majority are bridges or tunnels linking Ontario and the US. The prevalence of tolling at border crossings is consistent with the use of tolls to extract revenues from nonresidents. Three large facilities have been built by diverse mechanisms. The Coquihalla highway, which opened in 1986 and traverses 115 km of mountainous terrain between Hope and Merritt in British Columbia, is public. By contrast, Highway 407 in Toronto was publicly funded, but it is now owned and operated by a consortium, Highway 407 International. The Confederation Bridge which links Prince Edward Island to the mainland was financed, designed, built and operated privately. Tolls are levied, but most of the debt is being repaid from government subsidies rather than toll revenues.

Of the 19 tolled facilities, electronic tolls are collected on only five (Nix, 2002). All facilities differentiate charges by vehicle type and size.\textsuperscript{19} But in contrast to the VPPP projects, only Highway 407 charges by time of day. Freedom of mobility is respected in that, except for non-local trucks on Highway 104 in Nova Scotia, no user is forced to take a toll road.\textsuperscript{20} Highway 407 is by far the most heavily used facility. When it began operating as a toll road in 1997, it was the world’s first all-electronic open access toll highway.\textsuperscript{21} Tolling was facilitated politically by proximity to Highway 401: a toll-free and heavily congested alternative running roughly in parallel a few kilometres to the south.

Tolling roads in Canada has been spurred by factors similar to those in the US, although the impetus is not as strong for several reasons. First, there is a greater commitment to public funding in Canada, not only for roads but also for public transport. Second, traffic volumes and congestion are lower. And third, because of the size of Canada’s provinces and their “linear” configuration from east-to-west, the provinces are generally better able than are US states to tax non-resident users while they are in transit, and correspondingly less reliant on tolls for revenue.

Roads in Canada are mostly paid for with general tax revenues and property taxes. Road users in aggregate approximately pay their way\textsuperscript{22}, whereas transit and other modes are heavily subsidised. The extent of user-pays varies by province as a function of

\textsuperscript{18} A major bridge across the Fraser River in Vancouver is scheduled to open in 2008. Tolls will be collected electronically, and will vary by vehicle type and method of payment, but not time of day. See http://www.translink.bc.ca/goldenearbridge/project_information/funding.asp, accessed November 19, 2005.

\textsuperscript{19} An axle-based system was introduced on the Confederation Bridge on January 1, 2006. Prior to this, tolls were based on rates for the ferry service that the bridge replaced. See http://www.confederationbridge.com/images/New_Toll_Structure.pdf, accessed November 18, 2005.

\textsuperscript{20} Canadian policy has generally supported the availability of toll-free alternatives. According to Bryan (1972, p.47), during the brief revival of tolling in the 1950s “… it was generally accepted in principle that there ought to be an alternative to any toll route”. Legislation passed in Québec permits toll facilities where an alternative un-tolled route exists (Nix 2001, p.9). And British Columbia’s guidelines for tolling stipulate that “Tolls will be implemented only if a reasonable untolled alternative is available.” See British Columbia Ministry of Transport (2003, para. 2.3).

\textsuperscript{21} Mylvaganam and Borins (2004) provide an insightful history of the toll road.

\textsuperscript{22} According to Transport Canada (2004, Table 3-5) for 2003/2004 spending by all levels of government on roads amounted to CDN 13,647 million, equal to 69.4% of total spending on transport. Revenues from road users were CDN 13,989 million. In the three previous years, spending exceeded revenues by small margins.
traffic volumes and road construction costs (Nix, 2001, p.5). Canada lacks formal mechanisms for road funding on a scale comparable to the US Highway Trust Fund, and no legislation similar to ISTEA, TEA-21 or SAFETEA-LU has been passed. Only about 7% of federal fuel tax revenues are spent on roads and highways. And until recently the federal government provided almost no funds for urban transport. But under the New Deal for Cities and Communities, the government has allocated $5 billion in federal gasoline excise tax funding to cities over a five-year period.  

Federal policy recommendations

Transportation policy in Canada has been reviewed by three major federal studies in the last 15 years: the 1992 Royal Commission on National Passenger Transportation, the 1993 National Transportation Act Review Commission, and the Canada Transportation Act Review (CTAR) of 2001. In general these studies supported the subsidiarity principle, the user pays principle, and recognition of environmental costs in transport pricing. In addition to toll roads, the CTAR Panel investigated road funds and urban transportation agencies as financing arrangements for roads. All ten Canadian provinces have at some time employed earmarked taxes. But currently most fuel tax revenues and other user charges are added to the general account. There have been attempts to create provincial road funds. But these funds were either short-lived, or failed to be fully self-financing from user charges. The federal government has recently created several infrastructure funds, but the amounts are modest and none of the funds are earmarked specifically for roads. Urban transportation agencies have been established in Montreal and Vancouver, the second and third largest cities in Canada. These agencies have mandates that include public transit as well as roads, and powers to raise revenues through new charges on motorists. This gives them multiple objectives, as well as multiple instruments to assemble policy packages.

Climate change

Climate change is a factor that distinguishes Canada from the US. Only Canada has ratified the Kyoto Protocol, and Canada could be affected more strongly by global warming because of its northern latitudes. It is an open question whether the two countries will adhere to their current positions, and if so whether greener policies will be pursued more vigorously north of the 49th parallel. If Canada does follow through with its Kyoto commitment, there may be a concerted attempt to reduce consumption of fossil fuels for transport. The implications for road pricing are ambiguous. Because greenhouse gas emissions can be effectively targeted with a carbon tax, tolls or other usage-based charges do not appear to be required on this score. Moreover, with global warming there may be less damage to roads from the freeze-thaw cycle, and correspondingly less expenditure on road maintenance. However, reductions in fuel

25 The two agencies are L’Agence métropolitaine de transport (http://www.amt.qc.ca) created in 1996, and TransLink (http://www.translink.bc.ca) created in 1998. Both agencies were created before the CTAR was conducted.
consumption will reduce the base for fuel taxes, and consequently increase the need for other revenue sources.

4. Some questions about road pricing in the US and Canada

A number of questions and issues regarding road pricing have come to the fore in recent years. Attention is limited here to a few questions of concern to the US and Canada.

Design of road pricing schemes

An overarching question that has been addressed in European-Union funded research, and is currently under debate in the UK, is how to phase in road pricing over time. An implementation path has several dimensions: the numbers of steps or phases, the design at each step, the speed of progression from step to step, and the ultimate form and extent of road pricing. Since road pricing in the US and Canada has not yet progressed very far, discussion is focused here on the design of schemes rather than on the time dimension of implementation.

Road pricing schemes can be categorised as facility-based, area-based or network-based. Facility-based schemes include HOT lanes and individual highways. Toll cordons, area licenses and urban parking-fee structures are types of area-based schemes. Network-based schemes include highway networks, and systems that encompass all road travel such as GPS-based distance pricing. As Section 2 explains, most of the VPPP projects are facility-based. The prospects for area-based and network-based schemes in the US and Canada are briefly assessed here.

Area-based schemes

Fort Myers Beach in Florida is the only urban area in the US or Canada with a cordon toll, and no area charges have been implemented or initiated anywhere. To be sure, several schemes have recently been proposed. As noted in Section 2, a cordon toll was proposed for New York City and withdrawn, and a revised scheme has been put forward. The San Francisco County Transportation Authority has applied for a federal grant to study an area charge similar to that in London. A toll for driving into downtown Boston during the morning peak was recommended by a city councillor.

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And TransLink, Vancouver’s urban transportation agency, drew up a plan for tolls in 2004 but abandoned it after the New Deal for Cities and Communities was announced.\textsuperscript{29} These and other area-based road-pricing proposals have met various criticisms:

- travel patterns are dispersed in most North American cities. Congestion is not concentrated in city centres, and any charge schemes for downtown areas would have limited effectiveness\textsuperscript{30};
- motorists will divert around charge areas, resulting in displacement rather than suppression of congestion;
- public transport capacity is inadequate to accommodate a significant modal shift away from driving;
- business and commercial activity would be displaced to toll-free locations;
- those who would pay the charge (viz. suburban residents who work in the city) outnumber those who would benefit (viz. city-centre residents); and
- state or provincial legislation would be required, and various horizontal or vertical agreements between government departments would have to be made.

London’s area charge appears to have been successful because these difficulties were avoided (Litman, 2005). Few cities in North America seem as well-suited. This is not to say that area charges will not work anywhere, but one should not assume that positive experiences in one jurisdiction will necessarily be repeated elsewhere.

Network-based schemes

Four types of toll-road networks have recently been approved or recommended for the US. One, proposed by Poole and Orski (2003), are urban networks of HOT lanes and Bus Rapid Transit. These networks would comprise interconnected limited-access freeway lanes that are converted from HOV lanes and designed for relatively long-haul travel. Dynamic tolls would be levied on all vehicles except buses, and the revenues would be used to fund network construction on an incremental basis.

A second type of toll-road network for intercity travel has been launched in Texas. The Trans-Texas Corridor project (http://www.texastollways.com) already comprises more than 20 ventures. The long-range plan calls for 1,560 lane-km of new toll lanes on existing or new expressways. Construction of the lanes would be financed by private investors, who would be repaid from toll revenues. To exploit scale economies and revenue opportunities new highway corridors would be built that are wide enough to accommodate railway tracks as well as gas lines and other utilities.

A third type of toll-road network for trucks has been proposed by Samuel et al. (2002). Toll truckways would be established along Interstate rights-of-way in lanes separated from other traffic to enhance safety. The truckways could be owned and operated either privately or by the states. Tolls would be based on distance and conditioned on truck characteristics such as axle loads. To avoid double taxation, state and federal fuel taxes would be rebated. Size and weight regulations would also be

\textsuperscript{29} http://www.tricitynews.com/portals-code/listcgi?paper=74&cat=23&id=502071&more, article dated October 2, 2005.

\textsuperscript{30} According to Richardson and Bae (2004) differences between the US and Europe in land-use and travel patterns have been diminishing over time.
relaxed to permit trucking companies to use larger, more economical, vehicles. Samuel et al. (2002) claim that toll truckways would be self-financing under a wide range of scenarios, and that states would gain more from reductions in construction and maintenance costs than they would lose in fuel tax revenues. To take full advantage of the technology it would need to be harmonised with Canada and Mexico, as required under the 1994 North American Free Trade Agreement. Harmonisation would be especially desirable for Canada given the large volume of cross-border trucking traffic between Canada and the US. 31

The fourth type of road-pricing scheme, credit-based congestion pricing (CBCP), has been proposed by Kockelman and Kalmanje (2005). CBCP adds revenue neutrality to congestion pricing by giving each resident of a prescribed area a monthly allowance of travel credits equal to the average amount spent on tolls by residents (after deducting administrative costs) in the previous month. Individuals who drive less than average can either save the credit for future travel or exchange it for cash. Only those who travel more than average incur an out-of-pocket expense. Kalmanje and Kockelman (2004) conducted simulations of CBCP on the Austin, Texas, road network and found that it greatly increased the proportion of residents who benefit from pricing.

Networks of toll roads have some attractive properties. They embody scale economies for users similar to airline and public transit networks in that travel is possible between many origins and destinations. There are also likely to be scale economies in toll collection costs for both users and operators. And political approval might even be easier to gain than for single facilities insofar as spatial equity is promoted by providing a common type of service across multiple regions. Nevertheless, toll-road networks face design challenges and obstacles.

One issue is how to set tolls. Differences between links in construction costs and congestion levels would appear to call for differences in tolls to satisfy the user pays and efficient pricing principles. If tolls are set dynamically – as Poole and Orski (2003) recommend for urban networks – toll differences might be accepted. However, there are advantages in the Japanese Revenue Pooling System, established in 1972, whereby all routes have the same tolls regardless of construction costs and traffic levels. 32 The rationale offered for this system is that it minimises confusion for drivers and is seen to be fair. Furthermore, full cost recovery from toll revenues is unlikely to be possible for especially costly links that are nevertheless vital parts of the network. A system of common tolls may also forestall local governments from exploiting tolls as a cash cow – a danger that Heaver and Waters (2005, p.796) warn about in the Canadian context.

A second concern about toll-road networks that also arises with facility-based tolling is route diversion. This is perceived to be a problem, or potential problem, for small states that can be circumvented by using highways in neighbouring states. Levying tolls on Interstate highways or major urban arterials may also induce traffic to divert onto two-lane roads or residential streets, and exacerbate congestion as well as compromise safety.

Toll-road networks will face regulatory hurdles. In the case of toll truckways several policy changes would be required (Samuel et al., 2002): (i) further relaxation of prohibitions on tolls on Interstate highways, (ii) provision of truck rights-of-way along

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31 According to Transport Canada (2004, p.61), in 2003 approximately 63% of Canada-US trade was transported by truck.

existing corridors “on the federal-aid system”, (iii) relaxation of truck size and weight regulations, and (iv) procedures to issue rebates on federal and state truck user taxes. In this regard Samuel et al. (2002) comment favourably on Canadian regulatory policy, and note (p.12) that, in contrast to the US:

“Canadian trucking has benefited from its federal government acting as a facilitator rather than as a decisionmaker about truck sizes and weights. Provincial governments take final responsibility for the difficult trade-off decisions about which roads are designated for what class of heavy vehicles…”

Two points are worth noting. One is that both the subsidiarity principle and harmonisation – central concepts in European Union transport policy reform – also matter in North America. As far as subsidiarity there are advantages in having a number of jurisdictions (e.g. states in the US, or provinces in Canada) experimenting independently with ways to provide roads, particularly in light of rapid technological change. The second point is that to make toll truckways possible, let alone to realise their full potential, multiple regulatory changes are required that go well beyond pricing.

Scheme complexity

The difficulties of designing second-best policies in the real world of myriad economic distortions are well known, and opinions differ on what approach to take. Delucchi (2000) maintains that getting the price right may be impractical or impossible because of difficulties in estimating demand elasticities, externality costs, etc. But in a comment on Delucchi (2000), Litman and Greenberg (2000) argue that, besides road congestion and non-market externalities, various other price distortions apply to auto travel that are larger in total: unpaid parking, infrastructure costs and the heavy reliance on fixed costs that leave automobile travel severely underpriced at the margin (recall Section 2). Estimates from US studies cited by Litman and Greenberg (2000) indicate that efficient pricing would increase variable vehicle expenses by 200-500% over current levels. With respect to the implications for pricing policy they remark (p.7):

“The conceptual test of additional vehicle use charges need not be the theoretical ideal based on Marginal Social Cost, but rather, it simply needs to be better than existing taxes and fees. This is a far easier standard to meet.”

In their view, politics in the US are such that auto usage will always be underpriced, so that there is little risk in taking initial steps towards raising prices by whatever means. This assessment is almost surely more accurate for the US than for European countries, particularly those with lower levels of auto ownership and/or high fuel taxes such as Britain.

Earmarking of toll revenues

A longstanding question that goes beyond transportation is whether revenues from user charges should be earmarked for specific purposes. Practice varies widely. As
noted in Section 2, earmarking is the rule for VPPP projects, and the US Highway Trust Fund is earmarked in principle if not in practice. Earmarking is less common in Canada. Simple economic theory suggests that use of revenues should be kept flexible because the relative merits of different spending patterns change over time in ways that cannot be foreseen. However, earmarking can also be defended as a means of compensating losers, as well as a way to prevent politicians from misallocating funds.

Many recent studies of road pricing support earmarking as necessary to gain political or public approval. But earmarking has been opposed by some authoritative sources. The National Research Council committee on congestion pricing disagreed with the spending constraints written into the ISTEA legislation that enabled the VPPP. The US National Research Council Committee noted that voters might approve spending revenues for other purposes, and local governments should have the latitude to comply with their wishes.33 Similarly, the Canada Transportation Act Review (CTAR) Panel recommended that congestion and other road charges should not be allocated to road investments if expenditures on other transport modes would yield a higher return.34 However, Heaver and Waters (2005, p.795) recommend that revenues from the Canadian federal fuel tax should be dedicated to transport as a whole. Amongst other reasons they point out the pressing need for funds to rehabilitate road infrastructure, and the fact that the fuel tax is inconsistent with harmonisation of tax rates across economic sectors.

Policy towards environmental costs of driving

It is generally, but not universally, argued that drivers should pay for the environmental externalities they generate, but also that environmental charges should be levied on all economic sectors rather than just transportation. Fuel taxes are potentially effective for internalising climate change costs, but rather crude for addressing the health and other costs of local emissions. Tolls are being touted in the US primarily as a tool for pricing congestion rather than environmental externalities. One question that looms in the future is how to tackle environmental costs through fiscal measures if road pricing becomes widespread as either a supplement or a replacement for fuel taxes. One concern with Oregon’s proposed distance-based toll, which would replace fuel taxes, is that it would penalise fuel-efficient vehicles unless toll rates are conditioned on vehicle characteristics.

Another, more immediate problem, is how to treat vehicles with non-conventional fuels that are rapidly gaining in popularity. Some states and cities already provide incentives in the form of tax credits, exemptions from emissions-testing and even free parking. And with passage of the SAFETEA-LU Act, states can now grant free access to HOV and HOT lanes not only to electric and alternative-powered vehicles, but also to hybrid vehicles. These privileges have raised objections from owners of regular vehicles, and are also opposed on efficiency grounds since they undermine the primary goal of HOV and HOT lanes to combat congestion.

33 Transportation Research Board (1994, p.73).
34 CTAR (2001b, Recommendation 12.3). This recommendation applies both in the short term with respect to fuel tax revenues, and in the longer term with respect to any road funds that might be established.
Scope for private-sector involvement

The private sector plays a leading role in toll-road development in Europe, Australia and other parts of the world, in part because this is facilitated by government policy (Orski, 2005). Relatively speaking, the private sector has had a low profile in the US and Canada. Nevertheless, more than 50 urban toll roads have been developed in the US, most of them in the last 30 years (Poole, 2005a). Prominent examples include State Route 91, the Dulles Greenway in North Virginia, and the Chicago Skyway. In addition to Texas, where public-private partnerships (PPPs) are blooming, laws enabling PPPs in transportation projects have been passed in over 20 other states. And the federal government is encouraging private-sector involvement through its Special Experimental Project initiative (SEP-15). Amongst various projects under consideration are a series of new HOT lanes on the Capital Beltway in Washington, D.C. In Canada, Highway 407 is the only privately operated urban road – albeit a very profitable one with over 300,000 average daily trips on workdays.

From a public-sector perspective the main goal in harnessing the private sector is to attract private funding and/or operation of tolled facilities while avoiding both heavy subsidisation and exploitation of monopoly power. One challenge is that start-up projects are inherently risky because costs are high, highway infrastructure is sunk and long-lived, and willingness to pay is uncertain (Poole, 2005a). A public financing option was chosen for Highway 407 because Canadian companies were seen to be risk averse, and would demand a provincial guarantee (Mylvaganam and Borins, 2004, p.39). Proposals to build a corridor from Lewis County in Washington State to Canada, and a system of express toll lanes for Minneapolis-St. Paul, were cancelled after studies concluded that they could not be self-financing from user fees.

To reduce risks, governments have granted protection against competition. A “non-compete” clause was included in the contract for SR-91 which precluded capacity improvements to the freeway until 2030. But rapid traffic growth in the corridor led to severe congestion on the untolled lanes, and in 2003 the Orange County Transportation Authority took over the highway. According to Poole (2005b), the California Department of Transport (Caltrans) agreed to the non-compete clause because there was no precedent for SR-91 in the US, and it was not realised that some commuters are willing to pay appreciable tolls to save travel time. Current practice is less generous with respect to protection from competition.

To contain monopoly power, two regulatory models have been employed in North America. One form is rate-of-return regulation, which was applied to SR-91. This model allows operators to implement time-of-day pricing relatively freely. The second model is toll regulation, with maximum tolls determined by traffic levels and an inflation index. This model, which is applied on Highway 407, is designed to provide users with more assurance about future toll levels. The regulations for Highway 407 stipulate that tolls can be raised only if a minimum traffic level is met, and capacity expansion is required if flow exceeds 1,700 vehicles per lane-hour for more than 125 hours in a calendar year.

Private highways generally face less competition in European countries than in North America because a larger fraction of public highways is tolled.

See Mylvaganam and Borins (2004, pp.95-96). Interestingly, this policy contrasts with Interstate 15 (a public operated facility), which is required by law to maintain level of service C and is therefore constrained (on a real time basis) by a ceiling on traffic volume.
Besides competition clauses and regulations, another design question in privatising roads is whether to grant concessions only for individual roads or for networks. Both approaches are taken internationally (Estache et al., 2000). One consideration is the trade off between the disadvantage of networks in conveying greater monopoly power, and the advantage that the operator will internalise the complementarity in demand between links. The Ontario provincial government may be at a bargaining disadvantage vis-à-vis the incumbent operator, Highway 407 International, if Highway 407 is ever extended because the new segment would be less valuable to a new contractor than to the incumbent.37

Yet another consideration is foreign involvement. Most toll-road projects in the US and Canada involve large foreign partners because of their experience and ability to absorb risks (Orski, 2005). One potential drawback is illustrated by an ongoing dispute over toll regulations between Highway 407 International and the Ontario government. A Spanish firm holds an interest in the consortium, and the Spanish government threatened to disrupt free-trade negotiations unless the problem was resolved.38

On balance, the future for private-sector engagement in highway financing and operation appears to be relatively bright in the US. The picture is not as clear for Canada. According to Nix (2001, p.58) recent enthusiasm for a commercial approach to roads in Canada is driven by fiscal restraints and “does not appear to have been driven by any reliance on economic principles or regard to the recommendations of Commissions.” There appears to be a reluctance in Canada to part from a tradition of publicly operated and toll-free roads. In 2003, the British Columbia provincial government formulated a plan to privatise the Coquihalla highway on a 55-year lease. But it backed down in the face of massive opposition. As another example, a PPP contract to Design, Build, Finance and Operate part of a ring road in Edmonton, Alberta, was recently signed that “does not allow tolls or advertising to generate revenue”.39

5. Long-run prospects for road pricing

A number of experts have predicted that road pricing will never be widespread in the US.40 Arnott (2005) also sounds a cautionary note, identifying as his main concerns that congestion pricing may not reduce congestion very much, that tolling may exacerbate other distortions, and that implementation will be impeded by political barriers and high infrastructure and administration costs.

The brief review of evidence in this article indicates that the prospects for extensive road pricing in Canada in the near future are slim. Strong preferences for public funding are one factor. Another is that traffic volumes on most Canadian roads are insufficient to justify tolls, at least for the purpose of congestion pricing. Recent experience with the Value Pricing Pilot Program suggests, however, a more positive assessment for the US.

38 Mylvaganam and Borins (2004, p.96 ff).
Several VPPP projects have been surprisingly successful, and public support for road pricing has gained momentum. A strength of the VPPP, which it shares with the American economy at large, is its experimental and varied approach that facilitates identification of winning (and losing) strategies at relatively low cost. One of the lessons is that resistance to road pricing can be overcome by careful design of schemes and extensive marketing campaigns that engage the public. Another is that sophisticated dynamic congestion pricing is technologically feasible and politically acceptable. A third encouraging trend in the US is growth in private-sector involvement with road pricing.

It has been argued that congestion is less localised in North America than in Europe, and that consequently road pricing is less cost effective on the western side of the Atlantic. However, to the extent that auto travel is underpriced in North America compared to Europe, the case for road pricing may actually be stronger. A cautiously optimistic view is that road pricing may eventually be applied on much of the US road network, although implementation is likely to be punctuated by setbacks, and to be influenced by economic factors such as the business cycle and budgetary pressures on governments. In 1994 the National Research Council-sponsored congestion pricing study panel wrote\textsuperscript{41}

\begin{quote}
“The risks associated with congestion pricing and the nature of policy development in a pluralistic society imply that this policy will progress in small steps. Given that congestion pricing represents a substantial change from the current operation of the road system, such small steps are appropriate. If individual projects succeed, they will help convince policy makers and the public of the benefits of congestion pricing. This process will take time, however; thus it may be many more years before congestion pricing would be applied throughout a metropolitan area in this country. Whether congestion pricing will evolve to this level will depend on how it is implemented, how well it works, and how much motorists and voters come to accept it. Only time, experimentation, and careful evaluation will tell.”
\end{quote}

Although these words were written over a decade ago, they still sum up rather well the state of road pricing today.

\textit{References}


\textsuperscript{41} Transportation Research Board (1994, p.103).


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A model of residential location choice with endogenous housing prices and traffic for the Paris region

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Abstract

There is a growing interest in the development and the use of large-scale planning models. In this paper, we describe the first step of a project to integrate UrbanSim, a dynamic microsimulation land use model, and METROPOLIS, a dynamic traffic model. This is the first attempt, to our knowledge, to integrate a dynamic land use model and a dynamic traffic model. We briefly describe the two models and propose a unified framework for their integration. Within this integrated framework we develop a model of residential location choice, with endogenous housing prices and traffic. The study area for this research is the Ile-de-France (Paris region), for which we provide empirical results.

Keywords: Land use; Integrated model; Transportation modelling; Paris area.

Introduction

In metropolitan regions throughout the world, increasing population and urban expansion generate increased transportation congestion and rising housing prices. The need to coordinate land use policies with transportation investments has been widely recognized, but the task remains difficult for both technical and political reasons. Politically, the coordination of transportation and land use is difficult because land use decisions are controlled by local governments that by nature have a parochial mandate, whereas transportation investments are generally coordinated at a metropolitan level to ensure efficient coordination of the regional transportation network. Technically, the coordination of land use and transportation is challenging due to the lack of well-integrated models that provide a coherent behavioural basis to model not only the effects of changing patterns of locations of jobs and households and real estate

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investments on transport flows, but also the effect of changes in the transportation system and travel conditions on these location choices.

Though models that reflect the interaction between land use and transportation have been developed and used for at least three decades (Putman, 1983, de la Barra, 1990), the models have been characterized by a high degree of aggregation of space, agents, and time. Prior land use models have represented geography using a very aggregate zone structure, usually with 30 to a few hundred zones. Agents such as households and jobs have been aggregated to a small number of categories. But perhaps most importantly, chronological time has not been explicitly represented in prior land use models, in that they solve for an equilibrium with a given set of inputs, with no path dependence, and an assumption that all agents can adjust instantaneously, with no transaction cost. This approach requires making the assumption, for example, that the effect of building a major transportation facility in a given year will produce all of its effects on real estate development, location choices, and travel behaviour in that same year. Our approach, by contrast, avoids this assumption by representing the partial adjustment of households, firms and developers in annual steps of time, allowing the effects of a major shock such as a change in infrastructure to be spread over multiple years.

These restrictions are important constraints, and have led to recent innovations to overcome these simplifications to allow more behavioural realism in the modelling. This realism is important in making the modelling efforts responsive to current policy questions that require considerable behavioural resolution in order to represent the dynamic short-term and long-term effects of major transportation investments and their interaction with land use policies. Two models exemplify the recent trend towards microsimulation and dynamic temporal representation in the land use and transportation domain. UrbanSim is a simulation model developed since the late 1990’s to simulate the spatial and temporal evolution of household location, job location, and real estate supply and prices using microsimulation to allow complete disaggregation in agents, locations, and the representation of time (Waddell et al, 2003). This model has been applied to numerous cities in the United States and Europe, but until now has been connected to traditional four-step travel models that provide static equilibrium traffic assignment, usually for only a small number of time periods during the day. METROPOLIS is a dynamic traffic assignment model that simulates evolving traffic conditions on large-scale networks over the course of a day, representing individual travellers (de Palma and Marchal, 2002).

The major innovation developed in this paper, in addition to the operational integration for the first time of dynamic microsimulation land use and traffic models, is in the treatment of two types of endogeneity in residential location choices. Residential location is clearly interdependent with housing prices, and we develop an econometric specification and estimation methodology that correctly accounts for this endogeneity. We also treat the endogeneity of travel times for work trips with residential location by coupling the land use and traffic models. The paper proceeds as follows. In the next section, we provide an overview of UrbanSim and METROPOLIS and the proposed integrated model architecture. Following this, we describe the region that serves as the basis for this application, the data used for model estimation, and the model specification and empirical results. We conclude with some interpretation of results and discussion of further research.
Integrated model system design

In this section we briefly describe the UrbanSim and METROPOLIS models and our proposed approach to integrate them.

UrbanSim: a path-dependent land use model

UrbanSim is a disaggregate land use model used to simulate the spatial and temporal evolution of land use and the locations of households and jobs within metropolitan areas. It has been developed at the University of Washington since 1996, and released under an Open Source license; see (Waddell et al., 2003). In 2005 a new Open Platform for Urban Simulation (OPUS) has been implemented to support further development of UrbanSim and incorporation of other simulation models and tools (Waddell et al., 2005). UrbanSim simulates year-to-year changes in real estate development and in the location of households and jobs for each geographical unit. Geography has typically been represented using grid cells as small as one hectare, though in the current application to the Ile-de-France we use 1300 Communes, or local municipalities.

\[
A_i^O = \sum_{j=1}^{J} E_j e_i^j \quad \text{or} \quad A_i^H = \sum_{j=1}^{H} P_j e_i^j ,
\]

Figure 1: UrbanSim architecture.
Adapted from Waddell et al., 2003.

The principal modules in UrbanSim are presented schematically in Figure 1. Models of choice processes such as location of households, jobs and new real estate development use Discrete Choice Models (Multinomial Logit for standard version).

UrbanSim is typically interfaced with an external travel model system (normally a standard four-step travel model), which generates trip distribution and utility patterns used in UrbanSim to measure patterns of accessibility. Accessibility for the home to work and possibly other purposes is computed using a variety of alternative measures. One such measure uses the composite utility of travel from a particular origin to all destinations:
where $A_{Oi}$ is the accessibility of cell i as origin and $A_{Di}$ as destination, $P_j$ stands for the population that comes to the cell to work there, $E_j$ represents the jobs to which the people go and $L_{ij}$ is the logsum which is the surplus of the travellers.

The choice of agents (households and jobs) to relocate during a given year is modelled in the Relocation Choice Model, as a probability that depends on agent characteristics. Household age and income are the principal factors to predict differences in relocation rates, and employment sector is used to measure differing propensities to relocate jobs. New and moving agents choose locations from the existing available real estate in the Location Choice Models, using multinomial logit specifications.

Real estate development, or the construction of new housing and non-residential floor space, has typically been modelled in UrbanSim as a multinomial logit transition model, where we predict the probability that a particular location will experience one of many types of real estate development events in a year. This specification has been recently changed to reflect the real estate development process as a location choice for a developer with specialized projects.

Real estate prices are important in the model in that they capitalize locational amenities such as accessibility, and strongly influence the spatial distribution of households in the housing market and firms in the non-residential real estate market. In the current research, we use a semi-hedonic regression model that predicts housing prices as a function of location characteristics, demand and supply.

**METROPOLIS: a dynamic transportation model**

METROPOLIS is a fully dynamic transportation model that is particularly adapted for large networks. It is a mesoscopic event based model and uses a multi-agent methodology with a disaggregated representation of travellers. On the other hand, the supply system relies on a macroscopic formulation that computes travel time in function of the flow condition of the link. It has been developed since the 90’s and its main application on the Paris region has been the QUATUOR project (THEMA/TT&R, 98-02). It models the mode, departure time and route choices. The Logit formula is used for these models. The dynamic assignment procedure can be deterministic or stochastic.

The generalized cost function is:

$$C(t_d) = \alpha t (t_d) + \beta \max\left[0, t^* - t_a\right] + \gamma \max\left[0, t_a - t^*\right], t_a = t_d + t(t_d).$$

The generalized cost function $C(.)$ includes the schedule delay cost terms in $(t^*-t_a)$, where $t^*$ is the desired arrival time. Moreover $t_a$ and $t_d$ denote arrival and departure times and $tt$ is the travel time corresponding to the mode (private vehicle or public transport). The operator can enter some distributions for $\alpha$ (VOT), $\beta$ and $\gamma$ (penalties for arrival too late or too early) and $t^*$. These behavioural parameters are the only information that is necessary in addition to data required by the classical static traffic models, such as network topology, link characteristics and O-D matrices.

The other transportation modes (mainly public transit) are modelled in an aggregated and static way. For any pair of origin and destination zone centroids the travel time should be given in a matrix form. The trip cost is the sum of a constant part $p_{PT}$ that
represents the ticket fare or constant penalty of using public transport and a linear travel time-dependent part, $\alpha_{PT} \cdot t_{PT}$. We denote the part of private cars by $P_{PV}$, the generalized cost of private vehicles by $GC_{PV}$ and the mode choice heterogeneity factor by $\mu_m$. The mode choice is described by a binary logit model:

$$P_{PV} = \frac{\exp[-GC_{PV} / \mu_m]}{\exp[-GC_{PV} / \mu_m] + \exp[-C_{PT} / \mu_m]}$$

where $C_{PT} = \alpha_{PT} \cdot t_{PT} + p_{PT}$.

The output of METROPOLIS that we mainly use in this project is the surplus for any traveller’s category and for any O-D pair. As the departure time choice is modelled by a continuous Logit model, the surplus is given by:

$$L_{ij} = -\mu_T \cdot \ln \left( \sum_{k=PV,PT} \int_{t_i}^{t_j} \exp(-C_{ij}^k(u) / \mu_T) du \right)$$

where $C_{ij}^k(t)$ is the time dependent generalized travel cost between zones $i$ and $j$ and where $\mu_T$ denotes the departure time choice heterogeneity parameter (see above), PV represents private vehicles and PT represents public transit (see de Palma and Marchal, 2002 for details).

**Integrated model architecture**

We present in Figure 2 the architecture of the integrated system. The key information transferred between the traffic and the land use model is the travellers’ surplus matrix. To make a complete loop, we should feed a revised O-D matrix to the traffic model that is based on the new geographical distribution of population and jobs. This cycle is reproduced by time step that can correspond to one or more years according to the evolution of transportation system conditions and projects.

Figure 2: Architecture for the integrated model.

UrbanSim assigns locations ($l$) to jobs $E_s(\tau)$ and households $M_i(\tau)$ generated by the macro-economic model in year $\tau$, resulting in $E_{sl}(\tau)$ and $M_{sl}(\tau)$, which are used as inputs.
to the travel model. Since the Origin-Destination (O-D) matrix is not directly provided by UrbanSim, a three step travel model is needed to build the O-D matrices that represent the trips generated by population and activities and their distribution on origins and destinations. This module develops an O-D matrix using three steps:

- Trip emissions and attractions (by zone and travel segment),
- Trip distribution (zone to zone by travel segment),
- Mode choice: private vehicles and public transport.

We use the specific demand model developed for the Paris region by IAURIF and which was calibrated with the last Global Transportation Survey in 2001.

Data produced by METROPOLIS cannot be used directly by UrbanSim. A data preparation module is developed to convert these results to logsums and travel times for use by UrbanSim. In previous applications of UrbanSim with four-step travel models, the computation time of the travel models has prohibited the coupling of the models, usually by running the travel model only once in every 5 simulation years. Travel model run times of 18 hours or longer for one simulation year are not uncommon, mostly due to the computational burden in the traffic assignment component. Due to the computational efficiency of METROPOLIS, however, we interface the models every simulation year, providing a significant improvement in the model realism over prior integrated model applications.

**Descriptive analysis of the study area**

*The Ile-de-France*

The Paris area, namely Ile-de-France Region, embraces Paris and its suburbs. The city of Paris has about 2 million inhabitants, on a regional total of 11 million. The total number of jobs is 5.1 million. It covers 4,610 sq. miles (12,000 sq. km). Ile-de-France Region occupies 2% of the surface of France and represents 19% of the population, 22% of the jobs and 29% of the GDP of the country. There are 3 administrative divisions in Ile-de-France: 1 “région”, 8 “départements” (counties) and 1300 “communes” (municipalities). In addition, we consider the 3 counties around Paris as close suburbs or “inner ring” and the 5 counties far away from Paris as far suburbs or “outer ring”.

The land use is composed of built-up areas (30%), green areas (20%) and rural areas (50%). The public transportation network consists of:

- A main radial railway network, especially the RER lines (high speed train service between Paris and the suburbs),
- A subway network that provides comprehensive and timely service in the city centre,
- A bus network to complement the rail services.

The road network is organised into a hierarchy that is densely interconnected and often congested. The principal road network of the region is composed of 590 km of
motorways and 250 km of expressways, with a total of 4,500 lane-km. Road traffic flows attain the highest levels known all over the country. Despite the occasional rush-hour traffic jams, traffic conditions are on the whole remarkably good for a metropolis of this size, since the average duration of all car trips is 19 minutes, and commute trips by car average 25 minutes (EGT, 2001). The mode market shares for the home based work trips (2001) are: 50% private vehicles, 36% public transit and 14% bicycle or walk. Over the last twenty years, the public transportation mode share has decreased by 6% in the region, due principally to ongoing suburbanization of the region.

Socio-economic characteristics

Turning to a description of the socio-economic characteristics of the study area, and specifically focusing on households that have recently moved, Figure 3 presents the number of households according to the year of their last move. The mode is at 1998, the year just before the census. It should be noted that this cannot be seen as the distribution of how long the people live in housing units, since this duration is truncated here. These data confirm that many households remain in their locations for periods of ten years or longer, and support the argument that a partial adjustment approach is more plausible than a full, instantaneous adjustment to equilibrium.

![Figure 3: The distribution of the last move in year for the households living in Paris area in 1999. Source: Census 1999.](image)

The principle of multi-cored structure has been adopted for urban organisation to stem the rapid expansion of the agglomeration and to decentralize the jobs. So since 1965, the outer suburbs were structured around five poles, or “new cities”. Accordingly, 44% of the population surplus recorded in Ile-de-France between the 1975 and 1999 censuses, settled in these areas.
The analysis focuses on “recent movers”: households who settled or moved in the region recently, that is during year 1998. Among the 4,510,369 households living in the study area in March 1999, 589,355 moved during year 1998. Most of them (71%) are male headed. The “poor households” (that is, the 33% households in the region with the lowest per capita income, defined as household income divided by the square root of the number of persons in the household) are unevenly distributed in the region: only 26% of households living in district 78, located west of Paris; are poor, whereas this fraction goes up to 41% in district 93, located north-east of Paris. These same two districts contain the highest (38% in district 78) and the lowest (21% in district 93) proportions of rich households.

Single-person households are highly concentrated in Paris city (52% of households in Paris are single). Between 25 to 30% percent of households of all the counties have two members. The larger families are better represented in rural counties in the far suburbs. 25% percent of households have no working member. Among them, 28% percent live in Paris city. Near 50% of the families in far suburbs have two or more workers. Foreign households are concentrated in district 93 (19%), and are less represented in the larger ring (9%). 25% of households have a young head. They have a bigger share in Paris center and in district 92 (31% and 27%) and their part is uniform in other counties (23%).

Housing prices

Table 1 shows housing price data based on average prices of housing sales transactions for 1998 in each commune, using a weighted average of transactions of new and existing single-family houses and apartments. The data show important differences in average housing prices by district: prices are higher in Paris, intermediate in the close suburbs and decline in the more distant suburbs. In addition, prices are higher in the western part of the area than in the eastern part.

Table 1: Prices by district.

<table>
<thead>
<tr>
<th>Sub-region</th>
<th>District</th>
<th>Average</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paris</td>
<td>75</td>
<td>294,500</td>
<td>165,241</td>
<td>83,939</td>
<td>694,375</td>
</tr>
<tr>
<td>Close Suburbs</td>
<td>92 (West)</td>
<td>247,556</td>
<td>205,038</td>
<td>66,966</td>
<td>1,198,950</td>
</tr>
<tr>
<td>(inner ring)</td>
<td>93 (North)</td>
<td>115,709</td>
<td>49,055</td>
<td>47,876</td>
<td>259,163</td>
</tr>
<tr>
<td></td>
<td>94 (South)</td>
<td>144,998</td>
<td>74,603</td>
<td>53,356</td>
<td>373,499</td>
</tr>
<tr>
<td>Far away suburbs</td>
<td>78 (West)</td>
<td>135,122</td>
<td>65,714</td>
<td>38,112</td>
<td>373,815</td>
</tr>
<tr>
<td>(outer ring)</td>
<td>91 (South)</td>
<td>114,826</td>
<td>46,740</td>
<td>24,719</td>
<td>332,338</td>
</tr>
<tr>
<td></td>
<td>95 (North)</td>
<td>104,375</td>
<td>41,670</td>
<td>25,154</td>
<td>241,692</td>
</tr>
<tr>
<td></td>
<td>77 (East)</td>
<td>91,539</td>
<td>37,220</td>
<td>18,028</td>
<td>253,827</td>
</tr>
</tbody>
</table>

Source: Author’s computations from notaries’ database.

Accessibility

Figure 4 presents the average travel time in minutes from any city in the region by private vehicles and by public transit. The Paris boroughs are at the left of the figure and
the cities in the farthest Parisian suburbs are at the right hand side. The correlation between private vehicle and public transit average travel times is 0.97.

Figure 4: The average travel time for people travelling from any city.
Source: METROPOLIS simulation results.

Residential migration patterns

Table 2 and figure 5 present the origin and destination rings and counties for the moves during 1998. A majority of the moves has taken place in the same district, although households who move to Paris rather come from outside Ile-de-France. The most important part of the moves has been into Paris from outside of the region. After Paris, the outsiders go mostly to 92 in the close suburb that provides almost the same features as Paris. We do not observe out-migration from the Ile-de-France.

Table 2: The distribution of moves between different rings (origin by destination).

<table>
<thead>
<tr>
<th>Current District</th>
<th>Outside</th>
<th>Paris</th>
<th>C. S.</th>
<th>F. S.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paris</td>
<td>Frequency</td>
<td>77.579</td>
<td>67.027</td>
<td>18.192</td>
<td>18.023</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>42.9%</td>
<td>37.1%</td>
<td>10.1%</td>
<td>10.0%</td>
</tr>
<tr>
<td>Close Suburbs</td>
<td>Frequency</td>
<td>61.135</td>
<td>22.633</td>
<td>103.205</td>
<td>20.168</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>29.5%</td>
<td>10.9%</td>
<td>49.8%</td>
<td>9.7%</td>
</tr>
<tr>
<td>Far Suburbs</td>
<td>Frequency</td>
<td>49.936</td>
<td>9.299</td>
<td>23.967</td>
<td>118.191</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>24.8%</td>
<td>4.6%</td>
<td>11.9%</td>
<td>58.7%</td>
</tr>
<tr>
<td>Region</td>
<td>Frequency</td>
<td>188.650</td>
<td>98.959</td>
<td>145.364</td>
<td>156.382</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>32.01%</td>
<td>16.79%</td>
<td>24.66%</td>
<td>26.53%</td>
</tr>
</tbody>
</table>

Source: Census, 1999.
Model specification

In this section we develop the specification of the model components that comprise the focus of the paper: household residential location choice and housing price.

Household residential location choice model.

The commune \( j, j=1,\ldots,1300 \) contains \( C_j \) dwellings (housing units). We assume that all the dwellings \( i \) located in commune \( j \) have the same observable attributes, and therefore the same expected utility \( V_{ih} = V_j^h \) for household \( h, h=1,\ldots,N \). The total number of dwellings in Ile-de-France is denoted by \( I \).

The probability for household \( h \) to choose a dwelling \( i \) is given by the Multinominal Logit formula:

\[
P_{ij} = \frac{\exp(V_{ih})}{\sum_{i'=1}^{I} \exp(V_{i'h})},
\]

(1)

Since all the dwellings located in \( j \) have the same expected utility (since we do not have information on structural attributes of the housing units), and the same probability of being selected, Equation (1) implies that the probability that household \( h \) selects commune \( j \) is:
Under the IIA (Independence of Irrelevant Alternatives) assumption, one can obtain consistent estimates of $\beta$ (the preference parameters of $V^h_j$) by selecting a random sample of alternatives, with uniform sampling of alternatives, provided the correcting term $\log(C_j)$ is added to the likelihood. However, more efficient estimates can be obtained with importance sampling of alternatives, that is if the probability that alternative $j$ is included in the choice set is proportional to $C_j$, provided a second correcting term $-\log(C_j)$ is added to the likelihood. Since the two terms $\log(C_j)$ and $-\log(C_j)$ exactly compensate, no correcting factor is necessary to obtain consistent estimates of $\beta$ when importance sampling is used (see Ben-Akiva and Lerman, 1985 for details on this section).

Housing price model and endogeneity

One of the major factors affecting location choice is the price, which we predict using a semi-hedonic regression on the natural log of total price:

$$\ln P_j = X_j \lambda_i + S_j \lambda_s + D_j \lambda_d,$$

where the demand $D_j$ and supply $S_j$ levels are explicitly taken into account (in log form) and in which $X_j$ is the vector of local characteristics.

Housing price depends on the supply and demand for housing, and demand depends on price, so the two models (location choice and price) should be estimated jointly in order to correct for the potential bias implied by the endogeneity of prices $P_j$. The bias is tested for and corrected using the method proposed by Blundell and Smith (1989), which simply consists of introducing the residuals from the price equation in the location choice equation.

We therefore develop an iterative procedure in which prices depend on estimated demand and demand depends on observed price and price residual. We denote by $X^h_i = X^h_j$ the vector of commune attributes (except price), possibly crossed with household characteristics, and we assume a linear formulation for expected utility:

$$V^h_i = X^h_i \beta + P_j \delta_h,$$

where $\beta$ denotes a vector of parameters, to be estimated, and $\delta_h$ corresponds to the marginal utility of price, which may depend on household characteristics. The expected demand for commune $j$ is then: $D_j = \sum_{h=1}^N \varphi_j^h$. The vector of other commune attributes influencing price is denoted by $Z_j$, and we assume a log-linear formulation, so that the price equation is of the form: $P_j = Z_j \gamma + D_j \lambda + \epsilon_j$.

In order to test and correct for the endogeneity of prices, Equation (1) is replaced by:
\[ p_j^b = \frac{\exp(X_j^b \beta + P_j \delta + \epsilon \eta)}{\sum_{j=1}^{\beta} \exp(X_j^b \beta + P_j \delta + \epsilon \eta)}, \tag{3} \]

where no correction factor is necessary if importance sampling is used.

**Empirical results**

*Application of METROPOLIS to the Paris region*

To model the Paris region, we have used the road network coded by IAURIF (Institute for urban planning and development of the Paris Ile-de-France region). The coded network had 606 zones and 17957 links. The morning peak hour O-D matrix includes 970,000 trips. We have multiplied the peak hour O-D matrix by relevant factors to cover the whole day. The trips were divided by their purpose: work trips and others.

To obtain the dynamic behavioural parameters a survey, MADDIF, was conducted, (Fontan, 2003) in 2000. 4200 individuals were surveyed by telephone. It provided the distribution of schedule delay penalties, the Logit heterogeneity parameter proportional to VOT (value of time, for which the official value of 12.96 Euros per hour was taken) and the distribution of desired arrival time.

Table 3: The Paris Region Transportation Model Predictions.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time [min]</td>
<td>32.50</td>
</tr>
<tr>
<td>Free flow travel time [min]</td>
<td>24.34</td>
</tr>
<tr>
<td>Congested delay [min]</td>
<td>8.16</td>
</tr>
<tr>
<td>Early arrival delay [min]</td>
<td>28.28</td>
</tr>
<tr>
<td>Late arrival delay [min]</td>
<td>19.07</td>
</tr>
<tr>
<td>Average velocity [km/h]</td>
<td>28.90</td>
</tr>
<tr>
<td>Early arrivals percentage [%]</td>
<td>47.25</td>
</tr>
<tr>
<td>Late arrival percentage [%]</td>
<td>33.15</td>
</tr>
<tr>
<td>Average cost [€]</td>
<td>9.47</td>
</tr>
<tr>
<td>Free flow travel time cost [€]</td>
<td>5.26</td>
</tr>
<tr>
<td>Waiting time cost [€]</td>
<td>1.76</td>
</tr>
<tr>
<td>Average schedule delay cost [€]</td>
<td>2.45</td>
</tr>
<tr>
<td>Traffic volume [million de veh. x km]</td>
<td>63.70</td>
</tr>
<tr>
<td>Average travelled distance [km]</td>
<td>17.51</td>
</tr>
<tr>
<td>Number of links passed by a traveller</td>
<td>17.61</td>
</tr>
<tr>
<td>Congestion index</td>
<td>28.85</td>
</tr>
</tbody>
</table>

Source: METROPOLIS simulation results.

*Housing price*

The estimated coefficients for housing price model are presented in table 4. The R\(^2\) for the model is 0.53. We obtain the expected signs for demand and supply but they are not
exactly opposed. A purely structural equation (results not reported here, available on request) with only supply and demand gives coefficients exactly opposed, which means that the price only depends on the supply/demand ratio, and not separately on supply and demand. Once covariates are added, however, the coefficients on demand and supply are no longer equal in absolute terms, because the covariates are more correlated with demand.

A decrease in average travel time significantly increases the price: 10 minutes less travel time to work imply a 2.8% increase in housing price. The price is very sensitive to socio-economic structure of the commune: a 10% increase in the proportion of one-member households causes a 50% increase of the price. A similar 10% increase for the proportion of two-member households results in a 19% increase of the price (note that effects of households with one or two members should be interpreted with reference to the omitted fraction of households with three or more members). Similarly, the fraction of households with no or only one working member has a positive effect on the price. Strangely enough, the fraction of foreign households has a positive effect on price. We should notice however, that the data do not distinguish the nationality of the foreigners, and make no difference between OECD countries and third world ones. Finally, we notice the negative and highly significant effect of the proportion of low and intermediate income families on the price.

Table 4: housing price estimation results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>11.02668</td>
<td>0.12800</td>
<td>86.14</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Log(Supply)</td>
<td>-0.04791</td>
<td>0.02466</td>
<td>-1.94</td>
<td>0.0522</td>
</tr>
<tr>
<td>Log(Demand)</td>
<td>0.09918</td>
<td>0.02244</td>
<td>4.42</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Average travel time from j to work (minutes)</td>
<td>-0.00280</td>
<td>0.00085119</td>
<td>-3.28</td>
<td>0.0011</td>
</tr>
<tr>
<td>% households with 1 member</td>
<td>5.09136</td>
<td>0.37884</td>
<td>13.44</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% households with 2 members</td>
<td>1.87960</td>
<td>0.34135</td>
<td>5.51</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% households with no working member</td>
<td>1.25241</td>
<td>0.30954</td>
<td>4.05</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% households with 1 working member</td>
<td>0.82300</td>
<td>0.33762</td>
<td>2.44</td>
<td>0.0149</td>
</tr>
<tr>
<td>% poor households</td>
<td>-6.63187</td>
<td>0.50316</td>
<td>-13.18</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% households with medium income</td>
<td>-4.54311</td>
<td>0.33102</td>
<td>-13.72</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% households with a foreign head</td>
<td>1.58406</td>
<td>0.36279</td>
<td>4.37</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

Source: Authors estimations’ results (using SAS).

Location choice

Table 5 contains the results of the residential location choice model estimation. With a pseudo-R² of 22% this model has a moderate explanatory power. This estimation has been performed on a 20% sample of total moved households in order to improve the computational tractability of the model.

We notice the very significant role of the “same district as before” variable. This shows the strong preference of the households to move in the same district or neighbourhood in which they lived before. Testing the effect of the distance from last residence may be interesting but it was not possible with our available data. The Paris dummy variable has a negative coefficient, indicating that, ceteris paribus, the households who live in Paris and decide to move have a slightly higher probability of relocating to a district outside Paris than do residents living outside Paris. Note that this
is consistent with the intra-metropolitan migration patterns shown in Table 2 and Figure 5, and with general expectations that households moving into the region, and new households formed within the region locate initially within Paris, and may relocate to suburban neighbourhoods later. Note, however, that some of the other variables in the model, such as better accessibility in Paris, tend to have effects that at least partially offset this suburbanization preference, while others, such as housing prices, tend to reinforce it.

As expected, housing price has a negative effect on location preference for a commune. This effect increases with the age of the household head and decreases as the household income increases. The older heads of households are more sensitive to price and the richer households are less sensitive to it. Since price is entered using three variables to capture average effects as well as interactions with age and income, the combined effects are complex. We note that the average price effect as well as the age and income interactions, all have expected signs. However, for a small subset of the population, namely very young and very rich households, the net price effect from the interaction of these three coefficients would be predicted by this model to show a slight positive preference for higher prices in communes where they the neighbouring households are in the same socio-economic category and which have more amenities.

Table 5: residential location choice estimation results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same district as before move</td>
<td>2.5461</td>
<td>0.009353</td>
<td>272.24</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Paris</td>
<td>-0.2988</td>
<td>0.0267</td>
<td>-11.19</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Log(Price)</td>
<td>-1.7285</td>
<td>0.1009</td>
<td>-17.14</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Log(Price)* (Age-20)/10</td>
<td>-0.0653</td>
<td>0.004695</td>
<td>-13.92</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Log(Price)* Log(Income)</td>
<td>0.1783</td>
<td>0.0100</td>
<td>17.78</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Number Railway stations</td>
<td>-0.0129</td>
<td>0.002838</td>
<td>-4.56</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Number Subway stations</td>
<td>0.007070</td>
<td>0.001300</td>
<td>5.44</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Average travel time from j, commuting (TC)</td>
<td>0.000561</td>
<td>0.000483</td>
<td>1.16</td>
<td>0.2457</td>
</tr>
<tr>
<td>TC*(Dummy female)</td>
<td>-0.006842</td>
<td>0.000697</td>
<td>-9.82</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Average travel time from j, by private car (VP)</td>
<td>-0.001391</td>
<td>0.000481</td>
<td>-2.89</td>
<td>0.0038</td>
</tr>
<tr>
<td>Distance to highway [km]</td>
<td>-0.003392</td>
<td>6.273E-7</td>
<td>-5.41</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% households with 1 member * 1 member in h</td>
<td>2.6327</td>
<td>0.0851</td>
<td>30.95</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% households with 2 members* 2 members in h</td>
<td>0.9366</td>
<td>0.3060</td>
<td>3.06</td>
<td>0.0022</td>
</tr>
<tr>
<td>% households with 3+ members* 3+ member in h</td>
<td>3.2437</td>
<td>0.0810</td>
<td>40.03</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% hh with no working member * no working member  in h</td>
<td>6.1790</td>
<td>0.2287</td>
<td>27.02</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% hh with 1 working member * 1 working member  in h</td>
<td>0.3384</td>
<td>0.1455</td>
<td>2.33</td>
<td>0.0201</td>
</tr>
<tr>
<td>% hh with 2+ working member * 2+ working member in h</td>
<td>0.7132</td>
<td>0.1078</td>
<td>6.61</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% hh with a young head</td>
<td>-0.0147</td>
<td>0.1335</td>
<td>-0.11</td>
<td>0.9122</td>
</tr>
<tr>
<td>% hh with a young head * young head in h</td>
<td>4.7947</td>
<td>0.1351</td>
<td>35.50</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% poor households</td>
<td>0.3853</td>
<td>0.1706</td>
<td>2.26</td>
<td>0.0240</td>
</tr>
<tr>
<td>% households with a foreign head * foreign head in h</td>
<td>6.2094</td>
<td>0.1622</td>
<td>38.28</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% households with a foreign head * French head in h</td>
<td>-2.7905</td>
<td>0.1007</td>
<td>-27.70</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Total employment [/1000]</td>
<td>-0.0001349</td>
<td>2.348E-7</td>
<td>-0.57</td>
<td>0.5657</td>
</tr>
<tr>
<td>Density (Population/Surface) [1000 persons/km]</td>
<td>-0.004621</td>
<td>1.0479E-6</td>
<td>-4.41</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Log(Population)</td>
<td>0.0931</td>
<td>0.005506</td>
<td>16.90</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>% change in population, 1990 to 1999</td>
<td>0.0931</td>
<td>0.0168</td>
<td>5.54</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

Source: Authors estimations’ results (using SAS).
The relative sensitivity to price is as we would expect, though the potential for a small positive preference for higher prices for this specific subpopulation and sample of locations is likely to be due to some amenities that are not accounted for in the model, rather than an actual preference to may more for housing, ceteris paribus. Increase of the average travel time by public transit decreases the utility of households headed by a woman, though this effect is insignificant for male-headed households.

The number of metro stations in a commune increases the probability of location but the number of railway stations decreases it, after accounting for transit accessibility and other effects. These results may reflect the relative effects of positive and negative externalities associated with metro stations and railway stations. Metro stations are more likely than railway stations to be located within clusters of shopping and service employment or adjacent to major cultural attractions, and railway stations are larger and may be more likely to have negative localized externalities on the immediate neighbourhood, such as traffic, noise, and possibly petty crime. The average travel time by private car and the distance to the highway have a negative effect on the preference for a commune, as expected.

The estimated coefficients corresponding to the socio-economic structure of the commune show a general preference of the households to live with the people in the same social category. This preference is very strong for households without workers, or with a foreign or young head. The households with one worker are less sensitive to the concentration of similar households. Households of French origin tend to avoid locations in which there are higher concentrations of foreign households. The coefficients for the percentage of young head households and the total number of employments are insignificant. Households prefer more populated but less dense communes. The communes that have absorbed more population during the 90-99 period attract still more households. Considering these variables the composition of the population with regard to income does not remarkably influence the location choice of households. But the density of high, middle and low income families can be studied if we don’t take into account the total population, its density and its evolution.

Adding the residuals of the price equation as an explanatory variable, the estimated coefficients change trivially and the coefficient of this new variable is not at all significant. This result confirms that housing price is not endogenous with regard to the location choice model. In other words, the variables used in these two models fully explain the correlation between prices and location choice.

Conclusions

The research on which we report in this paper is from an early phase of a longer-term research collaboration to explore the interaction of land use and transportation. Our particular emphasis is on issues of dynamics, endogeneity and constraints. We have now succeeded in developing and estimating a model of residential location at a commune level for the Paris region, with a rigorous econometric treatment of the endogeneity of housing prices. Further, we have integrated UrbanSim with METROPOLIS, providing the first experience of connecting dynamic models of land use and traffic. By coupling these models we are able to represent the endogeneity of residential location and traffic, given a distribution of job locations. In related research, we are developing employment location choice models and real estate development models for the Paris region, and will
address the endogeneity among these choice processes. We are also developing a rigorous theoretical and empirical treatment of the problem of endogenous constraints on the availability of alternatives, where demand may exceed the supply of housing within popular neighbourhoods. In this field, there is a need to distinguish between unconstrained and constrained demand, and traditionally used estimation procedures tend to confound these two concepts (for a complete treatment of this topic, we refer the reader to de Palma, Picard and Waddell, 2006).

This research is in progress, and it is likely to evolve substantially as it moves to completion and into an operational framework for exploring the potential effects of combinations of transportation and land use policies. We hope that this line of research provides a valuable future direction for the integrated treatment of land use and transportation, and advances the state of the field by better representing these as dynamic processes with substantial endogeneity.

References


Acknowledgements

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A cost-benefit analysis of tunnel investment and tolling alternatives in Antwerp

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Abstract

A proposal has been made to build a new tunnel under the Scheldt river near the centre of Antwerp in order to relieve traffic congestion on the ring road and in an existing tunnel. The new tunnel is expected to cost more than €1 billion, and tolls have been suggested to help finance construction and to manage demand. This paper conducts a preliminary cost-benefit analysis of a new tunnel and three alternative tolling schemes, and compares them with a do-nothing scenario and an option to toll the existing tunnel without building a new one. The two tunnels are treated as imperfect substitutes, and a multi-year accounting framework is adopted that accounts for emissions, accidents and noise externalities, road damage, revenues accruing to the national and regional governments from existing transport user charges, and the salvage value of the new tunnel. With the base-case parameter values it is found that building the tunnel is worthwhile with all three tolling regimes and yields a higher benefit than not building the tunnel and tolling the old one. Nevertheless, the net benefit from building the tunnel differs appreciably between tolling regimes, and it is sensitive to the value assumed for the marginal cost of public funds.

Keywords: Infrastructure investment; Route choice; Congestion; Tolls.

Introduction

Urban traffic congestion is a serious and growing problem in many large cities around the world. The traditional response to congestion, building new roads, is now impeded or prevented by lack of space, high construction costs and long-lead times, environmental concerns and NIMBY (Not In My Back Yard) opposition. Emphasis has

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shifted since the 1980s towards demand-management approaches to controlling use of
the car, and road pricing has slowly been gaining ground as demonstrated by successful
urban road pricing schemes in Singapore, Norway, London, Melbourne, Hong Kong,
North America and elsewhere. However, road pricing in urban areas is still obstructed
by acceptability and other barriers that led to the rejection by referendum in February,
2005, of a cordon scheme for Edinburgh. Most transport researchers now argue that a
package approach of investment and demand-side measures has the best chance of
meeting both traditional efficiency-based standards for policy appraisal and
public/political acceptability hurdles.

Given the large expenditures and potentially high political stakes in building new
roads and designing tolling schemes, the need for careful cost-benefit and appraisal is
obvious. This is all the more true for combined investment and tolling projects or
schemes whose component parts need to be integrated into a consistent whole. For
example, it is well known that the welfare gains from capacity investments depend on
what pricing regime is in place (Small et al., 1989; Winston, 1991) and that building
new infrastructure can have perverse effects (e.g. the Braess Paradox) if congestion and
other transport externalities are not internalised.

The purpose of this paper is to conduct an exploratory cost-benefit analysis of
alternative tunnel investment *cum* tolling schemes in Antwerp, Belgium. Traffic in
Antwerp is heavy on weekdays, and congestion is particularly severe on one of the
tunnels that cross under the Scheldt river near the city centre. A proposal has been made
to construct a new tunnel to alleviate congestion through the existing tunnel, and to
offer a shorter route for some of the passenger and freight traffic. Tolls on the existing
and new tunnels have also been suggested as a way to manage congestion as well as to
pay for the construction and maintenance costs of the new tunnel. To assess the relative
merits of these proposals, a recently-developed cost-benefit model is used to evaluate
one toll-only and three investment *cum* tolling regimes, and to compare each scheme
with a do-nothing/business-as-usual scenario. With the base-case parameter values and
assumptions, constructing the new tunnel is found to be worthwhile for all three tolling
regimes. Nevertheless, the net benefit from building the tunnel and the impacts on
passenger and freight user groups vary appreciably across the tolling regimes.

1. Tunnel construction and tolling options in Antwerp

Antwerp straddles the Scheldt river as shown in Figure 1. Four tunnels cross the
Scheldt in the general neighbourhood of the proposed new tunnel: two very small
tunnels in the city centre (the St. Anna tunnel and the Waasland tunnel), the Kennedy
tunnel to the south and the Liefkenshoek tunnel far north of the city. Several bridges
also cross the Scheldt far to the south. Of these tunnels and bridges the two major
crossings are the Kennedy tunnel and the Liefkenshoek tunnel. The Kennedy tunnel lies
on the ring road R1 that circles the centre of Antwerp to the east of the Scheldt. The
Kennedy tunnel conveys a daily two-way flow of about 122,000 vehicles. The
Liefkenshoek tunnel lies far to the north of the city, and it carries a much smaller daily
flow of about 11,000 vehicles.
A proposal has been made to build an additional tunnel under the Scheldt between the Kennedy and Liefkenshoek tunnels. The future tunnel, known as the “Oosterweel” connection, would branch off the ring road R1 and offer a shorter route for traffic heading to or from the north of Antwerp. R1 is a crossroad for several motorways, and it is heavily used by cars and for national and international/transit freight transport. Building a new tunnel would alleviate traffic congestion through the Kennedy tunnel and on the ring road generally.

The new tunnel is expected to cost about €1.2 billion. One option is to fund it publicly, and another is to solicit private financing with cost recovery through tolls. The Liefkenshoek tunnel is toll-financed, and offers a local precedent for private-sector involvement with road construction and operation. However, tolling is politically controversial and may be opposed by truckers and other interest groups. It is therefore of interest to compare several alternative investment cum tolling regimes. Five candidates are: (1) do nothing and continue with business as usual; (2) refrain from building the new tunnel, but toll the Kennedy tunnel to alleviate congestion in the tunnel and on the ring road; (3) build the new tunnel and let traffic use both tunnels toll-free; (4) have the new tunnel built by the private sector and toll it on a cost-recovery basis; and (5) build the new tunnel and toll both tunnels to support an optimal overall level and division of traffic between the tunnels.

Toll collection costs and potential cost savings from harnessing the private sector aside, the socially-optimal (i.e. social-surplus maximising) choice would be either Option 2 or Option 5 depending on whether or not a new tunnel is warranted. Option 4 is feasible only if demand to use the new tunnel is sufficient to generate adequate toll revenues when the Kennedy tunnel offers a toll-free substitute. And, even if Option 4 is viable, an allocative efficiency loss will result if the break-even toll on the new tunnel exceeds the second-best optimal toll.

Comparison of the various alternatives is complicated by the system of road administration in Belgium. Belgium is a federal country with three regions (Flanders, Wallonia and Brussels). The regions are responsible for road infrastructure, but the principal taxes on road use (the excise taxes on fuel) are federal. Decisions at the two levels of government are not perfectly coordinated, and current fuel excise taxes differ from optimal Pigouvian levels for internalising environmental and other traffic externalities. Because the proposed tunnel would add only one short link to the overall road network, it is unlikely that building the tunnel would trigger a change in fuel tax rates or other user charges. Thus, transport taxes other than for tolls on the two tunnels are treated as given in the study.

From this discussion it should be clear that a model is required to analyse and compare the competing tunnel construction and tolling options. The model is described in the following section.

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1 For brevity it is called a tunnel here, but it is actually a combination of a tunnel and a bridge.
2 Several other regimes could be entertained. One is to compensate the private concessionaire in Option 4 through shadow tolls; i.e. a payment per vehicle that is funded from the public purse rather than from real tolls on users. Another regime is a mixed oligopoly in which the new tunnel is tolled by the concessionaire (perhaps under toll cap or rate-of-return regulations rather than strict cost recovery) and the Kennedy tunnel is tolled by the public authority. These and other alternatives could be explored in future work.
2. The model

The model (referred to as “MOLINO”) was recently developed as part of the European-Union funded REVENUE project to assess transport pricing, investments and regulatory regimes with emphasis on the allocation of revenues from user charges. The model is used in the REVENUE project for a variety of case studies that involve several modes. Since the model has to be applicable to many diverse problems, it is kept rather abstract and general. The present model version still has limited capabilities (in particular, it is limited to competition between two alternatives) and this application is one of the first tests of the model. The application needs further elaboration with respect to data and sensitivity analysis.

Structure of the MOLINO model

The MOLINO model is a policy assessment model, not a forecasting model. It is calibrated to an exogenous transport baseline that can be developed with any transport forecasting model. The time horizon, which can be chosen by the user, typically covers 10 to 50 years. MOLINO is a partial equilibrium model of the transport market: income levels of the private transport users, and production levels of the firms using freight services as input, are taken as given. The model includes separate modules for demand, supply, equilibrium, and the regulatory framework. In its present form the model
contains two transport modes (e.g. two parallel roads, a road and parallel railway, a railway and competing air link, etc.).

The demand module for passenger transport features an aggregate nested CES utility function with three levels: choice between transport and consumption of a composite commodity, choice between peak and off-peak periods, and choice between the two transport alternatives. Elasticities of substitution at each level are parametrically given. Passengers can be segmented into classes that differ with respect to their travel preferences, incomes and costs of travel time. The demand module for freight transport is based on an aggregate CES cost function (production levels are given) and also features three levels. The first level encompasses choice between transport and other production inputs, and the second and third levels are the same as for passenger transport. Freight transport can be segmented into local and transit traffic.

Transport users pay a generalised cost that contains several components: a resource cost (say fuel for a car), taxes levied by central and local governments (say fuel taxes and car taxes), a user fee (toll or rail fare) and a time cost. For a given infrastructure, travel time is assumed to be a linear function of traffic flows.

For each transport alternative a distinction can be made between an operator who takes care of maintenance and can set tolls or user charges, and an infrastructure supplier who decides on capacity extensions and on infrastructure charges. The costs of the operator have a linear structure: a fixed cost, constant variable maintenance and operation costs that depend on the type of vehicle or load, and finally a payment for infrastructure use that can be specified in different ways. The infrastructure provider also has a linear cost structure where the main costs are the investment and associated financial costs for the infrastructure. Operator and infrastructure suppliers can be private or public agents, and the cost level can depend on the contractual form.

The model includes a local and a central government that can pursue different objectives and control different tax and subsidy instruments including fuel taxes, public transport subsidies and profit taxes. Given the demand and cost functions, and the regulatory framework (see below) that specifies the behaviour of the governments, operators and infrastructure suppliers, the equilibrium module computes a fixed-point solution in terms of prices and levels of congestion for the two transport alternatives. In its present version the model has myopic expectations and is solved year by year.

It is the exogenous regulatory framework that dictates the rules of the game and the ultimate outcome. This exogenous framework specifies for each alternative the objective functions of the governments, operators and infrastructure managers (public or private objectives), the nature of competition, procurement policies, the cost of capital, and the source and use of transport tax revenues. Various market structures can be modeled, including no tolls (free access), exogenous tolls, marginal social cost pricing, private duopoly and mixed oligopoly. Public decisions can be made either by local or central governments that may attach different welfare-distributional weights to agents (e.g. low-income vs. high-income passengers, or local vs. transit freight traffic) as well as different weights to air pollution and other (non-congestion) external transport costs. Primary outputs from MOLINO are equilibrium prices, transport volumes, travel times, cost efficiency of operations, toll revenues and financial balances, travellers’ surplus and social welfare.
Application of the model to the Antwerp tunnels

The existing version of the model allows only two transport alternatives. Given the structure of the road network described in Section 1, these are selected as the Kennedy tunnel and the proposed Oosterweel connection. Henceforth they will be referred to respectively as the OLD tunnel and the NEW tunnel. The model therefore neglects the other tunnels and bridges, as well as the effects of changes in the transport flows through the two tunnels on other parts of the network. The elasticity of substitution between the OLD and NEW tunnels is assumed to be finite because the model provides an aggregate behavioural representation of users with different origins/destinations and potential travel time savings from using the NEW tunnel (cf Figure 1).

A time horizon of 20 years is chosen starting in 2000: the latest year for which calibration data are available. If the NEW tunnel is built, it is assumed to become available in 2010 and a salvage value for it is computed at the end of the horizon in 2020. An annual social discount rate of 5% is used to compute present values.

User groups

The model features two groups of passenger/car users and two groups of freight users. One group of car users is assumed to comprise commuters and travelers on business with high values of time; this type of traffic is referred to as work trips. The second group of car users have lower values of time and/or more flexibility in the timing of their trips, and are referred to as other users. Freight traffic is divided into transit traffic, and local traffic. For this preliminary case study the two freight groups are assumed to have the same behavioural parameters and are assigned the same weights in the welfare function. The two freight groups therefore fare identically in the various investment cum toll regimes. Freight vehicles have a Passenger Car Equivalent (PCE) of 2.0. Both passenger and freight traffic volumes are assumed to grow at 1% per annum, which is the growth rate commonly accepted for Belgian traffic.

Infrastructure costs and operation

The NEW tunnel is assumed to cost €1.2 billion to complete by Year 10. It is assumed to have a lifetime of 100 years, and with the 5% discount rate it has a salvage value of €751,055 at the end of Year 20.

Externalities

Every trip generates congestion externalities as well as air pollution, noise and accident externalities. (Values per vehicle-kilometre are specified in the Appendix.) In addition, freight vehicles create pavement damage of €0.27/vkm.

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3 Adding the small existing tunnels to the analysis would not change the traffic effects very much since these alternatives are already taken into account in the substitution patterns (demand functions) for the two tunnels considered. The welfare effects would change slightly if one of the other existing tunnels were tolled since the toll revenues derived from it would drop when a new tunnel is built.

4 A five percent annual discount rate is used by the public sector in Belgium for cost benefit analysis.

5 It could be argued that transit and local traffic should be treated separately since transit trucks tend to be heavier. Unfortunately, data limitations precluded a distinction.
Tolling costs and procedures

Differentiating tolls by vehicle size is common on both conventional and electronic toll roads around the world. This is the practice on the Liefkenshoek tunnel, and it is assumed to be implemented on the OLD and NEW tunnels if they are tolled. However, there is no discrimination between automobile travellers on work trips and other trips or between local and transit freight traffic. In the regimes with tolls, trucks are required to cover at least their pavement-damage related maintenance costs. In this application, the installation and operating costs of toll facilities are ignored and infrastructure management and toll operation are assumed to be vertically integrated.

The remaining parameter values and data used to calibrate the model are presented in the Appendix.

3. Simulation results

This section reports the simulation results for the do-nothing and the four investment cum tolling regimes. For ease of reference the five regimes are listed in Table 1.

Table 1: Alternative investment cum tolling regimes.

<table>
<thead>
<tr>
<th>Regime</th>
<th>Investment policy</th>
<th>Tolling policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Business as Usual (BAU)</td>
<td>OLD tunnel remains toll-free</td>
</tr>
<tr>
<td>2</td>
<td>NEW tunnel not built,</td>
<td>OLD tunnel is tolled to internalise congestion and other transport externalities from traffic using the OLD tunnel</td>
</tr>
<tr>
<td></td>
<td>tolling of OLD tunnel</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>NEW tunnel built, no tolling</td>
<td>Neither tunnel is tolled</td>
</tr>
<tr>
<td>4</td>
<td>NEW tunnel built &amp; tolled to recover costs</td>
<td>NEW tunnel is tolled to recover its construction costs</td>
</tr>
<tr>
<td>5</td>
<td>NEW tunnel built, both tunnels tolled</td>
<td>Tolls are levied on both tunnels to internalise congestion and other transport externalities on the two-link road network</td>
</tr>
</tbody>
</table>

6 Under first-best conditions the optimal congestion toll depends only on a vehicle’s contribution to congestion. Although motorists on work trips typically have higher values of time (and correspondingly lower sensitivity to tolls) than do motorists traveling for other reasons, the marginal external congestion costs they create are the same. In a second-best world, though, discriminatory pricing has a potential role to play in enhancing efficiency (Arnott and Kraus, 1998). Toll discounts for work trips have been endorsed on the grounds that work is discouraged by high employment taxes and other labour-market distortions. However, price discrimination of this sort is impeded by legal, practicality and acceptability barriers. Furthermore, labour-market and other distortions are largely ignored in the application of the MOLINO model undertaken here.

7 EU legislation on heavy vehicle charges is still evolving. Nevertheless, the assumption that trucks are charged for their marginal maintenance costs is consistent with the currently accepted principle that tolls must be related to construction and maintenance costs and can vary by vehicle type.

8 Operating costs of existing electronic systems generally run at about 10-20% of toll revenues (Small and Gómez-Ibáñez, 1998; Ramjerdi et al., 2004). London’s congestion pricing scheme is a notable exception with much higher operating costs because employees are required to aid motorists with some forms of payment and to read the license-plate images recorded by the Automatic Number Plate Recognition technology.
Regime 1: Business as Usual (BAU)

In the Business as Usual (BAU) regime, no NEW tunnel is built and the OLD tunnel remains toll-free. The number of daily PCE trips through the OLD tunnel begins at about 117,000 in Year 1, and rises to nearly 128,000 in Year 20. This growth reflects the combined effect of an assumed 1% annual growth rate in traffic with congestion held constant, and a build-up in congestion that depends on tunnel capacity. Column 1 of Table 2 reports the present-discounted daily benefits and costs from usage of the tunnel over the 20-year horizon at a 5% annual discount rate. Auto travel surplus and freight travel costs are recorded as a benchmark to compare with the welfare changes that result in the other four regimes. The regional government incurs the maintenance costs of the OLD tunnel, and both regional and national governments collect revenue from transport taxes.

Table (2): Welfare gains and losses (present-value daily sums in euros over 20 year horizon, 5% discount rate).

<table>
<thead>
<tr>
<th>Regime</th>
<th>1 (BAU)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct NEW tunnel?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tolling of tunnels</td>
<td>None</td>
<td>OLD, optimal</td>
<td>None</td>
<td>NEW, break even</td>
<td>OLD+NEW, optimal</td>
</tr>
<tr>
<td>Auto travellers' surplus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work trips</td>
<td>24,728,541</td>
<td>-694,943</td>
<td>1,604,221</td>
<td>786,603</td>
<td>1,191,196</td>
</tr>
<tr>
<td>Other trips</td>
<td>12,131,229</td>
<td>-366,582</td>
<td>431,486</td>
<td>57,876</td>
<td>274,971</td>
</tr>
<tr>
<td>Freight users' costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local traffic</td>
<td>30,328,753</td>
<td>-786,929</td>
<td>807,656</td>
<td>274,446</td>
<td>-16,169</td>
</tr>
<tr>
<td>Transit traffic</td>
<td>14,938,043</td>
<td>-387,592</td>
<td>397,801</td>
<td>135,175</td>
<td>-7,964</td>
</tr>
<tr>
<td>External costs other than congestion</td>
<td>1,367,587</td>
<td>283,525</td>
<td>-163,238</td>
<td>22,407</td>
<td>67,458</td>
</tr>
<tr>
<td>Toll revenues</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OLD tunnel</td>
<td>0</td>
<td>2,559,706</td>
<td>0</td>
<td>0</td>
<td>1,519,475</td>
</tr>
<tr>
<td>NEW tunnel</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,035,077</td>
<td>388,803</td>
</tr>
<tr>
<td>Tax revenues</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional government</td>
<td>344,188</td>
<td>-67,027</td>
<td>41,192</td>
<td>-5,088</td>
<td>-6,438</td>
</tr>
<tr>
<td>Central government</td>
<td>1,809,742</td>
<td>-356,431</td>
<td>216,487</td>
<td>-27,262</td>
<td>-43,593</td>
</tr>
<tr>
<td>Maintenance &amp; construct. costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OLD tunnel</td>
<td>1,091,096</td>
<td>283,077</td>
<td>344,651</td>
<td>147,780</td>
<td>541,523</td>
</tr>
<tr>
<td>NEW tunnel</td>
<td>0</td>
<td>0</td>
<td>-2,491,796</td>
<td>-2,141,006</td>
<td>-2,367,656</td>
</tr>
<tr>
<td>Salvage value: NEW tunnel</td>
<td>0</td>
<td>0</td>
<td>751,055</td>
<td>751,055</td>
<td>751,055</td>
</tr>
<tr>
<td>Welfare gain</td>
<td>N/A</td>
<td>466,804</td>
<td>1,939,515</td>
<td>1,037,063</td>
<td>2,292,661</td>
</tr>
<tr>
<td>Welfare gain relative to Regime 5</td>
<td>0</td>
<td>20%</td>
<td>85%</td>
<td>45%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: Authors' calculations.
Note: Positive entries correspond to welfare gains and negative entries to welfare losses.
Regime 2: NEW tunnel not built, tolling of OLD tunnel

In Regime 2 the NEW tunnel is again not built, but a Pigouvian toll is levied on the OLD tunnel. To economise on calculation, optimal tolls are computed for two years: Year 1 and Year 10. The Year 1 toll is levied from Year 1 to Year 9, and the Year 10 toll from Year 10 until the end of the horizon in Year 20. Optimal toll levels in the two intervals are reported in Table 3. As explained in Section 2, the same toll is levied on auto trips regardless of trip purpose and the same toll is applied on the two categories of freight traffic. Two features of the tolls in each interval may appear odd. First, the ratio of peak to off-peak tolls is much higher for autos than for trucks. Second, truck tolls are 3-7 times larger than auto tolls although trucks have a PCE of 2, and therefore contribute only twice as much to congestion apiece as do autos. Both these oddities are due to the fact that trucks create substantial pavement damage costs that are not charged in the BAU regime, but are included in the tolls.

Table 4 reports traffic volumes in Regime 2 for each user group for the peak period, the off-peak period and all trips as a percentage of volumes in Regime 1 (BAU). Total PCE traffic declines by about 20%. Auto volumes decline proportionally more for other trips than for work trips because values of travel time are much lower for other trips, and the benefits from congestion relief are correspondingly smaller. Freight volumes decline rather more than auto trips because of the much higher truck tolls.

Column 2 of Table 2 reports the present-value changes in daily surpluses. Positive values indicate welfare gains, and negative values indicate welfare losses. Before accounting for the use of the toll revenues, all four user groups are worse off because the monetary values of the travel-time savings are more than offset by the tolls. The total losses are relatively evenly spread between passenger and freight traffic. External costs of traffic fall although the benefits are fairly small compared to users' losses. Regional government is the big gainer since it receives the (sizeable) toll revenues that more than offset the increase in maintenance costs and the small loss of other tax revenues. The national government sees a modest reduction in fuel tax revenues.

The overall present-value of the daily welfare gain from tolling the OLD tunnel amounts to €466,804. A welfare gain is inevitable given the assumptions that tolls are set optimally and tolling is costless. However, the gain is only 20% of the gain derived from Regime 5 discussed below (see the last row of Table 2). Moreover, all four user groups are left worse off, and their aggregate losses of nearly €2.24 million are nearly five times the welfare gain. Consequently, nearly 80% of the tax and toll revenues received by government would have to be, somehow, transferred to users in order to leave them no worse off than in the BAU regime. In principle, compensation could be effected either by rebating the toll revenues directly to users in a lump-sum fashion or by spending them in ways that benefit users. Constructing the NEW tunnel, as in

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9 Optimal tolls are evaluated for only two of the 20 years in order to economise on computation time. There are no implacable institutional barriers in Belgium to prevent annual changes in tolls. However, depending on the toll-road enabling legislation, annual toll increases might have to be approved on an individual basis.

10 The figure of $283,525 denotes the benefits from a reduction in the costs.

11 Operating costs on existing toll facilities are actually considerable (up to 45% of revenues) but it is expected that developments in tolling technology would reduce these costs below 10% of the revenues.

12 If revenues were distributed to motorists this would raise household incomes and boost passenger travel demand. This feedback effect whereby drivers “buy back road space” is typically ignored in modeling exercises although it could be accounted for with the MOLINO model.
Regimes 3-5, is one way to benefit users. However, none of Regimes 3-5 features a toll on the OLD tunnel to fund construction of the NEW tunnel. The cost recovery regime in Regime 4 entails tolling the NEW tunnel after it is built.

Table (3): Toll levels (€/vehicle).

<table>
<thead>
<tr>
<th>Regime</th>
<th>2</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct NEW tunnel?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tolling of tunnels</td>
<td>OLD only, optimal</td>
<td>NEW only, break even</td>
<td>OLD and NEW, optimal</td>
</tr>
<tr>
<td>Years 1-9</td>
<td>Peak</td>
<td>Off-peak</td>
<td>Peak</td>
</tr>
<tr>
<td>Auto</td>
<td>1.8</td>
<td>0.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Freight</td>
<td>6.8</td>
<td>5.0</td>
<td>6.8</td>
</tr>
<tr>
<td>Years 10-20</td>
<td>Peak</td>
<td>Off-peak</td>
<td>Peak</td>
</tr>
<tr>
<td>Auto</td>
<td>2.2</td>
<td>0.9</td>
<td>3.5</td>
</tr>
<tr>
<td>Freight</td>
<td>7.1</td>
<td>5.2</td>
<td>11.0</td>
</tr>
</tbody>
</table>

Note: No tolls are levied in Regimes 1 or 3. Source: Authors’ calculations.

Table (4): Traffic volumes, Year 20 (BAU=100).

<table>
<thead>
<tr>
<th>Regime</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct NEW tunnel?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tolling of tunnels</td>
<td>OLD, optimal</td>
<td>None</td>
<td>NEW, break even</td>
<td>OLD+NEW, optimal</td>
</tr>
<tr>
<td>Auto Peak trips</td>
<td>Work</td>
<td>85.3</td>
<td>149.6</td>
<td>107.0</td>
</tr>
<tr>
<td>Other</td>
<td>60.8</td>
<td>124.3</td>
<td>95.5</td>
<td>124.5</td>
</tr>
<tr>
<td>Freight</td>
<td>76.0</td>
<td>143.0</td>
<td>100.3</td>
<td>105.3</td>
</tr>
<tr>
<td>Total</td>
<td>76.4</td>
<td>140.8</td>
<td>102.7</td>
<td>137.9</td>
</tr>
<tr>
<td>Off-peak trips</td>
<td>Work</td>
<td>90.0</td>
<td>134.7</td>
<td>98.3</td>
</tr>
<tr>
<td>Other</td>
<td>81.2</td>
<td>114.5</td>
<td>90.6</td>
<td>114.6</td>
</tr>
<tr>
<td>Freight</td>
<td>75.7</td>
<td>126.5</td>
<td>93.2</td>
<td>94.7</td>
</tr>
<tr>
<td>Total</td>
<td>81.3</td>
<td>123.2</td>
<td>93.5</td>
<td>116.3</td>
</tr>
<tr>
<td>All trips</td>
<td>Work</td>
<td>87.5</td>
<td>143.0</td>
<td>103.1</td>
</tr>
<tr>
<td>Other</td>
<td>74.8</td>
<td>117.5</td>
<td>92.1</td>
<td>117.7</td>
</tr>
<tr>
<td>Freight</td>
<td>76.0</td>
<td>129.8</td>
<td>94.6</td>
<td>96.8</td>
</tr>
<tr>
<td>Total</td>
<td>79.6</td>
<td>130.0</td>
<td>96.7</td>
<td>120.6</td>
</tr>
</tbody>
</table>

Source: Authors’ calculations.

Regime 3: NEW tunnel built, no tolling

In Regime 3 the NEW tunnel is built, and both tunnels are kept toll-free. Since the 20-year accounting time horizon begins in 2000 and no plan to build the tunnel has yet been made, it is assumed that the NEW tunnel goes into operation in Year 10. At the
end of the accounting period in Year 20, the NEW tunnel has a discounted salvage value of €751,055/day which is tallied in the accounting.

Building the NEW tunnel greatly reduces congestion delays throughout the accounting period, and by Year 20 traffic volumes on the two tunnels combined are 30% higher than in the BAU regime (cf Table 4). Because the NEW tunnel route is shorter than the OLD tunnel route for most users, the NEW tunnel captures over 80% of traffic from each user group in both the peak and off-peak periods (cf Table 5).13 Despite the large cost of building the tunnel and the increase in external transport costs, the social surplus gain in Regime 3 is more than four times the gain from tolling the OLD tunnel in Regime 2 (cf Table 2) and amounts to 85% of the maximum gain derived in Regime 5.

Table (5): Tunnel market shares, Year 20 (percentages).

<table>
<thead>
<tr>
<th>Regime</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct NEW tunnel?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tolling of tunnels</td>
<td>OLD, optimal</td>
<td>None</td>
<td>NEW, break even</td>
<td>OLD+NEW, optimal</td>
</tr>
<tr>
<td>OLD</td>
<td>NEW</td>
<td>OLD</td>
<td>NEW</td>
<td>OLD</td>
</tr>
<tr>
<td><strong>Peak trips</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto</td>
<td>Work</td>
<td>100.0</td>
<td>0.0</td>
<td>17.6</td>
</tr>
<tr>
<td>Other</td>
<td>100.0</td>
<td>0.0</td>
<td>17.7</td>
<td>82.3</td>
</tr>
<tr>
<td>Freight</td>
<td>100.0</td>
<td>0.0</td>
<td>17.0</td>
<td>83.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.0</td>
<td>0.0</td>
<td>17.6</td>
<td>82.4</td>
</tr>
<tr>
<td><strong>Off-peak trips</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto</td>
<td>Work</td>
<td>100.0</td>
<td>0.0</td>
<td>17.7</td>
</tr>
<tr>
<td>Other</td>
<td>100.0</td>
<td>0.0</td>
<td>17.7</td>
<td>82.3</td>
</tr>
<tr>
<td>Freight</td>
<td>100.0</td>
<td>0.0</td>
<td>17.1</td>
<td>82.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.0</td>
<td>0.0</td>
<td>17.6</td>
<td>82.4</td>
</tr>
<tr>
<td><strong>All trips</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto</td>
<td>Work</td>
<td>100.0</td>
<td>0.0</td>
<td>17.7</td>
</tr>
<tr>
<td>Other</td>
<td>100.0</td>
<td>0.0</td>
<td>17.7</td>
<td>82.3</td>
</tr>
<tr>
<td>Freight</td>
<td>100.0</td>
<td>0.0</td>
<td>17.1</td>
<td>82.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.0</td>
<td>0.0</td>
<td>17.6</td>
<td>82.4</td>
</tr>
</tbody>
</table>

Source: Authors’ calculation.

**Regime 4: NEW tunnel built & tolled to recover costs**

In Regime 4 the NEW tunnel is built by private enterprise and brought into service in Year 10. But unlike in Regime 3, the NEW tunnel is tolled to cover the costs of maintaining it and to pay back the construction costs by the end of the accounting horizon in Year 20.14 Similar to Regime 2, it is assumed that there is no toll discrimination between either the two groups of auto users or the two categories of freight traffic. But unlike in Regime 2, peak and off-peak tolls are assumed to be the

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13 The division of traffic between the tunnels is similar for all user groups because the elasticities of substitution are assumed to be the same (cf Table A1 in the Appendix).

14 Since the tunnel commences operation only in Year 10, cost recovery (except for the salvage value) has to be accomplished within 10 years. Alternative recovery periods could be investigated by varying the accounting time horizon.
same. Consequently, only two tolls are levied: an auto toll of €3.50 and a truck toll of €11.00 (cf Table 3). These relatively high tolls depress traffic even below the levels reached in the BAU regime, and the NEW tunnel captures a much smaller share since the OLD tunnel is left untolled. Passengers on work trips favour the NEW tunnel because the value of the travel time savings exceeds the toll. But majorities of the other user groups continue to use the OLD tunnel.

Although it turns out to be feasible to finance the tunnel by charging users, the tolls far exceed the external costs of autos and trucks and the auto toll adds to the distortion created by the pre-existing taxes. As a consequence, the welfare gain in Regime 4 is little more than half the gain from building the NEW tunnel without tolls (Regime 3).

Regime 5: NEW tunnel built, both tunnels tolled

In the final regime the NEW tunnel is built in Year 10 and both tunnels are tolled optimally. During Years 1-9 before the tunnel is built, tolls on the OLD tunnel are the same as in Regime 2 (cf Table 3). The auto toll drops to zero when the NEW tunnel begins operation because fuel and other user taxes exceed the combined congestion and other external costs of auto trips. Trucks are still tolled to cover maintenance costs and the small remaining congestion externality, but the toll is lower than in Years 1-9 and much lower than the truck tolls in Regimes 2 and 4.

Regime 5 turns out to be the most efficient of the five regimes (cf Table 2) and therefore achieves 100% efficiency. Auto drivers fare less well than without tolling (Regime 3) but better than with the break-even toll (Regime 4). Truckers do less well than in either Regime 3 or 4 because truck tolls are levied on all capacity throughout the accounting period. But reductions in external costs, and savings in maintenance costs, are higher than in either of these other regimes.

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15 An alternative would be to assume that separate peak and off-peak tolls are set for autos and for trucks according to Ramsey pricing rules. There has been surprisingly little published research on temporal price discrimination by private toll road operators, and it is not obvious whether the peak/off-peak differential would be larger or smaller for a private operator than a public operator. Because private operators exercise market power by including a toll markup, congestion tends to be lower in the peak period – which suggests that the temporal differential will be proportionally smaller than on a public road. However, the elasticity of demand also varies by time of day, and this provides another incentive for a private operator (but not a public operator) to engage in intertemporal price discrimination. One bit of empirical evidence comes from Highway 407: a limited-access electronically-tolled highway in Toronto. In 1998 when the highway was publicly operated, separate peak, off-peak and night time/weekend tolls were levied with a ratio of 10:7:4 for each vehicle category. The highway was privatised in 1999, and since 2002 the maximum temporal toll differential has ranged from nothing to about 7%. While this suggests that temporal toll discrimination is less pronounced on private toll roads, there are at least two confounding factors. First, traffic volumes have grown very rapidly on Highway 407 since it went into operation in 1997, and second, tolls are subject to complicated regulations based on traffic volumes.

16 Since the NEW tunnel provides a new option for drivers while the OLD tunnel remains as before, one might expect traffic levels in Regime 4 to remain above BAU even with very high tolls. The reason that traffic drops slightly is that the two tunnels are imperfect substitutes in the model. Introducing the NEW tunnel induces some users with strong preferences for the NEW tunnel to discontinue using the OLD tunnel, and to economise on their total amount of travel. This effect would weaken as the elasticity of substitution between tunnels (currently set at 5) is increased, and in the limit of perfect substitution the number of vehicle-kilometres would necessarily increase.
Sensitivity analysis

The simulations described above incorporate assumptions about a large number of parameter values that affect both the absolute and relative welfare gains and losses in the four investment cum tolling regimes. Both computation time and page constraints preclude an exhaustive sensitivity analysis, and attention in this subsection is restricted to two parameters of obvious significance: the cost of constructing the NEW tunnel, and the marginal cost of public funds.

Construction costs and private contracting

The €1.2 billion construction cost for the NEW tunnel is a conservative figure based on the premise that the tunnel is built according to best practice with no delays or cost increases due to technological, incentive or other contractual problems. Yet worldwide experience with major transport infrastructure projects indicates that substantial cost overruns are quite common (Flyvberg et al., 2003) and that construction costs depend strongly on the contractual framework. We therefore tested the case where construction costs of the tunnel would increase by 20% when it is not built and operated by the private sector. This means that in Cases 3 and 5, construction costs are increased by 20%, but not in Case 4 where operation and investment are private.

With the cost increases, the present-value welfare gains decrease by roughly €300,000-350,000 per day in Regimes 3 and 5 (cf panel (2) of Table 6). But the ranking of the four regimes is unchanged, and constructing the tunnel remains a viable proposition.

Table 6: Welfare gains sensitivity analysis (present-value daily sums in euros over 20 year horizon, 5% discount rate).

<table>
<thead>
<tr>
<th>Regime</th>
<th>1 (BAU)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct NEW tunnel?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tolling of tunnels</td>
<td>None</td>
<td>OLD, optimal</td>
<td>None</td>
<td>NEW, break even</td>
<td>OLD+NEW, optimal</td>
</tr>
<tr>
<td>Welfare gain</td>
<td>N/A</td>
<td>466.804</td>
<td>1.939.515</td>
<td>1.037.063</td>
<td>2.292.661</td>
</tr>
<tr>
<td>Welfare gain relative to Regime 5</td>
<td>0%</td>
<td>20%</td>
<td>85%</td>
<td>45%</td>
<td>100%</td>
</tr>
</tbody>
</table>

(1) Base case

| Welfare gain     | N/A     | 466.804 | 1.591.367               | 1.037.063              | 1.971.823              |
| Welfare gain relative to Regime 5 | 0%  | 24%   | 81%                     | 53%                    | 100%                   |

(2) Construction costs, maint. costs & salvage value of NEW tunnel rise 20% for Cases 3&5

| Welfare gain     | N/A     | 2.300.043 | 994.783                | 1.051.452              | 2.945.536              |
| Welfare gain relative to Regime 5 | 0%  | 78%   | 34%                     | 36%                    | 100%                   |

(3) Marginal cost of public funds = 1.5

Source: Authors’ calculations

17 Private operation is not a guarantee against cost overruns. It is the nature and the power of the contract that are decisive.
Marginal cost of public funds

Estimates of the marginal cost of public funds vary widely by jurisdiction and country (Kleven and Kreiner, 2003) and they are sensitive to how revenues are collected and spent. To assess the sensitivity of the welfare results to the premium on public funds, a value of 1.5 for the marginal cost of public funds (MCPF) was used in place of the base-case value of 1. Doing so raises the effective costs of constructing and maintaining the tunnel, but it also raises the salvage value of the tunnel as well as the value attached to toll and tax revenues.

Raising the MCPF has a more pronounced effect on the results than does the increase in construction costs (cf panel (3) of Table 6). The welfare gain from tolling the OLD tunnel without building the NEW tunnel (Regime 2) increases nearly five-fold relative to the base case. By contrast, building the NEW tunnel without introducing any tolls (Regime 3) drops by nearly 50% in benefits. Not surprisingly, building the tunnel under a break-even constraint (Regime 4) yields nearly the same welfare gain as in the base case because the premium attached to the toll revenue offsets the excess burden from the construction and maintenance costs. Finally, the welfare gain from the social optimum (Regime 5) rises moderately because the net increase in toll and tax revenues exceeds the construction and maintenance costs of the tunnels net of the salvage value of the NEW tunnel.

As a consequence of these changes, the relative welfare gain from Regime 2 increases from 20% to 78% and boosts it from fourth (last) place to second place in the rankings of Regimes 2-5, while Regime 3 drops from 85% to 34% in efficiency, and from second place to last. Naturally, these results would change with alternative values for the MCPF, but they do illustrate the importance of accounting for the public finance side of infrastructure projects in the real world of second best.

4. Concluding remarks

This paper has conducted a preliminary cost-benefit analysis of a proposed tunnel under the Scheldt river in Antwerp, Belgium. The analysis was performed using the MOLINO model: a cost-benefit tool for transport pricing, investment and regulation schemes that was recently developed as part of the European-Union funded REVENUE project. The model features a CES structure in which passengers and freight shippers make nested choices. For the Antwerp tunnel case study, three choice levels were implemented: (1) whether to travel, (2) to travel during the peak or off-peak period, and (3) to travel on one of two alternative links or routes.

MOLINO was implemented in the case-study area by treating the proposed “NEW” tunnel as one alternative and an existing “OLD” tunnel as the other. Four alternative investment cum tolling regimes were considered that differ according to whether the NEW tunnel is built, and whether tolls are introduced on the NEW and/or the OLD tunnels. With the base-case parameter values, building the tunnel is worthwhile in all three tolling regimes and yields a higher benefit than not building the tunnel and tolling the OLD one. Nevertheless, the net benefit from building the tunnel varies appreciably between tolling regimes. Tolling both OLD and NEW tunnels results in the highest benefits since tolling costs are ignored and tolling both tunnels supports an optimal level
and division of traffic between them. Building the tunnel without introducing any tolls compares relatively favourably since the new tunnel adds sufficient capacity to reduce congestion on the two-link network to a comparatively low level. By comparison, implementing a break-even toll on the NEW tunnel is far less efficient because it suppresses traffic through the NEW tunnel well below the optimal level and induces too much traffic to take the OLD tunnel.

Raising the construction and maintenance costs of the NEW tunnel by 20% in the two regimes with public operation does not affect the rankings of the regimes or other qualitative results. By contrast, setting the marginal cost of public funds at 1.5 pushes the two investment regimes with imperfect tolling down in the rankings, and raises the regime with no investment and optimal tolling of the OLD tunnel up to second place.

While the results of the case study provide some interesting insights, the analysis is preliminary and should be taken further in at least four respects. One is to extend the sensitivity analysis to include such elements as the elasticity of substitution for passenger and freight traffic between alternatives, the costs of installing and operating the tolling infrastructure, and more procurement issues related to the costs of public vs. private construction and how privately operated toll roads and tunnels should be regulated. The ramifications of reforming the existing system of transport taxes could also be explored. A second extension is to refine the analysis of the alternative investment cum tolling regimes by extending the time horizon beyond 20 years, optimising tolls in every year, and computing Ramsey-optimal tolls by jointly optimising peak and off-peak tolls for passenger and freight traffic. A third extension is to consider the other tunnels that cross the Scheldt river as a third alternative and to take into account the benefits or costs on the rest of the network. Finally one can study in more detail the decision making (investment and tolling the two tunnels) of the regional government when it weighs the benefits to transit users and to national government tax revenues differently.

References


De Ceuster, G. (2004) Internalising external costs of Road Traffic in Flanders (in Dutch), study of TML for Flemish Observatory of the Environment, MIRA


6. Appendix

This appendix describes the primary data used to calibrate the MOLINO model and to run the simulations. The model was calibrated using two sets of data: first a set of simulation results of a transport model with the NEW tunnel, and second the present equilibrium without the NEW tunnel. In the simulation with NEW tunnel, 80% of the travellers are expected to choose to cross the river using the NEW tunnel. Traffic on the OLD tunnel will be significantly reduced so that during the peak period the average speed is expected to be 100 km/h for both the OLD and NEW tunnel. During the off-peak period the average speed will be close to the free-flow speed. The parameters of the utility and cost functions were chosen to fit this simulation and at the same time also fit the present equilibrium by assuming that at present the tolls on the NEW tunnel are infinite.

Traffic volume data used for calibration

Table A1 records forecasted traffic volumes if a NEW tunnel is built and no tolls are levied. In this case 80% of the travellers are expected to choose to cross the river using the NEW tunnel. Total demand will rise from 120,000 vehicles per day to nearly 150,000. Nearly half (47%) of passenger trips are made during the peak period, with 70% of these trips taken for business or commuting purposes. During the off-peak more passenger trips are taken for other purposes than work. By contrast, only 22% of freight trips are made during the peak and local firms account for 67% of trips in both the peak and off-peak.

Table A1: Traffic volumes in base case.

<table>
<thead>
<tr>
<th>Category</th>
<th>Trip type</th>
<th>Peak</th>
<th>Off-peak</th>
<th>Total Peak</th>
<th>Total Off-Peak</th>
<th>Share all trips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NEW</td>
<td>OLD</td>
<td>NEW</td>
<td>OLD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passengers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>33,259</td>
<td>7,191</td>
<td>23,842</td>
<td>5,155</td>
<td>40,450</td>
<td>31,033</td>
</tr>
<tr>
<td>Other</td>
<td>14,254</td>
<td>3,082</td>
<td>29,736</td>
<td>6,429</td>
<td>17,336</td>
<td>32,818</td>
</tr>
<tr>
<td>Share pass. trips</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>47.0%</td>
<td>53.0%</td>
</tr>
<tr>
<td>Freight</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local</td>
<td>3,232</td>
<td>669</td>
<td>11,460</td>
<td>2,373</td>
<td>3,901</td>
<td>12,129</td>
</tr>
<tr>
<td>Transit</td>
<td>1,592</td>
<td>330</td>
<td>5,644</td>
<td>1,169</td>
<td>1,922</td>
<td>5,974</td>
</tr>
<tr>
<td>Share freight trips</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22.0%</td>
<td>78.0%</td>
</tr>
</tbody>
</table>


Parameters of utility functions

Passenger transport is described by a three-level decision tree with the following nested choices:

1. to cross the river or spend income on other goods
2. to cross the river in the peak or in the off-peak period
3. to take the OLD tunnel or the NEW tunnel
For freight transport the top-level choice is between transporting goods across the river and delivering the product or service to consumers using other inputs. The other two choice levels are the same as for passenger transport. Table A2 lists the elasticities of substitution at each choice level for passenger and freight transport.

Table A2: Elasticities of substitution.

<table>
<thead>
<tr>
<th>Category</th>
<th>Trip type</th>
<th>Transport &amp; other goods</th>
<th>Peak &amp; off-peak</th>
<th>OLD &amp; NEW during peak</th>
<th>OLD &amp; NEW during off-peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passengers</td>
<td>Work</td>
<td>1.2</td>
<td>0.8</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>1.2</td>
<td>1.5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Freight</td>
<td>Local</td>
<td>1.2</td>
<td>0.9</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Transit</td>
<td>1.2</td>
<td>0.9</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>


Travel time-flow

The travel time-flow function for each tunnel is assumed to be linear in traffic flow. To calibrate the function for the OLD tunnel, current speed and traffic flow counts on the ring road were used. The function for the NEW tunnel was calibrated using the forecasted results.

Speed data

The average distance traveled on the ring road for vehicles using the OLD (Kennedy) tunnel or NEW tunnel is 14 km. Average speed is assumed to be 60 km/h in peak, and 85 km/h during the off peak. If the NEW tunnel is built, average speed during the peak is expected to be 100 km/h for both the OLD and NEW tunnel routes and off-peak speeds are expected to be close to free-flow speeds (120 km/h).

Value of time

Values of travel time are reported in Table A3; they are assumed to be the same during the peak and the off-peak.

Table A3: Values of time (€/h).

<table>
<thead>
<tr>
<th>Category</th>
<th>Trip type</th>
<th>Value of time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passengers</td>
<td>Work</td>
<td>21.6</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>4.3</td>
</tr>
<tr>
<td>Freight</td>
<td>Local</td>
<td>46.2</td>
</tr>
<tr>
<td></td>
<td>Transit</td>
<td>46.2</td>
</tr>
</tbody>
</table>

Source: UNITE (Nelthrop e.a., 2001).

Infrastructure costs and external costs of traffic

The cost of building the NEW tunnel (“Oosterweel” connection) is estimated to be €1.2 billion (http://www.werkenantwerpen.be/BAM/corporate.aspx). To calculate the salvage value of capacity in 2020 we used a simple annuity technique in which the present value in 2020 is equal to the discounted sum of a constant annuity for the remaining years of the technical lifetime.
Variable operating, maintenance and external costs of the NEW tunnel are listed in Table A4.

Table A4: Operator and infrastructure manager costs & external costs.

<table>
<thead>
<tr>
<th></th>
<th>Peak</th>
<th>Off-peak</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NEW</td>
<td>OLD</td>
</tr>
<tr>
<td><strong>Variable operating cost [€/veh]</strong></td>
<td>Pass. veh</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Freight veh</td>
<td>0</td>
</tr>
<tr>
<td><strong>Variable infrastructure charge [€/veh]</strong></td>
<td>Pass. veh</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Freight veh</td>
<td>0</td>
</tr>
<tr>
<td><strong>Maintenance [€/veh]</strong></td>
<td>Pass. veh</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Freight veh</td>
<td>3.8</td>
</tr>
<tr>
<td><strong>External cost [€/vkm]</strong></td>
<td>Pass. veh</td>
<td>0.046</td>
</tr>
<tr>
<td></td>
<td>Freight veh</td>
<td>0.124</td>
</tr>
</tbody>
</table>


Users costs and existing taxes

Table A5 reports the resource costs (fuel, vehicle depreciation and insurance costs) and tax costs incurred by users per vehicle kilometre.

Table A5: Monetary costs borne by users.

<table>
<thead>
<tr>
<th></th>
<th>Passenger vehicles</th>
<th>Freight vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Work</td>
<td>Other</td>
</tr>
<tr>
<td><strong>Resource cost [€/vkm]</strong></td>
<td>NEW</td>
<td>0.134</td>
</tr>
<tr>
<td></td>
<td>OLD</td>
<td>0.134</td>
</tr>
<tr>
<td><strong>National tax [€/vkm]</strong></td>
<td>NEW</td>
<td>0.073</td>
</tr>
<tr>
<td></td>
<td>OLD</td>
<td>0.073</td>
</tr>
<tr>
<td><strong>Regional tax [€/vkm]</strong></td>
<td>NEW</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>OLD</td>
<td>0.014</td>
</tr>
</tbody>
</table>

Source: G. De Ceuster (2003).

Other parameters

The marginal cost of public funds is set equal to 1 so that no premium is attached in the welfare calculations to revenues collected by government from tolls and other user charges. In Regime 4, where the NEW tunnel is operated and managed by a private operator, the national government taxes profits at a rate of 35%. Profits are assumed to be allocated to the various user groups in proportion to the numbers of trips taken.

To calibrate the nested CES functions, the share of household income devoted to passenger transport was set at 20%, and the share of transport expenditures in total production costs was set at 10%.
Behavioural responses to road pricing.
Empirical results from a survey
among Dutch car owners

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Abstract

This paper presents the results from a questionnaire among Dutch car owners. We have analysed the
behavioural responses to three different, policy relevant, road pricing measures. Depending on the type of
measure and type of trip affected, we find reductions in the number of car trips of, on average, 11%. A flat
kilometre charge affects social trips considerably more than commuting trips. However, when policy
makers want to affect peak time (commuting) traffic, a time differentiated measure is more appropriate.
Slow traffic and trip suppression are most popular alternatives for non-commuting trips. Departure time
changes become very attractive for all purposes when the proposed measure varies over time.

Keywords: Road pricing; Behavioural response; Traffic reduction.

1. Introduction

People’s responses to transport pricing are not straightforward. Price increases may not
necessarily lead to trip suppression, it may also induce travellers to change their modal
use or change their departure time, depending on the type of measure. A wide variety of
transport pricing measures exists, having different consequences for travel behaviour.
Price measures are considered as one of the major tools for policy-makers to influence
transport development. The design of measures will generally depend on the objectives
set by the government. It is therefore important for authorities to have clear insight into

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the responses induced by transport pricing. This response will to a considerable extent depend on the exact design of the pricing scheme (e.g. a yearly tax on car ownership can be expected to affect kilometrage of a given vehicle relatively weakly, compared to a kilometre charge). Equally important, however, is the price sensitivity (often expressed as elasticities by economists) of transport users for the various relevant types of behaviour that together define transport behaviour. People have various possibilities to change transport behaviour, and can be expected to react differently to different pricing schemes. This paper presents the empirical results from a survey among Dutch car owners towards the behavioural effects of various, policy relevant (at least for the Dutch situation), road pricing measures. Three different type of measures have been evaluated by the respondents. We will analyse the short term behavioural responses in terms of sensitivity and type of change for three different trip purposes.

This paper is organised as follows. Section 2 discusses possible behavioural responses to transport pricing and it gives a brief overview of previous literature results. Section 3 explains the structure of the questionnaire and the type of price measures that have been evaluated by the respondents. Section 4 presents the effectiveness outcomes in terms of car trips that will be replaced by the respondents (including how these trips will be changed). Section 5 concludes.

2. Road transport pricing and behavioural responses

Governments have many different options to intervene in the transport market. Road pricing is one of the possibilities. Current widely implemented price measures in road transport include a tax on vehicle ownership (either at purchase or on an annual basis), parking fees and fuel taxes. Alternative pricing measures include distance related taxes (e.g. a kilometre charge) or particular emission based charges. Also the opposite of charging, viz. subsidising, is a price instrument. Public transport subsidies are for instance often seen as a useful second-best policy in cases where private road transport for some reason cannot be, or is not priced.

Transport users will respond differently to various pricing policies. The possible outcomes (in terms of behavioural responses) of pricing can be the following:

- trip suppression (travel frequency choice);
- departure time choice (and scheduling of daily activities);
- different route choice;
- changes in modal split;
- changes in vehicle occupancy;
- spatial choices related to re-location;
- change in driving style (e.g. speed choice);
- vehicle ownership;
- technology choice;
- changes in destination choice;
- class choice (for public transport).
Depending on the desired aim, policy makers may now decide to make use of a particular price instrument that is likely to steer travel behaviour in a more desired direction. However, it should not be forgotten that the real effect of a price change depends on various factors which makes the effect predictability of a certain measure rather difficult. Factors affecting price sensitivity include among others (VTPI, 2002):

- Type of price change: the different types of pricing measures can have different impacts on travel behaviour.
- Type of trip and traveller: commute trips tend to be less elastic than shopping or recreational trips.
- Quality and price of alternative routes, modes and destinations: price sensitivity tends to increase if alternative routes, modes and destinations are of good quality and affordable. For example, road users tend to be more price sensitive if there is a parallel untolled roadway.
- Time period: transportation elasticities tend to increase over time as consumers have more opportunities to take prices into effect when making long-term decisions (Oum et al., 1997). Dargay and Gately (1997) conclude that about 30% of the response to a price change takes place within 1 year, and that virtually all takes place within 13 years.
- Large and cumulative price changes: extra care should be used when calculating the impacts of large price changes, or when summing the effects of multiple changes, because each subsequent change impacts a different base.

In the next subsection we will briefly discuss some results from the transport economic literature on the behavioural responses to transport pricing (this draws on previous work carried out within the MD-PIT project, see Ubbels and Verhoef, 2003). We pay specific attention to work that analysed the effects of variabilisation in the Netherlands, because we will evaluate similar types of measures for the same country. Variabilisation refers to the situation where present car taxation(independent of car use) is replaced by a kilometre charge.

2.1 Previous literature

A substantial body of empirical economic literature analyses the effects of pricing measures on particular types of behaviour and reports elasticities (a measure of responsiveness of demand to a change in price). But not only own demand responsiveness can be captured by elasticities, also the use of other modes by changing a particular price can be measured (i.e. cross-price elasticities). Although it is possible to derive elasticities from empirical data (e.g., a before-and-after study of an infrastructure project), normally models are used to derive elasticities. Different types of empirical data are used to derive elasticities. Stated preference data give the reactions as stated by the respondents (e.g. travellers), when confronted with hypothetical alternatives. Revealed preference is based on choices actually made appearing from observed behaviour.

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1 The price elasticity of demand is defined as the percentage change in the quantity demanded divided by the percentage change in price (Stiglitz and Driffill, 2000).
A wide variety of estimates of price elasticities have appeared in economic literature. Among the most widely studied elasticities in transport is the fuel price elasticity. Most estimates of the price elasticity of gasoline consumption are in the range between -0.27 (short run) and -0.71 (long run) (see for an overview Oum and others, 1997 and Goodwin, 1992). Elasticities with respect to vehicle kilometre charges, interesting in the context of this study, are less often reported. There are only a few recent studies which consider the impact of kilometre charges on car use. The European Commission has carried out a major survey on road pricing elasticities (European Commission, 1996). The estimated elasticities consider the effect of road pricing on car use, modal split and route choice. The effects on car use depend on the purpose of the trip: shopping and social trips have the highest, commuter trips the lowest elasticities. The cross-price elasticities range from 0.05 to 0.4 and depend on the transport mode considered (rail or metro) and on the level of charge applied. Geurs and Van Wee (1997) report the results of a variable costs elasticity by using the FACTS model. The effects on car use of a kilometre charge have been simulated by increasing the variable maintenance costs with €cent 5 per kilometre (on a default of €cent 0.5 to 1.5). This results in an elasticity of around –0.20.

Empirical results have been analysed to derive revealed effects and behavioural responses to road pricing in practice (of which effects can also be expressed in elasticities). Despite the fact that road pricing is only rarely implemented, the experiences so far show interesting results. Singapore and Orange County, for instance, are interesting and valuable examples of situations where road pricing is actually implemented. It appears that the effects depend very much on local situations (e.g. public transport availability) and the charging scheme at hand. Road pricing in Singapore, aimed at reducing peak period congestion, was first implemented in 1975 in the form of the Area Licensing Scheme (ALS) and upgraded in 1998 to Electronic Road Pricing (ERP). A method of shoulder pricing is used, which involves increasing the rate in steps every half an hour before the peak and decreasing it after the peak (with charges depending on vehicle type). It appears that traffic is quite sensitive to the road pricing system even though the charges are relatively low, the maximum rate for cars on expressways and to enter the restricted zone is comparable to a 1-hour parking fee in the city (about €1.50) (Olszewiski and Xie, 2005). The elasticity values shown in Table 1 indicate that time of driving will change with time dependent charges. Evening peak traffic flows show the highest demand sensitivity, with an elasticity of -0.32 for cars. The low figures for the morning peak can be explained by arrival time restrictions for commuters, whereas trips to home in the evening can be postponed to avoid the high peak charge.

Table 1: Elasticity of traffic entering the restricted zone by time interval.

<table>
<thead>
<tr>
<th>Time period</th>
<th>Cars</th>
<th>Other vehicles (motorcycles, taxis, LGV's, HGV's, buses)</th>
<th>All vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:30-9:30</td>
<td>-0.106</td>
<td>-0.019</td>
<td>-0.069</td>
</tr>
<tr>
<td>9:30-15:00</td>
<td>-0.082</td>
<td>-0.080</td>
<td>-0.083</td>
</tr>
<tr>
<td>15:30-17:30</td>
<td>-0.123</td>
<td>-0.151</td>
<td>-0.143</td>
</tr>
<tr>
<td>17:30-19:00</td>
<td>-0.324</td>
<td>-0.189</td>
<td>-0.265</td>
</tr>
<tr>
<td>7:30-19:00</td>
<td>-0.123</td>
<td>-0.106</td>
<td>-0.118</td>
</tr>
</tbody>
</table>

Source: Olszewski and Xie (2005).
The toll charge levied by Orange County depends on the vehicle occupancy and on the level of congestion on the free lanes next to the toll lane. It appeared that the traveller’s decision to use the toll lanes is very closely related to hour-by-hour variations in traffic conditions. Results show that a marginal increase in the peak period tariff on the toll facility has only little effect on (increased) travel demand in shoulder peak periods, only very large price changes would induce considerable effects. Moreover, only a few drivers decide to car-pool.

2.1.1 Variabilisation studies in the Netherlands

Since we study the effects of different types of kilometre charges (including measures where revenues are used to compensate for abolition of fixed car taxes), it is interesting to discuss results from so-called variabilisation studies. A few studies have been completed on this issue in the Netherlands, initiated by the increasing policy interest for a kilometre charge.

One of the first studies towards the mobility effects of variabilisation was conducted by MuConsult in 1998 (MuConsult, 1998). A model was used to study the effects of different kilometre charges with the restriction that the revenues for the government remain constant (fixed car taxation was lowered accordingly or abolished). They show that, depending on the level of the charge, implementation may lead to a considerable reduction in total kilometres driven. A kilometre charge of 7 €ct, for instance, leads to a total reduction of 19%. Business traffic is least affected in this scenario (7%), whereas social traffic (23%) and commuting traffic (19%) are most sensitive. Most of these car kilometres is replaced by bicycle use and car-pooling. Effects are less strong when the charge is lower. A charge of 3 €ct is estimated to decrease commuting traffic with 5% and social traffic with 8%. A remarkable prediction of this study is the decrease in car ownership for all scenarios considered; apparently the effect of the increase in the variable charge dominates the effect of lower ownership costs.

A stated preference survey among car owners as well as non-car owners reported in MuConsult (2002) has also analysed the behavioral responses to different types of a kilometre charge with abolition of fixed taxes. We will here discuss their predicted effects of the replacement of the Dutch car ownership tax (the so-called MRB) only, and both the MRB and the tax on car purchase (the so-called BPM). The charges were differentiated according to fuel type, the MRB-only scenario included a charge of 2.4 €ct per kilometre for petrol using cars (with slightly higher charges for cars running on diesel and gas), whereas the MRB+BPM scenario contained a charge of 4.9 €ct (equal levels for other fuel types). In contrast to the earlier MuConsult study, this study predicts an increase in car ownership levels for all alternatives considered. The car stock is assumed to show a stronger growth under the MRB-only scenario compared to the MRB+BPM scenario (2.8% vs. 1.2%). The higher charges in this latter scenario induce relatively more car owners (4.6% vs. 1.3%) to sell their car. The effect on the second-hand market where prices may go down on the car stock has not been included. The results in terms of kilometres indicate a small reduction for the MRB-only scenario of about 0.9% and a somewhat larger effect of 3.4% for the other scenario. These effects include a decrease in kilometres by car owners and an increase of kilometres driven by respondents that
indicate to purchase a new car (estimated around 2% for both scenarios). Especially social, shopping and recreational trips will be adjusted, whereas business traffic and kilometres driven for school or educational purposes remain almost unchanged. Commuting trips will be adjusted (about 30%), but less often than the social and shopping trips.

Recently (initiated by a request from the Dutch Minister to search for a new, widely approved, pricing regime), the traffic effects of various road pricing alternatives have once more been investigated using the LMS (Landelijk Model Systeem, a network model developed to forecast traffic flows for the Netherlands) model (Adviesdienst Verkeer en Vervoer, 2005). Among the ten different alternatives that have been evaluated, there were four variabilisation measures. When all fixed taxes (MRB and BPM) are replaced by a kilometre charge (with budget neutrality for the government), the model predicts a decrease in car use (in terms of kilometres) of 11% (compared with the reference situation in 2020). The average charge per kilometre causing these effects was about 5.7 €ct, and depended on fuel type and weight of the car. The level of congestion in 2020 is assumed to be reduced with 40% (in terms of vehicle hours lost). People will change mode (use of train, bus/metro and slow transport increases in terms of kilometres with about 6%) and especially social traffic (29%, in terms of car driven kilometres) and, to a lesser extent, commuting (9%) will be reduced.

Another considered alternative included variabilisation of all car ownership taxes and one quarter of the car purchase taxes. The average kilometre charge is consequently lower (3.4 €ct) than the previous measure, but an additional charge of 0.11 €ct was levied on locations and times with severe congestion. The LMS model outcomes suggest that growth of congestion will be reduced with about 45%. Trip distances will decrease. This effect is limited for commuting trips but larger for social trips. Business traffic (6%) and freight traffic (1%) is predicted to increase, but total traffic demand will decrease (with 10%) due to considerably less commuting (16%) and social kilometres (25%).

The modelling studies predict larger effects on car use than the stated preference study of MuConsult (2002). However, comparing these studies is not straightforward due to differences in the types of measures (e.g. differentiation according to weight versus fuel type) that have been evaluated and underlying assumptions (e.g. the LMS model does not include car ownership effects). Charge levels in the modelling studies have been on average somewhat higher than in the MuConsult 2002 stated preference study, which may be one explanation for the larger effects.

3. Data collection and survey description

3.1 Data collection

The data have been obtained through an (interactive) internet survey among Dutch car owners. The total sample consists of 562 respondents, half of which are car commuters
facing congestion on a regular basis, investigated in an earlier questionnaire. These respondents were confronted with three different road pricing measures, and we asked them if and how they expect to change their behaviour when facing these measures. The focus is on the short term responses: the more long term decision of car ownership and car change have been included in the survey, but these will not be discussed in this contribution. The actual data collection was carried out by a specialised firm (NIPO), which has a panel of over 50,000 respondents. The data were collected during three weeks in February 2005.

3.2 Survey

Three different pricing measures will be considered, each in multiple variants. Table 2 shows the various measures that have been developed: 6 different alternatives for measure 1, 2 alternatives for measure 2, and again 6 alternatives of the third measure (a more detailed description of these measures can be found in Appendix 2). The alternatives were divided randomly over the respondents, and each respondent evaluated one alternative of each measure (so three in total). As a result, we obtained at least 88 observations for each alternative of measure 1 (see also Table 4), 282 for measure 2A and 280 for measure 2B, and again about 95 for each alternative of measure 3 (see also Table 8 in Section 4.3).

Table 2: Short description of the road pricing measures presented to the respondents.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Variant</th>
</tr>
</thead>
</table>
| 1: Flat kilometre charge with different charge levels and different revenue use | A: 3 €cent, abolition of car ownership taxes  
B: 6 €cent, abolition of existing car taxation (purchase and ownership)  
C: 12 €cent, abolition of existing car taxation and investment in new roads  
D: 3 €cent, revenues used to lower income taxes  
E: 6 €cent, revenues used to lower income taxes  
F: 12 €cent, revenues used to lower income taxes |
| 2: Differentiated kilometre charge with different charge levels and different revenue use | A: 2 €cent with multistep (morning and evening) peak time toll on bottlenecks, revenues used to abolish car ownership taxes  
B: differentiated according to weight of the car, revenues used to abolish existing car taxation |
| 3: Crude peak/off-peak kilometre charge with different charge levels and different revenue use | A: 2 €cent outside peak times and 6 €cent in peak, abolition of car ownership taxes  
B: 4 €cent outside peak times and 12 €cent in peak, abolition of existing car taxation  
C: 8 €cent outside peak times and 24 €cent in peak, abolition of existing car taxation and new roads  
D: 2 €cent outside peak times and 6 €cent in peak, revenues used to lower income taxes  
E: 4 €cent outside peak times and 12 €cent in peak, revenues used to lower income taxes  
F: 8 €cent outside peak times and 24 €cent in peak, revenues used to lower income taxes |

All descriptions of the measures, as shown to respondents, consisted of two major components: we explain both the structure and level of the charge, and the allocation of the revenues. Furthermore, we provided each respondent individually with an estimation

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2 These respondents have been selected from the first MD-PIT questionnaire of which the results are presented in earlier work (Ubbels and Verhoef, 2005). Note that this first survey was ‘over sampled’ in the lower income groups so as to obtain a sufficient number of observations.
of the financial consequences of the implementation of the proposed measure (on the basis of self-reported current travel behaviour and car ownership for unchanged behaviour). This estimation depends on the charge level (costs) and on the type of revenue use (benefits). Information on the annual number of kilometres driven, and for some measures also on the type of vehicle (measure 2B) and time of driving (measures 2A and 3) is the input for the cost estimation based on present behaviour. The financial benefits shown to the respondent depend on the type of revenue use. Because it was impossible to give respondents a personal estimation of the financial benefits involved with a recycling via lower income taxation, we only presented the savings for those measures where existing car taxes are abolished. We explained also some practical issues that were meant to prevent various practical considerations from affecting the response: the privacy of car users is guaranteed, electronic equipment registers the toll and the driver can choose freely the payment method (e.g. credit card, bank transfer etc.).

Concerning the representativeness of our sample, we make the following remarks. All respondents own a car, which is used for different trip purposes. This is not necessarily commuting because not all respondents have a job (17.6% is not employed). The educational level of our sample seems relatively high. About 29% of the Dutch car owners has a bachelor or masters degree (based on own calculations of CBS data for 2003), this share is considerably higher in our survey (40%). CBS statistical data also suggests that car ownership increases with income. About 20% of the car owners in this sample has an income below €28,500 (with 9% having no income). Younger people seem to be overrepresented in our survey. About 30% of the car owners in the Netherlands is older than 55, while this share is only 16% in this survey. Most of the respondents are located in the Randstad area (rest west and large cities), the northern part of the Netherlands is only modest represented with 6.4%.

After a concise description of each measure, the respondents were asked whether they would change the number of car trips for three different trip purposes (only in those cases that the respondent indicates that he/she actually makes this type of trip):

- commuting trips (made at least sometimes by 70.7% of the respondents);
- trips to visit people (made at least sometimes by 80.8% of the respondents);
- other type of trips (e.g. shopping, sports activities etc., made at least sometimes by 92.7% of the respondents).

Commuting trips are only made by 70% of the respondents, but the intensity of these trips during a week is relatively higher.

If respondents indicate that they indeed expect to adjust their travel behaviour, they were next asked to indicate the share of trips that will be changed, and also how these will be changed. Depending on the type of measure (it makes little sense to ask whether

3 The benefits from paying less car taxation depend on the type of car the respondents own (i.e., on fuel type and weight). We have estimated averages for nine categories (a combination of three fuel types and three weight categories), for an abolition of annual car ownership taxes (MRB) only and an abolition of all existing car taxation, namely MRB and the fixed purchase tax (BPM).

4 It is possible that people indicate to make more car trips, in that case we only asked how many extra trips this person would make.
respondents will change departure time when a flat kilometre charge is presented), various possibilities were presented:

− public transport;
− slow transport (walking, bicycle);
− motorised private transport (motorbike, motor);
− carpool (only asked for commuting trips);
− work at home (only asked for commuting trips);
− travel at other times (only when measure is time dependent)\(^5\);
− give up the trip.

In order to analyse the behavioural responses to the proposed pricing measure in a quantitative way, we asked the respondents to indicate for each purpose how many trips they make in a normal week. Because some type of trips are only made once a week, we have asked the respondents to indicate how many trips they will change in a period of 4 weeks (with presenting their total number of trips made for each purpose (4 times the number of trips in a week)). Hence, a respondent indicating that he/she makes 5 commuting trips a week can change 20 trips at most. Next it was asked how these trips will be changed. Respondents could not continue with the survey when the total number of trips to be changed was unequal to the sum of numbers allocated to different alternatives.

Stated preference studies like this one may suffer from various biases, e.g. due to the hypothetical nature of the questions or due to strategic answering. By asking people to indicate very precisely how a certain expected change in total trips was to be accomplished, we hope to have minimised the hypothetical bias as much as reasonable possible. The strategic bias may result in people understating their willingness to change trips, when hoping that ineffectiveness may reduce the chance of the policy to be implemented. Because road pricing was not under public debate at the moment the questionnaire was held, we have good hopes that the strategic bias is not too large.

4. Effectiveness of different pricing regimes

The aim of this survey is to analyse the behavioural responses to realistic and policy relevant road pricing measures\(^6\). This section focuses on the sensitivity and type of effect of the short term responses to three different road pricing measures presented to the respondents for three different trip purposes (i.e. commuting, social traffic (visits) and other (e.g. shopping)). We have information on the behavioural responses in terms of number of trips that an individual will adjust, and how these will be adjusted. Since we also have an individual estimation of the yearly number of kilometres driven for each trip

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\(^5\) Departure time changes have been extensively analysed in an earlier phase of MD-PIT (results obtained from a stated choice experiment).

\(^6\) At this moment policy makers in the Netherlands are seriously considering the implementation of a kilometre charge that replaces current car taxation.
purpose, it is also possible to express changes in terms of kilometres. Information on both outcomes will be presented below.

4.1 Measure 1: kilometre charge (3, 6 and 12 €ct) and different revenue use

The numbers of respondents that indicated they would adjust their car trips when measure 1 becomes reality were 42 (11% of the total number of respondents that makes commuting trips) for commuting, 111 (27%) for visits and 111 (23%) for other trip purposes. After weighting these adjustments by numbers of trips made and by the length of these trips, we can transform these figures into changes in numbers of trips and kilometres. Table 3 shows the aggregated outcomes for all alternatives together; Appendix 2 gives the detailed results for each measure separately.

The numbers vary considerably over the various trip purposes. The proposed kilometre charge is relatively most effective for trips made to visit people, and least effective for commuting trips. This may be explained by the fact that a trip suppression is no serious alternative for commuting trips (only 0.5% of trips to be adjusted will not be made anymore), whereas for other reasons people seriously consider the alternative of not making the trip. Popular alternatives (for all purposes) for car trips include slow transport and public transport. Cycling and walking are in particular an alternative for visits and other trips, apparently these trips are often of short distance. The effectiveness in terms of adjusted number of kilometres is smaller than for numbers of trips, probably people driving relatively less adjust their behaviour.

Table 3: Aggregated outcomes of behavioural responses to measure 1: flat kilometre charge.

<table>
<thead>
<tr>
<th></th>
<th>Commuting</th>
<th>Visits</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total number of trips (driven in 4 weeks)</strong></td>
<td>6800</td>
<td>3620</td>
<td>7780</td>
</tr>
<tr>
<td><strong>Number of trips adjusted</strong></td>
<td>400 (5.9%)</td>
<td>513 (14.2%)</td>
<td>846 (10.9%)</td>
</tr>
<tr>
<td>Of which:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public transport</td>
<td>31.8%</td>
<td>17.8%</td>
<td>13.3%</td>
</tr>
<tr>
<td>Slow traffic</td>
<td>32.2%</td>
<td>44.6%</td>
<td>64.9%</td>
</tr>
<tr>
<td>Motorised</td>
<td>9.5%</td>
<td>8.9%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Carpool</td>
<td>19.5%</td>
<td>not relevant</td>
<td>not relevant</td>
</tr>
<tr>
<td>Working at home</td>
<td>6.5%</td>
<td>not relevant</td>
<td>not relevant</td>
</tr>
<tr>
<td>Not making trip</td>
<td>0.5%</td>
<td>28.6%</td>
<td>19.9%</td>
</tr>
<tr>
<td><strong>Number of kilometres adjusted</strong></td>
<td>3.9%</td>
<td>11.6%</td>
<td>9.2%</td>
</tr>
</tbody>
</table>

It is also interesting to consider the relative effectiveness of the various alternatives of measure 1. As expected, a kilometre charge of 12 €ct tends to have more effect than a similar measure with lower charges. Table 4 shows the impact of each alternative for the various purposes. Some results are different than expected: a measure with a higher charge is not always more effective. For instance, measure 1D (with a charge of 3 €ct) seems slightly more effective than measure 1E (6 €ct) for particular trip purposes. Measure 1F induces the strongest trip changes. Alternatives A, B, and C are variabilisation measures, these seem to be less effective than the measures where
revenues are used to lower income taxes. The data do not allow us to identify the reason for this difference, but we can speculate. One possible explanation is that we could not inform the respondents on how much they would receive due to the lowered labour tax, while we could make an estimate for the vehicle taxes. If respondents were pessimistic on the net benefit from reduced labour taxes, a perceived stronger income effect might explain the stronger effectiveness. But respondents might also have been less rational. Perhaps they work, implicitly, with predetermined budget allocations over broader groups of consumer products. If so, they may not have realised that they could allocate all benefits from reduced labour taxes to the mobility budget. This is not a very satisfactory explanation, but we can simply not exclude the possibility of irrational responses from at least some of our respondents. As stated, we can only hypothesise about the true reason for this surprising result.

Table 4: Effectiveness related to the alternatives of measure 1.

<table>
<thead>
<tr>
<th>Measure</th>
<th>% of total trips adjusted</th>
<th>Number of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1A (3 €ct/MRB)</td>
<td></td>
<td>96</td>
</tr>
<tr>
<td>1B (6 €ct/MRB+BPM)</td>
<td></td>
<td>94</td>
</tr>
<tr>
<td>1C (12 €ct/MRB+BPM+new roads)</td>
<td></td>
<td>88</td>
</tr>
<tr>
<td>1D (3 €ct/income taxes)</td>
<td></td>
<td>101</td>
</tr>
<tr>
<td>1E (6 €ct/income taxes)</td>
<td></td>
<td>91</td>
</tr>
<tr>
<td>1F (12 €ct/income taxes)</td>
<td></td>
<td>92</td>
</tr>
</tbody>
</table>

4.2 Measure 2: kilometre charge with multistep bottleneck toll (2A) and kilometre charge differentiated according to weight of the vehicle (2B)

The second measure consists of two (very) different alternatives that have in common that the charge is strongly differentiated. The first alternative is a peak period charge combined with a flat kilometre fee, while the measure 2B is differentiated according to weight of the vehicle.

Table 5 shows the behavioural responses for both alternatives separately. Compared to measure 1, we see that one type of response has been added: travel at other times. Because only measure 2A is differentiated according to time, this type of behavioural response is only relevant for that alternative. Changing travel time is very attractive for all trip purposes; people prefer car use at other times over public transport and slow traffic, especially for commuting trips. The respondents will try to avoid the bottlenecks at certain times and are less inclined to give up trips for social or other purposes (relatively to alternative 2B). Note that this alternative has a fine differentiation compared with measure 3, and only applies to certain (bottleneck) locations. Measure 2B seems relatively less effective for commuting trips, only 4% of the total number of commuting trips will be changed. Table 6 confirms this. It shows that measure 2A is responsible for almost three quarter of the adjusted commuting trips. Finally, it appears that slow traffic is an attractive alternative especially for social purposes. These trips probably often have nearby destinations.
Table 5: Behavioural responses to measure 2.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Measure 2A</th>
<th>Measure 2B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trip purpose</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number</td>
<td>3188</td>
<td>1824</td>
</tr>
<tr>
<td>of trips (driven</td>
<td>3892</td>
<td>3612</td>
</tr>
<tr>
<td>in 4 weeks)</td>
<td>1796</td>
<td>3888</td>
</tr>
<tr>
<td>Trips adjusted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(% total)</td>
<td>358 (11.2%)</td>
<td>166 (9.1%)</td>
</tr>
<tr>
<td>Of which:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public transport</td>
<td>22.3%</td>
<td>16.9%</td>
</tr>
<tr>
<td>Slow traffic</td>
<td>8.9%</td>
<td>29.5%</td>
</tr>
<tr>
<td>Motorised</td>
<td>2.5%</td>
<td>29.5%</td>
</tr>
<tr>
<td>Carpooling</td>
<td>1.4%</td>
<td>1.7%</td>
</tr>
<tr>
<td>Travel at other</td>
<td>1.4%</td>
<td>1.7%</td>
</tr>
<tr>
<td>times</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working at home</td>
<td>10.6%</td>
<td>NR</td>
</tr>
<tr>
<td>Not making the</td>
<td>0.3%</td>
<td>10.2%</td>
</tr>
<tr>
<td>trip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kilometres</td>
<td>11.3%</td>
<td>10.3%</td>
</tr>
<tr>
<td>adjusted</td>
<td></td>
<td>8.2%</td>
</tr>
</tbody>
</table>

NR = not relevant, measure may not be differentiated according to time (2B) or alternative is not relevant for trip purpose.

Table 6: Effectiveness related to the alternatives of measure 2.

| Measure                        | Number of respondents | % of total trips adjusted |
|------                          |                       |                          |
| 2A: multistep bottleneck toll | 282                    | 71.2                     |
| 2B: km charge weight vehicle  | 280                    | 28.8                     |

4.3 Measure 3: peak and off peak kilometre charge with different revenue use

The third measure is a kilometre charge differentiated crudely according to time (peak and off peak only) with different revenue use allocations. Compared to the previous measures, this measure is, in terms of total number adjusted trips (for all purposes), most effective (14.1% versus 9.7% (measure 1) and 7.6% (measure 2). This measure has relatively more impact on commuting trips. The number of trips commuting changed is 1004 (about 15% of the total trips made for commuting reasons), considerably more than 400 (measure 1) and 503 (measure 2). Almost half of the trips that will be adjusted, will be replaced by trips made off-peak (see Table 7, and Appendix 2 for the disaggregated results). Slow traffic is also an attractive alternative, but again only for the non-commuting purposes. The motor or motorbike is not a serious alternative for the respondents, the same holds for carpooling.

The pattern shown in Table 8 is somewhat different from what could be expected. This measure combines different charge levels with different types of revenue use. Alternative C and F have the highest charges, considerably higher than A and D. The estimated benefits of revenue use for alternatives A to C have been presented to the respondents, this has not been done for the alternatives where revenues are used to lower income taxes (D to F). Since higher charges tend to have more effect, alternative C and F may be expected to have more effect than the other alternatives, and B and E again more than A.
and D. This is not entirely true. Measure 3B, for instance, is considerably less effective than measure 3A for all purposes. The amount of compensation is larger for measure 3B (not only MRB, but also BPM is abolished), but we explained that for both measures the government does not obtain extra revenues (revenue neutrality). A similar pattern is found for measure 3E (compared with 3D), but in this case allocation of revenues was unchanged. Most remarkable is that alternatives with the lowest charge levels (A and D) are even more effective than alternative C and F for certain purposes. The findings for the impact of revenue use (abolition of car taxation vs. income tax reductions) are for most trip purposes equal to the results for measure 1: variabilisation is said to be less effective. Only the outcomes found for measure 3C (visits) and 3A (other purposes) are different in this context, revenues hypothesised to reduce car taxation dominates income tax compensation in terms of effectiveness.

Table 7: Aggregated outcomes of behavioural responses to measure 3: peak and off peak kilometre charge.

<table>
<thead>
<tr>
<th>Total number of trips (driven in 4 weeks)</th>
<th>Commuting</th>
<th>Visits</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trips adjusted</td>
<td>6800</td>
<td>3620</td>
<td>7780</td>
</tr>
<tr>
<td>Of which:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public transport</td>
<td>930 (15%)</td>
<td>529 (14.6%)</td>
<td>1028 (13.2%)</td>
</tr>
<tr>
<td>Slow traffic</td>
<td>17.6%</td>
<td>13.6%</td>
<td>14.1%</td>
</tr>
<tr>
<td>Motorised</td>
<td>12.7%</td>
<td>28%</td>
<td>28.9%</td>
</tr>
<tr>
<td>Carpool</td>
<td>8.8%</td>
<td>1.7%</td>
<td>1.5%</td>
</tr>
<tr>
<td>Travel at other times</td>
<td>4.5%</td>
<td>not relevant</td>
<td>not relevant</td>
</tr>
<tr>
<td>Working at home</td>
<td>47.7%</td>
<td>47.8%</td>
<td>47.3%</td>
</tr>
<tr>
<td>Not making trip</td>
<td>7.9%</td>
<td>not relevant</td>
<td>not relevant</td>
</tr>
<tr>
<td>Number of kilometers adjusted</td>
<td>14.6%</td>
<td>13.2%</td>
<td>11.2%</td>
</tr>
</tbody>
</table>

When we look at the effects of the measure for trip purposes, it seems that measure 3C has more effect on social visiting trips than for the other purposes. The reverse holds for the same purpose for measure 3F. Measure 3D tends to be less effective for other trips, while on the other hand measure 3A seems most effective for this type of trips. There seems not much of a difference over trip purposes for the other measures.

Table 8: Effectiveness related to the alternatives of measure 3.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Number of respondents</th>
<th>% of total trips adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>3A: 2/6 €cent (off-peak/peak), MRB</td>
<td>96</td>
<td>16.0</td>
</tr>
<tr>
<td>3B: 4/12 €cent, MRB+BPM</td>
<td>91</td>
<td>13.8</td>
</tr>
<tr>
<td>3C: 8/24 €cent, car taxation and new roads</td>
<td>97</td>
<td>15.8</td>
</tr>
<tr>
<td>3D: 2/6 €cent, income taxes</td>
<td>96</td>
<td>19.0</td>
</tr>
<tr>
<td>3E: 4/12 €cent, income taxes</td>
<td>94</td>
<td>13.9</td>
</tr>
<tr>
<td>3F: 8/24 €cent, income taxes</td>
<td>88</td>
<td>21.3</td>
</tr>
</tbody>
</table>
5. Concluding remarks

The results indicate that road pricing may have considerable effects, much depends on the design of the measure. In terms of trips adjusted, the effectiveness of the measures is in the range of 6% to 15% for all purposes. The effect in terms of kilometres is somewhat smaller. It is often difficult to compare these results with previous literature because of differences in the measures analysed and the research methods applied (modelling vs. stated preference). The work discussed here probably comes closest to the research by MuConsult (2002), although that study included also respondents not owning a car. The outcomes in terms of kilometres for measure 1A and 1B may be comparable to the results of the MuConsult study. Our results then show stronger effects, which cannot entirely be explained by the fact that we have not included non-car owners.

There are considerable differences between trip purposes, with commuting generally being least sensitive when the charge is time independent. Measures 1 and 2 seem to have less effect on commuting trips, which is a rather usual result (e.g. see previous literature results on elasticities and modelling outcomes). In contrast, measures 3 and 2A have a stronger effect on commuting trips. A common characteristic of both measures is the differentiation according to time. Measure 3 seems to be most effective overall, especially for commuting trips.

Slow transport is a popular alternative for trips to visit people or shopping trips, especially when it concerns a flat kilometre charge. This suggests that people often take the car for short trips that can be easily replaced by walking or cycling. Driving at other times is also a popular alternative, especially for the (car dependent) commuting trips. Commuting trips are hard to suppress (working at home or not making the trip are no serious options for most of the respondents), but there seems to be some flexibility allowing the rescheduling of trips. This is confirmed by the empirical results from Singapore (see Olszewski and Xie, 2005).

The impact of the type of measure is not straightforward. Previous research and common sense suggest that higher kilometre charges have more impact. Our results are somewhat mixed on this issue and are difficult to explain. The effect of revenue use is obvious in most cases, the measures with revenues allocated to lower income taxes have generally more effect. Although not very satisfactory, this may be explained by the perceived financial disincentive. Income reduction may be effective, it may not be very acceptable. Ubbels and Verhoef (2005), for instance, show that income reductions might not be very acceptable, whereas abolition of car taxation is. This suggests a possible trade-off between acceptance and effectiveness, which is relevant to keep in mind.

The decision whether or not to implement a price measure remains a political decision, but one should be aware that the effects depend very much on the type of measure. This work shows that when policy makers want to affect peak time (commuting) traffic a time-differentiated measure seems most appropriate. The kilometre charge with additional peak charge is most effective overall, especially for commuting trips. Governments should be aware that implementation of these (time-dependent) charges most probably lead to driving at other times, especially for commuting trips.
References

MuConsult, (1998) Variabilisatie van de autokosten, final report, Amersfoort
Appendix 1: Description of measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Alternatives</th>
</tr>
</thead>
</table>
| 1: Flat kilometre charge with different revenue allocations | A: 3 €cent, revenues used to abolish car ownership taxes (MRB)  
B: 6 €cent, revenues used to abolish existing car taxation (purchase (BPM) and ownership (MRB))  
C: 12 €cent, revenues used to abolish existing car taxation and construct new roads  
D: 3 €cent, revenues used to lower income taxes  
E: 6 €cent, revenues used to lower income taxes  
F: 12 €cent, revenues used to lower income taxes |
| 2: Flat kilometre charge with additional bottleneck charge (2A) or differentiated according to weight of the car (2B) | A: 2 €cent, additional multistep toll during peak times (morning and evening) on working days at daily bottlenecks: 6:00-7:00 € 0.50, 7:00-7:30 € 1.00, 7:30-8:00 € 1.75, 8:00-8:30 € 2.50, 8:30-9:00 € 1.75, 9:00-9:30 € 1.00, 9:30-10:00 € 0.50. The same structure for the evening peak (16.00-20.00). Revenues used to abolish car ownership taxes (MRB)  
B: Light cars pay 4 €cent per kilometre; middle weight cars pay 6 €cent per kilometre; heavy cars pay 8 €cent per kilometre, revenues used to abolish existing car taxation (MRB and BPM) |
| 3: Peak and off peak kilometre charge and different revenue allocations | A: 2 €cent outside peak times and 6 €cent in peak on working days (7.00-9.00 and 17.00-19.00), abolition of car ownership taxes  
B: 4 €cent outside peak times and 12 €cent in peak on working days (7.00-9.00 and 17.00-19.00), abolition of existing car taxation  
C: 8 €cent outside peak times and 24 €cent in peak on working days (7.00-9.00 and 17.00-19.00), abolition of existing car taxation and new roads  
D: 2 €cent outside peak times and 6 €cent in peak on working days (7.00-9.00 and 17.00-19.00), revenues used to lower income taxes  
E: 4 €cent outside peak times and 12 €cent in peak on working days (7.00-9.00 and 17.00-19.00), revenues to lower income taxes  
F: 8 €cent outside peak times and 24 €cent in peak on working days (7.00-9.00 and 17.00-19.00), revenues used to lower income taxes |
### Appendix 2: Behavioural responses to each alternative of measure 1 and 3

<table>
<thead>
<tr>
<th>Measure</th>
<th>Measure IA</th>
<th>Measure IB</th>
<th>Measure IC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trip purpose</td>
<td>Commuting</td>
<td>Visits</td>
<td>Other</td>
</tr>
<tr>
<td>Total number of trips (driven in 4 weeks)</td>
<td>1104</td>
<td>556</td>
<td>1468</td>
</tr>
<tr>
<td>Trips adjusted (% total)</td>
<td>0 (0%)</td>
<td>49 (8.8%)</td>
<td>115 (17.8%)</td>
</tr>
<tr>
<td>Of which (%):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public transport</td>
<td>30.6%</td>
<td>15.6%</td>
<td>20%</td>
</tr>
<tr>
<td>Non-motorised</td>
<td>38.8%</td>
<td>46.3%</td>
<td>10%</td>
</tr>
<tr>
<td>Motorised</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Car pooling</td>
<td>NR</td>
<td>NR</td>
<td>60%</td>
</tr>
<tr>
<td>Working at home</td>
<td>NR</td>
<td>NR</td>
<td>10%</td>
</tr>
<tr>
<td>Not making the trip</td>
<td>36.6%</td>
<td>20%</td>
<td>0%</td>
</tr>
</tbody>
</table>

NR = not relevant, alternative is not related to trip purpose.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Measure ID</th>
<th>Measure IE</th>
<th>Measure IF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trip purpose</td>
<td>Commuting</td>
<td>Visits</td>
<td>Other</td>
</tr>
<tr>
<td>Total number of trips (driven in 4 weeks)</td>
<td>1212</td>
<td>592</td>
<td>1408</td>
</tr>
<tr>
<td>Trips adjusted (% total)</td>
<td>100 (8.3%)</td>
<td>77 (13%)</td>
<td>179 (12.7%)</td>
</tr>
<tr>
<td>Of which (%):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public transport</td>
<td>12.0%</td>
<td>27.3%</td>
<td>14.0%</td>
</tr>
<tr>
<td>Non-motorised</td>
<td>55.0%</td>
<td>53.2%</td>
<td>63.7%</td>
</tr>
<tr>
<td>Motorised</td>
<td>14.0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Car pooling</td>
<td>11.0%</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Working at home</td>
<td>7.0%</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Not making the trip</td>
<td>1.0%</td>
<td>19.5%</td>
<td>22.3%</td>
</tr>
</tbody>
</table>

NR = not relevant, alternative is not related to trip purpose.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Measure 3A</th>
<th>Measure 3B</th>
<th>Measure 3C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trip purpose</td>
<td>Commuting</td>
<td>Visits</td>
<td>Other</td>
</tr>
<tr>
<td>Total number of trips (driven in 4 weeks)</td>
<td>1256</td>
<td>636</td>
<td>1572</td>
</tr>
<tr>
<td>Trips adjusted (% total)</td>
<td>161 (12.8%)</td>
<td>75 (11.8%)</td>
<td>222 (14.1%)</td>
</tr>
<tr>
<td>Of which:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public transport</td>
<td>2.5%</td>
<td>34.7%</td>
<td>16.2%</td>
</tr>
<tr>
<td>Non-motorised</td>
<td>0%</td>
<td>10.7%</td>
<td>23.4%</td>
</tr>
<tr>
<td>Motorised</td>
<td>13%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Car pooling</td>
<td>0%</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Travel at other times</td>
<td>71.4%</td>
<td>45.3%</td>
<td>56.3%</td>
</tr>
<tr>
<td>Working at home</td>
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<td>9.3%</td>
<td>4.0%</td>
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NR = not relevant, measure may not be differentiated according to time or variant is not related to trip purpose.

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<thead>
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<td>Visits</td>
<td>Other</td>
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<td>640</td>
<td>1256</td>
</tr>
<tr>
<td>Trips adjusted (% total)</td>
<td>191 (16.8%)</td>
<td>100 (15.6%)</td>
<td>148 (11.9%)</td>
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<tr>
<td>Of which:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Public transport</td>
<td>23.0%</td>
<td>4%</td>
<td>3.4%</td>
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<tr>
<td>Non-motorised</td>
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<td>38%</td>
<td>43.9%</td>
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<td>2%</td>
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<td>NR</td>
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<tr>
<td>Not making the trip</td>
<td>0.5%</td>
<td>4%</td>
<td>4%</td>
</tr>
</tbody>
</table>

NR = not relevant, measure may not be differentiated according to time or alternative is not related to trip purpose.
The German HGV-toll

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Abstract

After many delays, technological problems, and renegotiations between the government and the system operator Germany has successfully introduced a satellite based tolling system for heavy goods vehicles (HGVs) in January 2005. Since then the system is running smoothly. Currently the toll applies only to state motorways (the so called Autobahnen) but there are plans to extend it to the secondary level of federal long-distance roads (the Bundesfernstraßen).

This paper describes the political and economic background of the introduction of the HGV-toll in Germany. The paper sketches the history of the implementation process, describes the major structural elements of the toll, and discusses current problems and possible future developments. Finally some policy conclusions are drawn.

Keywords: Road Pricing; Road Transport; HGV-toll

1. Introduction

In January 2005 Germany has introduced a toll for heavy goods vehicles (HGVs). The toll system started with a delay of two years due to many technological, managerial and political problems which were covered by the media at great length (sometimes scathingly). But since the starting date the system is running smoothly. The only major area of discussion today seems to be the problem of toll avoidance traffic, that is, traffic deviating from the motorways to secondary roads in order to avoid paying the toll. Currently the toll applies only to state motorways (the so called Autobahnen) but due to avoidance traffic there is discussion to extend it to the secondary level of federal roads (the Bundesfernstraßen). Unfortunately official data on avoidance traffic are not publicly available yet (although they are known to exist). Estimates of avoidance traffic therefore have to rely on anecdotal evidence and on simulation exercises.

This paper sketches the political and economic background of the introduction of the HGV-toll in Germany (section 2), describes the history of the implementation process (section 3), presents the structure of the toll (section 4), presents the results of a

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simulation study done at Dresden Technical University concerning avoidance traffic (section 5) and draws some policy conclusions (section 6).

2. The background

Due to substantial budgetary deficits on all federal levels Germany is currently facing severe problems with the financing of the country’s infrastructure. These problems exist with respect to maintenance as well as with respect to new investment. The need to spend more on maintenance is illustrated by looking at the so-called “degree of modernity”\(^1\) of the German road network over time. This measure has decreased from around 80% in the 70s to around 70% in 2002. In accordance with this statistical evidence road-users in Germany are facing a substantial amount of congestion due to frequent road-works and the bad technical condition of the road network in general.

But apart from maintenance new investment is urgently required. First, there is the need to remove “old” bottlenecks, some of which have now existed for quite a while. Second, “new” bottlenecks have arisen due to German reunification and the enlargement of the European Union. After EU enlargement Germany has become the main transit country for freight transport in Europe. Dramatic increases in freight transport are forecast. According to official forecasts published by the Federal Ministry of Transport and Housing HGV traffic will grow by 70%-83% in the period from 1997 to 2015.\(^2\) As part of this development the traffic volume between Germany and the new member states in the east (CEECs) will almost treble.\(^3\) Already today 35% of HGV-transport (in ton-km) on the German motorway system is operated by foreign trucks.

The German government recognized these financing problems already during the 90s. In the summer of 1999 a High Commission for Financing the Federal Transport Infrastructure was established to examine these problems and to develop policy proposals to remedy the situation. The Commission (called the Pällmann-Commission, after its chairman Wilhelm Pällmann) came up with the proposal to convert the system of infrastructure financing from a tax-based regime to a regime of usage based charging.\(^4\) To this end the commission advocated to set up a special highway funding company (Fernstrassenfinanzierungsgesellschaft) that should act largely independent from the state. The commission proposed that the proceeds from the toll should be earmarked for road-building only. There was to be no cross-subsidizing between road-

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\(^1\) The degree of modernity is defined as the ratio of net assets to gross assets.


\(^3\) There have been some doubts about these forecasts. It has been argued, for example, that there were association agreements between Germany and the CEECs already before the official membership of these countries, so that trade was already liberalized before EU enlargement. It has also been argued that in modern economies the service sector is more important than manufacturing. Nevertheless, the substantial growth that is currently underway in the new member countries is probably the dominant factor. In addition, and relatedly, it remains the case that the low labour costs in these countries stimulate relocation of manufacturing activities into the east generating a substantial increase of transportation of the manufactured goods back to the west. A special aspect of low labor costs are the low cost for HGV operators in the new member countries who increasingly operate in Germany from their own home base. This contributes to the growth of international HGV traffic on German roads.

\(^4\) Kommission Verkehrinfrastrukturfinanzierung (2000).
infrastructure and other modes of transportation. In the end, however, the German government chose not to follow this advice (see below). It decided that 50% of the revenues are to be used to finance infrastructure investments of railways and inland-waterways.

Apart from remedying financing needs the toll is intended to serve other policy goals as well.

German road hauliers have complained for a long time that foreign truckers do not pay a fair share of Germany’s road infrastructure cost. Given the fact that the German road infrastructure is largely paid out of the proceeds of the gasoline tax and given the large capacity of modern HGV tanks foreign trucks can avoid paying infrastructure costs simply by not refuelling within Germany.\(^5\) Therefore the introduction of a usage dependant HGV-toll was seen as a major tool to generate equal competitive conditions for the national trucking industry.

A further goal that was to be served by the introduction of the HGV-toll was to influence the current modal split in freight transport in favour of rail and inland-waterways and to create “fair” competition between road and rail. Currently rail transport in Germany has a share of around 14% of all ton-kilometers, inland-waterways a share of around 13% and road transport of around 70% (measured in ton-kilometres).\(^6\) By making road-transport more expensive it was thought that the two other modes would become more attractive to shippers. However, in a study predating the introduction of the toll (Doll and Rothengatter 2002 predicted only very limited modal shift effects at the current level of the toll. According to their calculations notable substitution effects would only occur at a toll level of 40 cents per kilometer provided the German railroads would be able to meet the increased demand with offers of sufficient quality and logistic sophistication.

Likewise the government saw the toll as a means to further environmental goals. The toll contains some differentiation according to emission classes. But the main effect on the environment was expected from the incentives of the toll on route optimization, fleet management and a shift towards rail and inland waterways.

Finally, there was a strong element of industrial policy in choosing a satellite based tolling system and sticking to it, notwithstanding the substantial technological problems that emerged during the implementation process.

Roughly the German system works as follows: The onboard unit is equipped with a GPS receiver for satellite signals and a microwave transmitter. Based on the GPS satellite signals the onboard units is able to locate the truck’s position and to compare it continously with a map which is stored in the onboard unit. The onboard unit calculates the corresponding amount of the toll and sends these data via microwave technology to the system’s central data processing unit which does the billing.

The German technology can be extended to other types of vehicle (provided corresponding onboard units can be installed at reasonable costs) and it can be extended to the secondary road network without major difficulty. The system can easily be extended to the territory of other European countries and it can be exported to Non-European countries as well. The German system is certainly the technologically most ambitious system in Europe. It should be noted, however, that this advantage is bought at a cost. It is reported that currently 16-20% of the toll-revenues (approximately 0,6

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\(^5\) The capacity of modern tanks allows a truck to travel 2500-3000 km without refueling.

billion € p.a.) go to the system operator Toll Collect. Probably not all of the proceeds are used to cover operating costs but at least this figure gives some indication of the systems cost.

A further technological advantage of the German system consists in the fact that it provides the technological basis for a host of value-added services that can be offered “piggy-back” to the system, like navigation systems, tracking and tracing, generation of consumer patterns, etc. There is concern (also on the part of the EU Commission) that the operator of the German tolling system, Toll Collect, might acquire a monopoly over these services, and that suitable access provisions should be legislated. Some of these value added services may also cause problems of data protection. It cannot be denied, however, that with this system the political aim to establish Germany among the world’s technology leaders with respect to tolling-technology has been reached. It has to be mentioned in this context that the European Commission is strongly in favour of satellite based tolling systems.7

3. History of the implementation process

The current HGV toll in Germany has replaced the Eurovignette system which was introduced in 1995 in tandem with the Benelux countries and Denmark. Sweden joined the Eurovignette group in 1998. The Eurovignette applied for HGVs with a weight over 12t. It was time based and was sold in variable time chunks (1 year, 1 month, 1 week or 1 day.) Introducing the Eurovignette was a first attempt to reduce the fiscal imbalances that existed in the European trucking sector. In tandem with the introduction of the Eurovignette gasoline and vehicle taxes were harmonized although some inequalities remained. These remaining differences together with the possibilities of foreign trucks to avoid the German gasoline tax by not refuelling in Germany caused sympathies on the part of the German truckers for the government’s plans to change from tax financed system of highway financing to a usage based system.

In 1999 the High Commission for Financing the Federal Infrastructure was established which recommended this change to be made. It advocated the founding of a Highway Funding Company. This company was to be a joint-stock company whose shares, however, were to be held exclusively by the federal government (with the option to sell part of the shares later). The company was to finance its investments partly out of the revenues of a distance based toll and partly out of raising debt on the capital markets. The proceeds of the toll were exclusively to be earmarked for motorways. No cross-subsidies to other modes of transport were to be possible.

This company was in fact established in October 2003, however, with several important changes to the commission’s recommendations. First, it was legislated that cross-subsidies to rail and inland-waterways were to be possible. This change shows up already in the name of the company which was changed from Highway Funding Company (Fernstraßenfinanzierungsgesellschaft) into Infrastructure Funding Company (Verkehrsinfrastrukturfinanzierungsgesellschaft, VIFG). 50% of the toll revenues are now earmarked for investments into the infrastructure of these two competing modes.

(Rail is to obtain a share of 38%, inland-waterways a share of 12%). Second, it was legislated that the toll revenues should not flow to the company directly but first to the federal government which then would distribute the revenues to the company.\(^8\) In this way the High Commission’s important postulate that the company’s budget should be totally independent from the state budget seems to be in question. This is important because the German government had always argued that the toll would not just be “another tax”.

In the fall of 2001 after public tender the system operator Toll Collect was selected. Toll Collect is a consortium of Deutsche Telekom (the dominant telecommunications operator in Germany), Daimler Chrysler, and Cofiroute (the French operator, which holds a share of 10%). The choice of Toll Collect was contended by the competitors but was upheld by the courts so that Toll Collect was finally awarded the official licence in 2002. (The licence has a duration of 12 years.) In April of the same year the necessary legislation for raising a HGV toll in Germany (Autobahnmautgesetz, ABMG for short) went into effect.

It was expected that Toll Collect’s proposed system would be operative in August 2003. Instead a series of technological problems lead to two postponements of the starting date. The main difficulties related to the on-board units which interfered with other board electronics of the vehicle and which exhibited compatibility problems with radio antennae. In addition, the software did not work properly. After extremely critical reporting in the press and after several rounds of renegotiations between the Federal Ministry of Transport and Housing and Toll Collect in February 2004 there was a cancellation of Toll Collect’s contract followed, however, by a withdrawal of the cancellation shortly after under the condition that Toll Collect would be restructured.

The situation was even more strange given the fact that the government had prematurely abolished the Eurovignette in August 2003. This entailed that domestic hauliers paid neither vignette nor toll until January 2005. As a consequence the government suffered substantial financial losses which are now the subject of a law suit concerning penalties for Toll Collect.

Finally it was agreed that the toll would be introduced in two steps. A preliminary version was to be installed in January 2005 and the “full version” by January 2006. The preliminary version still exhibits a limited functionality of the onboard unit. The improved version of the onboard unit (“OBU II”) will contain better software which, in particular, will make it possible to include secondary federal motorways (Bundesfernstraßen) into the tolling system. This fact is important, given the current discussion about deviation or avoidance traffic from the primary motorways to the secondary motorways.

4. Main elements of the German toll

The Pällmann commission (see above) had proposed a basic average toll level of 15 Cents per kilometer. This figure was based on a study by IWW Karlsruhe which relies

\(^8\) At present an amount of approximately the same volume as the revenues from the former Eurovignette is subtracted in order to compensate the Ministry of Finance for the income loss. In addition, the system’s operating costs are subtracted.
on a fully distributed cost methodology. In order to compensate German truckers for still remaining competitive fiscal disadvantages in comparison to foreign trucks the final level was set slightly lower at 12.4 Cents per kilometer. This reduction corresponds to a volume of 600 Mio € for the German trucking industry as a whole and is to be phased out over the next years. In addition, the German government legislated several other compensation measures to make the toll more palatable to German hauliers. It was decided to lower the vehicle tax to the absolute minimum compatible with EU directive 1999/62. In addition, truckers are allowed to subtract the gasoline tax from the toll. This applies to foreign HGVs as well as to domestic HGVs but is considered a temporary measure. Finally, there is a state financed programme of subsidies for the acquisition of new HGVs with a better emission performance.

The current level of 12.4 Cents per kilometer is only the basic average level of the toll. The toll is differentiated according to emission standards and number of axles. There is no differentiation, however, according to time or place. The toll currently applies only to HGVs over 12 tons and only on federal motorways (the Autobahnen) which in total have a length of approximately 12 000 kilometers. Interestingly, busses are not included. Substitute roads are not covered by the toll although there are plans to include at least some of the secondary motorways.

There are two ways of payment: First, the user can pay manually by using a terminal at a gasoline station or via the Internet. Second, the user can be billed automatically via his onboard-unit. The second option requires prior installation of the onboard-unit, of course. The onboard-unit is supplied free of charge by Toll Collect. The truck owner only has to pay for the technical installation of the unit. At the time of this writing approximately 400 000-500 000 units are installed. The total number of liable trucks is around 800 000. Enforcement occurs by video cameras installed on gantries or via mobile control vehicles, which move within the traffic flow. At present the violation rate is below 2% (out of a total volume of 8.5 million vehicles that were checked).

It is expected that in its first year (2005) the toll will have generated revenues of 2,867 billion € of which 0.6 billion € will go to the system operator Toll Collect. The Eurovignette, for comparison, only generated around 450-460 million € per annum. Moving to the toll system therefore has generated a substantial increase in revenues for the German state.

It has to be remarked that apart from the just mentioned temporary possibility to subtract the gasoline tax from the toll the German government has no plans to lower the gasoline tax permanently as a compensation for the toll (as was recommended by the Pällmann commission). This fact is interesting because attempts of economists to allocate infrastructure costs according to vehicle type have shown that currently the gasoline tax payments by HGVs in Germany exceed the cost share of trucks considerably (DIW 2000). These calculations depend on the fully distributed cost methodology and are therefore to some extent arbitrary. Nevertheless the government has depended on these calculations in setting the level of the toll. Thus, in principle a

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lowering of the gasoline tax would have been possible and consistent with the whole policy approach of changing from a tax financed to a usage financed system.

The government bases its denial to lower gasoline taxes on a budgetary principle taken from the German public finance literature, the so-called “Non-Affektationsprinzip”. This principle states that taxes (as opposed to user charges) by definition cannot be earmarked but have the purpose to cover all types of state expenses, not specific ones. This view is open to discussion. In fact, past German governments have already departed from the non-affectation principle and earmarked at least increases in the gasoline tax for the purpose of road building. Even today a part of the gasoline tax is earmarked for infrastructure investments in public transport.

Some experts have argued that the current level of the gasoline tax for trucks is justified because the margin of the tax level over allocated costs can be viewed as an implicit environmental tax imposed on HGVs. It may be true that such an environmental tax might be desirable nevertheless the principles of taxation require that the existence of such a tax should be made explicit and be decided upon in the political process. To the knowledge of this author this has never occurred.

There are plans to extend the toll to HGVs under 12 tons but over 3,5 tons and there are also plans to extend the toll to 15 substitute long distance roads which suffer particularly from traffic seeking to avoid the toll on the primary motorways. In addition, some of the federal states of Germany recently have brought forward the proposal to introduce a toll for private cars within their territory as well. Technically speaking it would be possible to extend the HGV tolling system in this way. Doing this would require, however, that in Germany 45 million private cars would have to be equipped with onboard units. At present the corresponding investment costs seem far too high (although economies of scale and technological progress may change this in the near future). Likewise, operating and enforcement cost are considered to be prohibitive. Moreover, there are two different jurisdictions involved. The current tolling system is operated under the authority of the federal ministry of Transport which is responsible for the motorways (the “Autobahnen”) and the long distance federal roads. The federal states are responsible for the road network within their own territory. Decisions to extend the HGV toll nationwide would require cooperation between the federal states and the federal government.

5. First results and the problem of avoidance traffic

At the time of writing this paper official data on the effects of the toll are still scarce. Nevertheless, the Minister of Transport and Housing in a recent interview\(^\text{10}\) indicated that there have been significant modal-shifts from road to rail. This statement is contradicted, however, by the Federal Agency for Road Transport (Bundesamt für Güterverkehr, BAG) which claims that there is no shift in general but only a small shift in favour of intermodal transport. According to the minister inland transport of containers terminals has increased by 7%. Likewise the amount of inefficient no-load trips has decreased by 15%.

Some federal states and communities have reported a substantial increase in HGV traffic since introduction of the toll. Unfortunately up to now there is only casual

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\(^{10}\) “Maut-Einnahmen auf Rekord Niveau“. In: Die Welt, Sunday, October 8, 2005, p.4.
evidence available although the government had promised systematic and official data for autumn 2005.\footnote{The government has commissioned two studies concerning the effects of the toll. These studies are completed but not publicly available at the moment because they serve as input into the decision processes of the federal states of Germany (the Länder) concerning the question of which of the secondary roads should be included in the tolling system. The Länder have been asked by the Federal Ministry of Transport and Housing to develop a position on this question.} Two examples therefore must suffice to illustrate the problem.

The small wine-growing village of Oppenheim located on federal route B9 with 7000 inhabitants has seen an increase of 1600 trucks per day. This means an increase by a factor of three and implies a density of more than 1 truck per minute.

On federal road B1 the number of HGVs has risen from 338 to 771 vehicles per day which corresponds to an increase of 128%.

The federal states and the communities have reacted to these developments by prohibiting or rationing through-traffic and by imposing detours or drastic speed-limits. Whereas in April 2005 the federal government still denied the existence of serious avoidance traffic it has admitted lately that there are problems at some regional focal points. The Minister of Transport and Housing announced that up to 15 secondary roads might have to be included in the tolling system to remedy the overload of trucks at these focal points.

Some experts doubt that these measures will work. Casual evidence seems to show that a large share of the HGVs on German roads is based in the new member states, in particular Slovakia, Hungary, and Poland. Labor costs in these countries are so low that detours have no high opportunity costs. The sceptics therefore assert that if the German toll is extended to secondary roads HGV operators from these countries will simply incur even greater detours to avoid the toll.

In a study conducted at Dresden Technical University Henninger (2005) has used the VISUM traffic simulation software to simulate the effects of the HGV toll for the federal state of Bavaria. Bavaria was chosen for two reasons. First, Bavaria has the longest road network in Germany. Second the motorway (Autobahn) network is not too dense (unlike, for instance, the motorway network of Northrhine-Westfalia). Thus in Bavaria deviating to secondary federal roads is really an economic option. The network of Bavaria is modelled in the so-called VALIDATE network that was developed by the consulting firm ptv AG in cooperation with Kessel and Partner who implemented in VALIDATE a special model for simulating freight traffic.

Henninger performed two sets of simulations based on two different route choice models. The first route choice model is the TRIBUT model developed by INRETS especially to model the effects of tolls and the second is the so called Multilernverfahren ("Multilearning Procedure") developed by Lohse (Schnabel, Lohse 1997 and ptv 2004). Both methods use value of time (VoT) to estimate the opportunity costs of possible route alternatives. The latter model allows for dynamic adjustment processes of route choice. In contrast to the Multilernverfahren methodology TRIBUT uses the VoT in a variable way to reflect existing differences between individuals in a better way.

To calculate the avoidance effects Henninger differentiates between long-distance traffic (>150 km), regional traffic (51-150 km), local traffic (<50 km), and between trucks and cars. She assumes a value of time of 34,59 €/h for long distance traffic which corresponds to the values assumed in the German federal infrastructure planning procedure. Not surprisingly higher values of time would lead to less avoidance traffic in the simulation.
Both types of route choice modelling identify the same Bavarian roads as candidates for avoidance traffic. The average substitution volumes in both models are as follows:

<table>
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<tr>
<th>Vehicle Type/Type of Traffic</th>
<th>Average Change</th>
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</thead>
<tbody>
<tr>
<td>Cars</td>
<td>+4.46%</td>
</tr>
<tr>
<td>HGVs under 12t</td>
<td>+16.55%</td>
</tr>
<tr>
<td>HGVs over 12t</td>
<td></td>
</tr>
<tr>
<td>Long distance traffic</td>
<td>-1.3%</td>
</tr>
<tr>
<td>Regional Traffic</td>
<td>-21%</td>
</tr>
<tr>
<td>Local traffic</td>
<td>-7%</td>
</tr>
</tbody>
</table>


The increase in cars reflects the time savings of private car owners due to less congestion by HGVs.

<table>
<thead>
<tr>
<th>Vehicle Type/Type of Traffic</th>
<th>Average Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars</td>
<td>+7.12%</td>
</tr>
<tr>
<td>HGVs under 12t</td>
<td>+4.33%</td>
</tr>
<tr>
<td>HGVs over 12t</td>
<td></td>
</tr>
<tr>
<td>Long distance traffic</td>
<td>-21.09%</td>
</tr>
<tr>
<td>Regional Traffic</td>
<td>-27.80%</td>
</tr>
<tr>
<td>Local traffic</td>
<td>-32.03%</td>
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It can be seen from the two tables that although the precise values differ somewhat the effects are nevertheless substantial. It will be interesting to compare these numbers with the official data when these become finally available.

6. Policy conclusions

It comes as a surprise that the German toll was accepted without much discussion and without much resistance. The major reason seems to have been that there was a “grand coalition” of actors who supported the toll. Politicians advocated it because of the hoped for gains to the federal budget and the hoped for position of Germany as a worldwide technology leader in tolling systems. Truckers favoured it because they saw it as a major step towards establishing a level playing field in the competition with foreign hauliers. The environmental groups and the green party advocated it because they generally believe that transport is “too cheap”, because they saw the toll as a first step towards traffic-management by pricing and as a means to influence the modal split in favour of the more environmental friendly transport by road and inland-waterways. The public at large, in particular the car owners, saw the toll as a means to reduce the substantial amount of HGV traffic on German motorways and to decrease the
corresponding congestion. (The sympathies of private car users for a tolling will probably change when a toll for private cars will be brought on the political agenda.)

Another important factor for acceptance of the toll was that the media concentrated their reporting about the toll mainly on the technical and management problems of Toll Collect and the politicians, not on the economic and social issues. After a while the public seemed to believe that it had become a matter of national honour to get the toll working. Economic and social questions increasingly began to play a secondary role.

On the level of economic theory the German example seems to confirm the mounting evidence that large infrastructure projects involving private firms must be dealt with from the perspective of the theory of incomplete contracts (see Hart (1995) and Hart, Shleifer, Vishny (1997)). Apparantly major mistakes were made when the government set up the contract with Toll Collect. It seems to be a worthy object of future research therefore to inquire in how far the theory of incomplete contracts can inform policy making in the area of implementing tolling systems.

Finally, the German example shows the necessity to find binding political mechanisms with respect to the use of the revenues of the toll. It is known from the economic theory of second best that allocating these revenues to road building must not necessarily be the optimal option. On the other hand acceptance may increase if the citizen can be convinced that the toll is not “just another tax.” No matter how this question is decided, politicians must find ways to clarify from the outset how the toll revenues are to be used and ways to commit themselves credibly to these uses.

References

Bundesminister für Verkehr, Bau- und Wohnungswesen: Verkehr in Zahlen 2003/4, Hamburg, p. 239.
Verkehr in Zahlen

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A new approach for the freight transportation system in Venice

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Abstract

Venice is worldwide known as one of the most intriguing places, hosting an average of 15 million tourists per year. This paper describes the causes of the economical inefficiency of the freight transportation system in Venice, and analyses the problems caused by the damages done by the waves. A properly modified form of road pricing, aiming at improving the efficiency of the traffic chains by introducing the pressure of competition between the freight operators, is thereby conceived and the possible deriving scenarios are described.

Keywords: Venice; Lagoon; Wave; Road pricing; Freight; Transportation.

1. Introduction

A “peculiar” city of Arts has “peculiar” traffic problems and requires thereby a “peculiar” approach. In Venice, the increasing amount of freight boats causes an unsustainable wave motion which jeopardizes the survival of the foundations of the old buildings by the sides of some canals.

After reviewing the past attempts to reduce the problem of the wave motion, this paper considers hereby the movement of the boats as a mere kinetic phenomenon, considering the effects of congestion and pollution ultimately not much relevant.

Taking these preliminary remarks into account, a new traffic tool is conceived and thoroughly explained. The possible scenarios deriving from the effectiveness of the tool, and their consequences on the freight delivery system are analysed, leading to the conclusion that the intervention proposed in this paper should be possible, even in a such complex, “peculiar” background.

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1.1 Short notes on the city

An incessant, slow, physical metamorphosis has characterized Venice from its foundation till the present days, due both to the erosion produced by the sea and to the deposits carried by the rivers (Caniato et al., 1999).

This evolution has led to several interventions, accomplished especially by the Venice Republic in the 18th century, meant to keep under control on the rivers of the region, to open new canals, to create the so-called “bocche di porto” (i.e. the openings that connect the sea and the lagoon), and other interventions to protect the seafront of the lagoon.

The city changed along its history especially with the establishment of the railway bridge which connects the islands and the mainland (1846) and with the road bridge (1932): San Marco lost then its role of city headquarters becoming a tourist hotspot; the Arsenal and Salute dismissed their respective docking and duty roles. Unlikely, Rialto always kept its ancient role, having always been the commercial centre of Venice with markets and banks. The terminal of Piazzale Roma and the Tronchetto Island were also created as the new access gates for Venice, both for freight and for passengers. This area (Tronchetto, Piazzale Roma and the Rail Station, see figure 1) receives the 100,000 people arriving daily in Venice, switching them to the public boat service.

![Figure 1: Plan of the city of Venice.](image)

The transport network of the city is made from a central axis (Gran Canal) starting in Piazzale Roma and crossing the whole city up to San Marco, and a set of smaller canals which connect the Gran Canal with an external ring of greater canals surrounding the
whole city (Giudecca and Fondamenta Nove, figure 1). This network has never changed, despite the creation of Rio Novo (1933, in order to link more directly San Marco and Piazzale Roma) and the burial of some canals during the Austrian and French occupancy along the 19th century.

1.2 Transportation issues in Venice

The appearance of different kinds of motor boats in the lagoon is quite recent: the first motor boat for public transport appeared in 1881 and remained for a long period the only motorized typology allowed. The first private motor boats appeared later (1960s). They were mainly used for freight transport, and suddenly took control over the canals. Nowadays, several typologies (both for passengers and freight) are sharing the available water space. The boats for passengers are:

- Public transport service, provided by the firm ACTV (Venice Transport Public Company), serving the stops spread in the city, whose allowed speed along the main canals (Gran Canal, Giudecca canal, Fondamenta Nove) is 11 km per hour.

- Taxis, which are allowed to run at 20 km per hour on the external canals and 5-7 km per hour in the inner ones. These boats are smaller than the ACTV ones and are able to run along the smaller canals of the city.

- Gondolas, divided in two categories: traghetto, used especially by Venetians, which link continuously the two banks of the Gran Canal, and the gondolas providing tourist sightseeing trips. There are no official estimations about the number of gondolas in use but they can roughly be considered around 500 units.

- Private boats, used by hotels and cruise organizers collecting people at Tronchetto.

The mobility network of Venice (both for passengers and freight) can not be compared with those of other cities (considering canals as roads), given the poor employment of boats for individual mobility and the very high ratio of foot-traffic.

Besides, pollution and congestion are not to be seen as the main issues in the Lagoon of Venice: the boat traffic is not the main pollutant factor for Venice, as the pollution produced both from the chemical industries of Marghera and the vehicular traffic of Mestre (both on the mainland of Venice) is carried by the wind. On the other hand, congestion affects just the main canals in the rush hours.

Unlike other cities, vehicles are then to be considered not as a pollutant, but as a kinetic concern. The boat traffic causes damages through the formation of waves, whose height depends on the speed and the tonnage of the boat, and on the section and the depth of the canals. The flow of boats produces mainly two forces on the banks: the first is caused by the waves directly generated by a boat itself (this is typical of smaller ships) and the second by the whirlpool of the seabed water (dominant for bigger boats). The waves cause a faster process of erosion, augmenting the porosity of the stones and the bricks that constitute the banks.

The small amount of boats for passenger mobility and the review of some previous analyses (see also section 2.2) suggest to focus on the freight.

The delivery of freight within the city is carried out by an oligarchy of carriers: a small percentage of this oligarchy uses private boats for transporting their own freights, while the greatest amount of the deliveries are carried out by transporters operating for
third party clients. Presently, there are about 400 licensed boats, but a large amount of unlicensed carriers is present in the city (almost 200 boats).

This fleet is composed of boats different in terms of size and materials. These characteristics define the load capacity of the boats (defined for each ship at the registration). The most common boat for freight transport is the so-called “mototopo” (6-14 meters long, with a minimum 3.5 tonnage).

Half of the fleet is equipped with peculiar features like freezers, safe-deposit boxes etc., while the other ships are often used for general freight transport and pony express deliveries (figure 2).

![Figure 2: A typical Venetian boat used for freight transport.](image)

The logistic chain of Venice has its centre in San Giuliano, on the mainland, in the Tronchetto Island (the switching point with the road network) and in the Fondamenta Nove (figure 1).

The shipments are mainly concentrated early in the morning and, leaving from the collecting points described above, concern the city centre, through the Gran Canal and the smaller canals. Different paths are followed according to the final destination: ships directed in the city centre from the railway station follow the Gran Canal up to Rialto. The ones directed in the areas between Rialto and San Marco follow the Rio Novo. The Rio Novo is one of the busiest canals, counting up to 1800 passages per day of freight boats (60% of the overall boats passing through the Rio Novo - Coses, 2003).
Nearby *Piazzale Roma*, the railway bridge represents a hot spot for the ring navigation. This is due to its height, which does not allow the transit of big boats, and force them to transit in the *Gran Canal* in front of the rail station (2100 passages per day, Coses, 2003), extending significantly the length of each trip (Coses 2002a, 2002b, and 2003). The latest surveys showed an increase of 40% of the boat passages between 2001 and 2002 (Coses 2002a, 2002b, and 2003).

A very weak competition among the shipment companies, which apply flat rates reflecting a standard fare for all the operators, comes out from this picture. An external tax, evaluated according to the principles described further in the paper (with the free-of-charge tolls given to the shippers and the possibility of selling them back to the public administration) would cause a change in the actual non-competitive stuck situation.

1.3 Previous attempts to solve the problem of the wave motion

The economical and traffic systems of the city of Venice have already been object of numerous studies: a staff of Worcester Polytechnic Institute led by Dr Fabio Carrera promoted a study within the UNESCO project “Venice inner canals” to evaluate how to reduce the damages for the shopkeepers caused by the closing of the canals for their extraordinary maintenance.

The proposal of Carrera, developed in three different publications (Carrera, 1999a, 1999b & 2005), assigned to a public corporation (which was later identified with the municipality of Venice) the coordination of the contracts for the deliveries, which were to be granted to the lowest bidder. This would have caused a zone-oriented (instead of the present product-oriented) distribution, reducing the amount of circulating boats and thereby the wave motion.

The increase in the number of landing places in the islands and a different management of the warehouses would have allowed to reschedule the deliveries with less on-board and more ashore workers.

The researches of Coses (2002a, 2002b, and 2003), and Insula (2002) offered the numerical surveying, upon them several strategies for solving the problems related to the mobility (such as speed limits, traffic restricted areas, specific hours of accessibility, one-way canals and so on). Most of them failed because they were not negotiated with the subjects involved.

The authorities dealing with boat traffic have been recently unified in the so called “Governor’s supervisor for Wave Motion”, aimed at “facing the emergency occurred in the City of Venice, in its lagoon and in the sea canals”.

The Governor’s supervisor identified the new proposals for interventions defined by the Traffic Restricted Zones regulation (17 June 2005): according to the greater or smaller section of the canals and the weakness of the environments, the supervisor for the traffic within the Venetian Lagoon has defined the new speed limit along the canals (figure 3).
In spite of this rule, the problem of the wave motion does not seem to be solved: only the smaller canals gained advantage from the limitation to the passage of motorboats. The new rule has not changed much the traffic in the other canals, mostly due to the deficiency of a concrete policy in the freight movements.

2. Description of the pricing tool and its effects on the lagoon

2.1 Introduction

The pricing tool considered in this section is part of a wider plan, containing several proposals meant to solve the problematic transportation system within the Lagoon of Venice, and meant to reduce the impact of the waves.

In order to keep control on the mileage covered by boats, a direct equivalence between mileage and money is proposed. A credit is defined as the right to cover a length unit, identified as a canal between two check points.
2.2 Choice of the freight boat as target

The 35-40% of the total distances daily covered within the canals is run by freight ships (Coses 2002a, 2002b, and 2003). As a consequence, the attention has to be focused on the freight boats: their number and their size makes them chiefly responsible for the formation of waves.

Previous studies (Carrera 1999a, 1999b, and 2005) and the analysis of the current state have underlined a wide margin of optimization for both the delivery paths and the load ratios of the ships, since the actual ratio is lower than the 60% of the maximal tonnage.

The total mileage of the paths followed by freight boats could be cut down at the 20% of the distances currently covered (Carrera, 2005). This inefficiency is due to several reasons:

- a “product-oriented” delivery principle: each kind of good required by a store is delivered by a different shipper (e.g.: a brand of beer is distributed by one boat at several bars in Venice, while a second boat ships other kinds of beverages at the same bars, a third one ships food, and so on);
- A large amount of empty trips: the incomes of shippers are much higher than the fuel price and thereby they are not encouraged to improve the paths of their deliveries;
- A society based on close personal relations: shippers use every day the same bar and the same restaurant for their lunch, no matter in which part of the city they are at lunch time.

A “natural” suggestion for the pricing tool would then drive towards an increase of load ratios and a different choice of the paths of the freight boats.

2.3 Proposal for an innovative road pricing tool

This particular road pricing system implies the application of road pricing on the network of canals that constitute the road system of Venice (figure 4).
Differently from other cases, in which the checkpoints are located along the perimeter of the city, in this pricing system the checkpoints are extended along the whole net of canals with a hot spot distribution having increased density along the most sensitive banks (meant to preserve them from the destroying effects of the waves).

The solution proposed is meant to keep control over the rates applied to each shipment; this is a particular deal within Venice as far as the high costs of transport are declared to be the reason of the high prices applied in the city compared with the same products sold in the mainland.

With the aim of avoiding an immediate rise of the fares, the procedure gives any shipper an amount of free-of-charge tolls, the amount of which is calculated with the procedure described in section 2.5. This amount can be increased by buying permits from the government/system administrator, whenever needed.

The innovative aspect of this proposal is the possibility of either selling back each year the unused tolls to the administration, or keeping them for a future use. The income gained aims at promoting an optimization of the paths travelled, in order to save as many credits as possible.

Better delivery trips, a higher load ratio, and, above all, an effort for a different delivery procedure, would change the present product-oriented (“one good – one shipper”) shipment in a destination-based one (see section 2.2).

The only subject allowed to buy back someone’s unused credits is the public administration: this avoids speculations (e.g. people forced by someone to sell them their unused credit at an excessively low price), which would make the pricing tool ineffective.

The free tolls must be distributed by the public administration, considering an existing division within the carriers: the pricing tool will affect only the ones who convey freight mainly within the City Centre, avoiding those running through external canals.

A period of 20 years is considered suitable for reaching the goals proposed from this tool. Considering the difficulty of improving the supply chain within a shipping enterprise, a function is required to establish an appropriate schedule in the distribution of the free tolls (see following section 2.4). This function is represented by a concave curve. Since the first years have a higher improvement margin, the optimization rate is set at 15% for the first two years and then is decreased progressively every 5 years. The limit of this curve is set at the value corresponding to the 20% of the distances covered nowadays. This value is increased by 2.5% each year according to the increasing tax of freight transportation in Italy (Cappelli et al., 2005).

2.4 Description of the procedure adopted to assign the free of charge tolls

In this section the schedule of application of the pricing tool will be described, focussing onto the method used to calculate the free tolls distributed each year.

The first year of application (year 0) will be used for placing the check-point gates and for providing the shippers with the equipment to be installed on the boats. Other important tasks carried out in year 0 are awakening the shippers and collecting the data required for calculating the amount of free tolls to distribute the following year. The distances covered during year 0 are computed by analyzing the receipts compiled by the shippers for each delivery, which will contain the exact list of the canals used. The
mileage covered corresponds to the amount of credits that the shipper would have used if the pricing tool had already been applied.

According to this basic value, on year 1, which is the first year of real application of the pricing tool, the function adopted provides a total amount of credits that corresponds to the 110% of the distances covered on year 0.

The increase provided is meant to avoid a limit in the companies’ commercial growth by the tax eventually caused. The efficiency of the pricing tool for year 1 is measured through the effort of the shippers in saving the greater amount of free tolls, which, if sold back to the public administration, would produce an additional income in the company’s financial balance.

The next year (year 2) the amount of free tolls distributed to each operator is lowered of 15% (93.5% of the distances covered during year 0). The constructive part of the pricing tool begins here: the shippers, aiming at keeping their commercial share, are forced to improve their logistic efficiency, in order to avoid the payment of the additional mileage covered. The improvement, which implies the reduction of 6.5% of the distances run compared with year 0, could be achieved just avoiding the unpaid trips (the ones covered for leisure or for a private use). The unused tolls are sold back as well.

2.5 Possible scenarios: success, failure and expected results

The total expense for the public administration (besides the costs for the equipment and its maintenance) is given by the success or failure of the pricing experience:

The following formula explains the economical sustainability of the tool proposed here by expressing the income (or the costs) for the public administration:

\[
F = \left[ \sum_{i=1}^{N} (t_i - t_{gi}) \cdot p_i - K \right] \cdot (1 + r)^{N-1}
\]  

(1)

where:

- \( F \): income or costs for the public administration;
- \( N \): amount of years taken into account;
- \( t_i \): amount of tolls used in year \( i \);
- \( t_{gi} \): amount of free tolls distributed in year \( i \);
- \( p_i \): price of a free toll in year \( i \);
- \( K \): fixed payments (equipment, maintenance etc.)
- \( r \): current interest rate

The case of a total inefficiency of the procedure (the shippers keep on travelling the canals without any logistic improvement, making the final customers pay for the additional tolls bought) is considered in figure 5: in this case, the income for the public administration would be given by formula (1), considering a rising in the mileage covered according to the general increasing in freight transport.

This result can also be drawn from figure 5, considering the quantity \( (t_i - t_{gi}) \) as the difference between a black and a white column at a given year \( i \).
Formula (1) can describe the opposite outcome as well. A perfect response of the operators (figure 6) would mean that the actually covered mileage reaches immediately the minimum possible value, which, according to previous studies (Carrera, 2005), can be estimated as the 20% of the current one. The public administration will face in this case a total cost given by the purchase of the free tolls distributed and not used, being $t_{gi}$ (white columns) lower than $t_i$ (black columns).

Figure 5: Description of the worst result of the tool.

Figure 6: Description of the optimal result of the tool in the best desired scenario.
Figures 5 and 6 represent two polar, opposite situations, but at the same time show clearly that the main issues of the pricing tool proposed here are the price paid by the shippers for an extra toll and the one paid by the administration for buying the unused tolls back.

In case of an excessively low price for the extra tolls, compared with the delivery fares adopted, the tendency would probably be similar to the first described scenario. It would mean no improvement in the supply chain: the shippers would keep on with the present delivering procedures.

On the contrary, an excessive price would cause the paradox of a complete stop of all the delivery operations, due to the fact that the shippers would consider more remunerative to stop their boats and sell all the credits back to the public administration (with the obvious consequences for the city).

A moderate toll price would produce the desired intermediate scenario: a substantial and progressive increasing of the logistic chain, in which the most of the operators would be located around the toll-refund line. Some of them would optimize their deliveries optimizing the load ratio of the ships and taking advantage by the final return of the unused tolls. Other transporters would instead be forced to buy a few more tolls, being unable to optimize their supply chain (figure 7).

The red line in figure 7 represents the same function of distribution of free credits, as the one expressed from the white column in the figures 5 and 6. The blue lines try to predict the behaviour of the shippers, who are expected to be closer and closer to the red tendency, as the pricing tool becomes established.

This gap in the final income (effective income plus refunding of the unused tolls or effective income minus price paid for buying additional tolls) will improve the competition within the sector, which is almost nonexistent nowadays. The ones who spare miles will be able to lower their rates in order to attract new users, as far as they can have benefits by selling their unused tolls back. The others, unable to save tolls, will on the contrary face additional costs given by the extra credits bought; as a
consequence, they will increase their fares running out of market, which will force them to improve their logistics for the next year.

The analysis of figures 5 and 6 has not to be considered in mere economical terms: also environmental aspects play a role in the overall consideration of the effects. Venice would gain from the tool in any case: in the polar, worst case (figure 5) the inefficiency of the tool would be rewarded by some extra money, which the municipality could invest in a more frequent maintenance of the banks. In the opposite, best case (figure 6), the tool would effectively reduce the mileage covered by the boats and then directly the erosion of the banks. In the more realistic, intermediate scenarios described in figure 7, the total expenses for the public administration would be the maintenance of the equipment, as the tolls refunded would be almost equal to the additional tolls sold.

The optimal distribution of the check points must be evaluated carefully, in order not to worsen the accessibility of some inner areas of the city, but for avoiding the crossing of those areas for the delivery of small amounts of goods.

For this reason, a maintenance of the free access in the external canals (Giudecca Island and Fondamenta Nove – see figure 1) is proposed, aiming at moving the trips connecting the opposite parts of Venice to the less vulnerable areas. This is to be achieved through:

- The creation of a logistic centre located on Tronchetto Island;
- A stronger policy of controls and penalties;
- An educational program for improving both the load ratio of boats and the logistics.

The cause of the present disorganization is not to be found only within the transporters, although they are responsible for a general lack in the observation of rules and technical progress. The public administration is guilty as well, since it was not able to find an alternative, suitable location for the logistic centre of Tronchetto (the first projects were developed in 1980 – TransCare, 2003) and has not arranged financial aids for the renewal of the fleets (the most of the boats are from the seventies and many of the others even from the sixties).

Also some shop holders share a portion of responsibility, as they swapped large social external costs for small private incomes.

3. Conclusions

This paper sums up different measures of intervention on the urban mobility system, belonging in the literature to the two main topics of "Road Pricing" and "City Logistics".

Particular originality and complexity are imposed by the area of application, i.e. the city of Venice, in which the mobility through water canals determines externality and needs therefore more complex control systems.

The pricing tool described here has the objective of modifying the status quo of the organization of the freight movement in the lagoon, with the aim of introducing the pressure of competition between the operators, who nowadays operate in a sheltered market system with low efficiency.

Because of the weakness of the ecological system and the strong rootedness of oligopolistic customs, the developed system needs to be tested (in its first year of application, always referred to as "year zero" in the previous sections), in order to
calibrate the elasticity of demand, the yearly percentage of optimization of the mobility (i.e. the obtained reduction of the traffic flows) and the final objective of its total reduction (i.e. the level of reachable efficiency).

The conditions of feasibility of the intervention are in any case comparable with those of similar initiatives, with the only complication of dealing with a segment of market rather closed to external measures of rationalization, and which has been accustomed in the years "to take advantage" of the particular economical and urban conditions of the lagoon of Venice.

The analysis of the possible scenarios, however, leads to the conclusion that the margin of action of this pricing tool has to be estimated as significant, and by all means greater than the ones present in comparable situations in the traditional city areas, being the current state of freight transport demand far away from efficiency. This consideration leads to the conclusion that this intervention should be feasible even in a complex background such as Venice.

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