Instruments for a durable development policy

INTEGRATION OF TRAFFIC AND ECONOMIC MODELS

For the Assessment of Urban Transport Policy

ITEM

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Content

1. Introduction

The goal of the ITEM consortium is to integrate economic pricingmodels and traffic models (network models), in order to improve the assessment of urban transport and environmental policies.

Economic models of urban transport emphasise total transport demand per transport mode, and evaluate policies in terms of welfare (including costs of congestion, pollution, accidents and noise). Traffic models emphasise the influence of network characteristics on traffic flows. The combination of economic modes and traffic models in a unified methodology allows detailed analysis of a broad range of new policy instruments for urban transport.

The construction of the ITEM models starts from two existing models: TRENEN II URBAN (CES), an economic pricing model, and ATES (GRT), a typical traffic network model. Both models are merged by simplifying the ATES network structure and by making the definitions of equilibrium and of costs mutually consistent. The merging consists of an automated interaction of both models.

The new model is used for the assessment of new forms of urban transport policy (road pricing), in an experimental case study for Namur.

This research is fully consistent with section 3 “Responses” of the research programme on durable development, and more specifically durable mobility. It treats the optimisation of mainly pricing tools, for the guidance of modal choice and of total mobility. The objective in the assessment of transport policy is social welfare, including:

- valuation of the environment through monetary valuation of external costs such as noise, air pollution (ozone, particulates, greenhouse gasses,…);
- aspects of traffic safety through external accident costs per transport mode;
- private costs (time, resource costs, transaction costs);
- resource costs of public transport and problems concerning government expenditures (through the marginal cost of government revenues).

This is a systematic and comprehensive way to capture the multidimensional aspects of durable development.

The research presented here is a continuation of research which was initiated by the Transport and Mobility Programme of the SSTC and by the European Communities Transport Research Programme.

The economic analysis of pricing in transport networks recently attracts increasing attention in the economic literature. Research within the ITEM project has allowed to intensify existing contacts at CES, and to extend these contacts. Informal coöperation was established with Dr Erik Verhoef (Vrije Universiteit Amsterdam) and Prof. Ken Small (University of California, Irvine). Parts of this research was presented during workshops at KULeuven, at the University of Essex and at the University of California, Irvine. Two research papers from this project were accepted for the World Conference on Transport Research (WCTR) in Seoul, Korea (july 2001).

2. Summary of methodology and results

2.1 Context

Excessive time losses, reduced reliability of the transport system, accidents, pollution and health damage are perceived as important economic and social problems connected to the transport sector. These problems receive ample attention in the economic literature. Often road pricing is put forward as a necessary component in a better, durable, transport policy. Two remarks are of importance here. First, the economic analysis of congestion pricing often (implicitly) assumes that a charge can be introduced on the complete road network, by means of technological solutions which create no congestion in themselves. Second, congestion is often studied in isolation, without taking account of other specific characteristics of the transport sector.

These two remarks give rise to the research topics of the ITEM project. It is analysed how congestion pricing, which is a direct translation of the principle of internalisation of external costs, needs to be adapted when not all links in a traffic network are subject to a tax. Also, there is an analysis of the necessary adaptations of congestion pricing, when (a specific type of) returns to scale prevails in public transport, and when an important share of the traffic flow consists of commuting trips. Regarding this last point, it is important to take account of the fact that current labour taxes are high.

The research topics of the ITEM project can be seen as extensions of the basic analysis of pricing in transport. We start, in the next section, with a summary of the results of the basic analysis, for a case study for Brussels. Next, the results of the ITEM projects are summarised against this background. Detailed explanations of the research work can be found in the appendices of the full report.

2.2 Results of the basic analysis

Current transport prices do not reflect the full social costs of transport. First, the transport taxes are not used to internalise the external costs of congestion, air pollution, accidents and noise. Second, some direct resource costs are not charged for, for example when free parking spots are available. An application of the TRENEN model for Brussels in 2005 (under the assumption of an unchanged pricing policy with respect to 1996; see Proost and Van Dender, 2001, for some detail on the methodology; see Van Dender, 2001, for a detailed presentation of the case study for Brussels) produces the following orders of magnitude for the gap between prices and social costs:

- The resource costs of parking (0.13 Euro/km) is not charged for the majority (70%) of trips. This cost represents ca. 40% of the total trip cost, for an average trip.
- The external cost of congestion amounts to ca. 1.79 Euro/km during peak hours. Addition of external costs of atmospheric pollution, accidents and noise brings the marginal external cost per kilometre to 1.83 Euro.

The introduction of an optimal pricing policy with respect to parking and to external costs leads to an increase of social welfare of 1.3%. Daily traffic volume decreases by 9%. Simultaneously an important modal shift takes place from car trips to public transport trips, during peak hours. The optimal transport prices (including time costs) during peak hours increase by ca. 40%.

As mentioned, the exercise for Brussels assumes that optimal charges are introduced on the full network, and returns to scale in public transport as well as interactions with the labour market are not taken into account. The next sections summarise the results of dropping these simplifying assumptions. The emphasis is on qualitative conclusions. Detailed discussions of results and methodological insights are found in the appendices of the full report.

2.3 Partial network charges

Theoretical analysis

Price instruments for the internalisation of marginal external congestion costs are imperfect when the charges can not be differentiated fully over space and time. Differentiation of charges is expensive, and full differentiation is probably imposible. Consequently, imperfect charges are the rule rather than the exception. An analysis of the problem of limited spatial differentiation of congestion charges should be pursued within a spatial model of pricing. The basic approach here is to combine a static traffic network model with an economic model of optimal taxation.

In a static network model the network users behave according to the Wardropian principles. This means that users minimise their private costs, without coördination with other users, and under the assumption of perfect information. The consequence is that the average travel times are minimised, and that travel times on all actually used routes between an origin and a destination are equal. Because of the congestion externality, this Wardropian equilibrium is not efficient from the social point of view. In the socially optimal solution the marginal travel times, instead of the average travel times, are equalised on all used paths. The socially optimal solution can only be reached by perfect charges on all network links. The ITEM project analyses what the optimal pricing rules are when not all links in the network can be taxed perfectly (partial network charges).

The optimal partial network pricing rule determines that the tax on every taxeable link depends on the marginal external congestion cost on the taxed link, and on network interactions. Regarding the network interactions, three important effects can be distinguished. First, when the taxed link belongs to a route for which non-taxed alternatives are available, the optimal tax falls below the marginal external congestion cost on the taxed link. This lower tax avoids excessive re-assignment of traffic flows to non-taxed routes. Second, taxing a link which is part of a longer route leads to an upward pressure on the optimal tax. The reason is that the tax on the link is used to internalise marginal external congestion costs on the complete route. The first two effects relate to the efficiency of network usage for a given level of transport demand.

The first effect usually outweighs the second one, so that the optimal tax is below the marginal external congestion costs on the taxed link. Third, however, the optimal tax on a link can rise above the marginal external congestion costs, because of the obtained demand reductions. This is so because the non-internalised congestion externality leads to inefficient network use, but also to an excessive demand for trips. When a tax on a link is mainly used to reduce the overall demand for transport, the optimal tax level often rises above the marginal external congestion cost on the taxed link. Which of the three effects finally dominates, is an empirical matter.

The determination of optimal network prices needs to take account of the fact that the network is used by households with different locations. The different locations imply directly that transport costs for identical destinations differ across households. These differences are reflected in the optimal pricing rules. The theoretical importance of this result is that optimal network charges differ from the marginal external congestion costs, even when all links in the network can be taxed. This implies that the distributional effects of network charges need to be made explicit in the social welfare objective.

Using an illustrational model, it is shown that partial network charges may produce good results in terms of social welfare, on condition that the correct links are taxed in a way that reflects the network interactions. Furthermore, it is suggested that alternative pricing instruments, e.g. parking charges, may perform well, when the initial distribution of traffic flows over the network is not strongly inefficient. The reason is that these instruments are well suited to obtain the desired demand reductions.

Applied analysis

Within the ITEM project a simulation model was developed for the evaluation of partial network charges in general static network models. The simulation model consists of a demand module, in which the consumer equilibrium is computed, and a network module, in which the network equilibrium is determined. The simulation model iterates between both modules untill a simultaneous equilibrium in both modules is reached.

The reason for opting for a simulation model, instead of an optimisation model, is that an optimisation model is confronted with an discontinuous objective function. This discontinuity is generated by the complementarity condition which characterises t he network equilibrium. Intuitively, the problem is that different prices can lead to usage of different sets of routes for a given origin and destination. The set of used routes hence is endogenous. This is a discrete aspect in a furthermore continuous optimisation problem. Standard algorithms for this type of problems are not (yet) available.

The simulation model is applied to a stylised, but non-trivial network for Namur. The model is calibrated to a dataset with demand data for the morning peak of an average working day. By means of a grid search technique (computation of all relevant models solutions), it is found that optimally taxing a limited number of links is very effective in terms of social welfare. A system of optimal taxes on four (out of thirty) links generates 75% of the welfare gain produced by a system of optimal taxes on all thirty links. The optimal system of four links illustrates that the network interactions which have been identified in the theoretical analysis, are of importance. Two of the four links are mainly interesting because of the obtained demand reductions. The other two mainly work to improve the efficiency of network use. Further, it is illustrated that the set of used paths indeed depends on the charging system. The discontinuity of the welfare objective in an optimisation model is not just a matter of theoretical interest.

The important policy conclusion of the analysis is that limited systems of congestion charges may be very effective, when they are carefully designed.

Applications of the simulation technique to larger networks are still in development. An efficient software has been developed and tested.

2.4 Returns to scale in public transport

Analyses of congestion charges often are limited to private passenger cars. Extensions to public transport usually do not take scale returns in public transport into account. A specific type of scale returns relates to the economies of density of demand. When public transport demand for a given area increases, the public transport operator may respond by increasing the frequency of service. This reduces the average waiting time for each public transport user.

When the analysis of optimal pricing in urban transport takes account of the economies of density, the most important effect is that the optimal prices of public transport are revised downwards. The effect on the optimal prices of passenger cars is small. If only the public transport prices are optimised, while the passenger car prices remain at their current levels, it is possible that the optimal price of public transport during peak hours equals zero. During offpeak hours, zero prices have a negative effect on welfare.

2.5 Interactions between congestion charges and labour taxes

A tax on commuting trips ultimately is a labour tax, independent of the presence of (congestion-)externalities. In case all commuting trips are made by car, and when commuting is the only trip purpose, it is of no importance whether a labour tax or a transport tax is used to generate tax revenues (at least when the commuting trip is perfectly complementary to the supply of labour). If several transport modes are available, correct relative prices are required to obtain the socially efficient modal split of commuting trips. In the presence of multiple trip purposes, it is desirable to have differentiated charges across trip purposes.

The importance of these interactions is analysed within a numerical model. Differentiation of congestion charges between trip purposes is seen to be important in terms of social welfare, even more so when labour taxes are fixed. The policy conclusion is that, when congestion pricing is introdued, the charges should give rise to a reduction of labour taxes (by a direct reduction, or through tax deductions).

3. Conclusion

The analyses from the ITEM project suggest that the conclusion of the basic analysis remains valid: congestion charges are possible and desirable. They are desirable in the sense that a differentiation of transport prices according to marginal external costs, is welfare improving. The welfare improvement follows from the increased efficiency of the urban transport system. The charges are possible, also when account is taken of the constraint that not the full network is subject to charges. The analyses make clear however, that designing a partial network pricing scheme is not straightforward, and that simple rules (such as taxing the busiest links) may be counterproductive in some cases. It is also shown that it is important to differentiate between charges for commuting trips and leisure related trips.

Public transport pricing can not be seen apart from private transport pricing. When private transport prices are closer to the optimal prices, the public transport prices can rise accordingly. This improves the financial situation of public transport, and allows improvements in service quality.