TØI report 507/2001
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Oslo 2001, 116 pages English language

Summary:

Road pricing strategies for the greater Oslo area

Background

Due to increases in household car ownership rates, demographic changes and changes in the geographical patterns of housing, work and leisure activities, urban road networks are getting increasingly congested in cities all over the world. This entails not only time losses to private and business transport, but also severe noise and pollution problems and degradation of the quality of life in the city centre and surrounding neighbourhoods. For 40 years now, economists have advocated road pricing as a solution to these problems, but somehow the idea seems difficult to get across to the public, and almost impossible to implement in practice. During this time, major road capacity expansion schemes have been carried out in some cities to relieve the problems. However, road transport is still rapidly increasing and congestion is returning as a problem.

In Oslo, a toll ring was erected in 1990 to help finance a road network expansion plan for the urban area. Although much of the plan has already been implemented, congestion is expected to continue. The toll ring will cease operation in 2007, according to current plans. Further plans to relieve the situation is seen as necessary, and differentiated charges by time of day at the toll ring is an option.

Purpose

The purpose of this report is to make a contribution to the implementation of efficient and equitable road pricing strategies in urban areas. Two rather different paths are pursued to this end.

On the one hand, we want to show by a detailed example that it is possible to identify optimal road pricing strategies with the use of a fairly standard transport model and an appropriate optimisation technique, and to study the efficiency gains and distributional issues arising from these strategies by way of cost benefit analysis and a spatial equity analysis. By doing this, we want to invite more studies of a similar nature – and hopefully to solve some of the remaining problems that we have encountered. There is still a lot to be learnt about marginal cost pricing by such studies. Naturally, this purpose entails the need to be fairly technical. The most technical parts of the report are chapters 3-6.

On the other hand, we want to disseminate our findings from the analyses we have performed for the Oslo region, because we think they merit broad discussion among

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planners and decision-makers. These results are set out and discussed in chapter 7 and 8. Even these chapters are however not entirely non-technical, we have to admit.

Policy conclusions

The following main conclusions were drawn from our study of first-best and second-best road pricing strategies for Oslo and Akershus:

- Marginal cost road pricing based on available instruments (including the present location of the Oslo toll ring) can produce significant or even substantial economic benefits.
- The benefits do to a large extent depend on the value of the shadow price of public funds, which again depends on whether taxpayers' money is a particularly valuable resource, and whether transport taxes have less distortionary effects than other taxes. If this is the case in the Oslo region, then road pricing is above all an efficient form of taxation. Therefore, the actual distortionary effects of transport taxes merit further study.
- Road pricing produces significant environmental benefits.
- In the conditions prevailing in the Oslo region, travellers' time gains from road pricing are always less than their monetary loss. Consequently, travellers as a group stand to lose by road pricing unless the revenue in one way or another is distributed back to them (e.g. in the form of income tax cuts, lump-sum payments or the provision of a public good for which there is sufficient willingness-to-pay).
- The revenue is usually high enough to allow full compensation to travellers. Road pricing, when coupled to such a recycling scheme, could then be a Pareto improvement. (This statement is subject to the qualification that the effects of the redistributed income on travel decisions have not been studied.)
- Prior to redistribution, road pricing has slightly unfavourable equity effects, as the costs borne by low-income groups will be a proportionally higher share of their household income.
- If, however, the revenue is redistributed to the households in a way that gives approximately the same amount of money to every household, then the negative distributional effects will be reversed, and a more equitable income distribution is achieved.
- According to our calculations, road pricing does not lead to a greater loss of mobility in the low income groups than in the other groups – rather the opposite. There are no indications that the less affluent travellers are priced off, while the rich pay their way. This can probably be explained by the fact that the high-income groups have a higher travel frequency, especially by car during the rush hours, and are therefore harder hit by high peak toll charges.
- Road pricing entails a sharp conflict between efficiency and equity objectives. If the revenue is redistributed so as to improve the income distribution, road pricing will not contribute to improve the efficiency of the tax system. Thus

there will be no "double dividend". If, on the other hand, the revenue is used to cut marginal taxes on labour, or used to produce a public good for which there is a high willingness-to-pay, there *will* probably be a double dividend. But in that case, the initial inequality brought about by road pricing is not counteracted.

- Marginal cost road pricing will lead to a significant mode shift from car to public transport in the high-income groups. Even walking and cycling is expected to increase significantly. The health effects of this, consisting of the benefits of physical activity and improved air, and the costs of more accidents, merit future study.
- Assuming a shadow price of public funds of 0,25, and toll charges and parking charges as available instruments, the optimal toll charge in rush hours becomes approximately 4.0 Euro (4.2 times the current level of 0.95 Euro) in Oslo. The optimal toll charge in the off-peak period becomes 2.7 times the current level.
- These charges generate a revenue capable of reducing the municipal income tax in Oslo and Akershus by 1,7 percent units, or to allow a lump-sum transfer to each household of approximately 290 Euros per year.
- Assuming a zero shadow price of public funds, the optimal toll charge in the rush hours becomes about 2,7 times the current level, whereas crossing in off-peak periods should be free. In this case, the revenue is significantly lower, corresponding to 0,3 percent of gross income or 57 Euros per household per year.
- Assuming that the fuel tax could be used as a local instrument, the optimal fuel tax in Oslo and Akershus under the assumption of a shadow price of public funds of 0.25 would be twice the current level. In this case, there are less need for high toll charges: 3.5 times the current level in rush hours and 2.3 times the current level in off-peak periods.
- This policy would generate a revenue sufficient to reduce the income tax by 4 percent of gross income, or to give to each household in Oslo and Akershus a sum of 679 Euros per year.
- Although these effects are substantial, only a fraction of the theoretically achievable welfare effects are reaped by marginal cost road pricing at the present toll ring. There is a case for considering slightly more advanced forms of road pricing, including a more favourable location of the ring or a system consisting of several rings.

Commercial traffic has only been treated in a very crude way in this study.

Some methodological issues

The shadow price of public funds

Road pricing is, among other things, a form of taxation. Generally, taxes create inefficient allocations in the economy because they drive a wedge between the marginal cost of production and the price the consumer has to pay. The seriousness of this problem differs however between the different kinds of taxes. Too little is known about how transport taxes perform in this respect.

The inefficiency loss to the economy as a whole when an additional Norwegian krone (NOK) of public funds is raised by raising all existing taxes proportionally is called *the shadow price of public funds*. For Norwegian cost benefit analyses, it is officially recommended to use a shadow price of public funds of 0.20, meaning that for each additional krone that will have to be raised by taxation, the economy will suffer a loss of 0.20 (or conversely, each taxpayers' krone saved contributes 0.20 to the economy).

Road pricing strategies inevitably produce a large revenue for the government. The social value of this effect depends on the following factors:

1. Does road pricing itself produce distortionary effects in the economy outside of the transport sector?
2. How is the revenue used? Is it used to cut back the most distortionary forms of taxation (like the tax on labour) or to provide a public good for which there is a high willingness-to-pay, or is it used for other purposes than to improve the efficiency of the economy?

If road pricing – or transport taxes in general – have much less distortionary effects than the labour tax, and if the revenue is used to improve the efficiency of the economy, then there is a case for valuing the revenue at a rate of say 1.20 or 1.25 per krone. Since we know so little about the distortionary effects of transport taxes, all our analyses have been performed under the two different assumptions of a shadow price of public funds of 0.00 and 0.25. The first assumption covers the cases where transport taxes are just as distortionary as other taxes, and even the cases where they are not, but the revenue is used for other purposes than to improve efficiency. The second assumption covers the case where transport taxes are efficient forms of taxation and the revenue is used to cut back inefficient forms.

Furthermore, we have assumed that if the purpose of revenue recycling is to counteract the adverse distributional effects of road pricing, the efficiency of the tax system will not be improved. So for these cases, a zero shadow price of public funds is used to value the revenue from road pricing. Conversely, a 1.25 shadow price is used when no measures are taken to improve the income distribution. Under these plausible assumptions, there is a potential conflict between efficiency and equity objectives. Our analyses show that this conflict is in fact quite acute.

A spatial equity analysis

In the equity analysis, the population of the urban areas is divided by household income per consumption unit into eight equally-sized income brackets. However, the gains and losses that a particular income group gets from a particular road pricing strategy depend on where they live. Thus we will have to assess the effects separately for each of the income groups in each of the zones of the urban area. Only after this is done can the results be aggregated to produce the new income distribution in the area as a whole, and to compute measures of inequality.

To perform this spatial equity analysis, we have made use of the disaggregate nature of the transport model and its underlying empirical data. From the empirical sample, synthetic zonal populations, resembling the real populations as closely as possible with respect to the income distribution, have been constructed. This "prototypical sample" technique of constructing the transport model permits us to compute benefits and gains for each income group in each of the zones.

Optimisation

The base case is the mid-nineties situation in Oslo, except that the charges at the toll ring are set to zero. A social efficiency objective function is used to assess the benefits and costs of each pricing strategy relative to the base case. It consists of benefits and costs to travellers, operators, the government and the environment. To compute value of the objective function for a given pricing strategy, the pricing strategy is implemented in the transport model, and the transport model output is used to compute the social efficiency of the strategy.

It is well known that social efficiency is maximised if and only if prices are set equal to marginal social costs. Thus if we are able to find the maximum point of the social efficiency objective function, the corresponding prices should be marginal cost prices. The whole purpose of road pricing is to maximise social efficiency by letting travellers face – as closely as possible – the marginal social costs that their choices imply.

Two different techniques are used to optimise the social efficiency objective function. They correspond to the cases of "first-best" and "second-best" pricing respectively. In first-best road pricing, all links in the road network can be charged. Since this is an awful lot of policy instruments, we must make use of what we know about the structure of charges in the optimal solution. Such charges are then added to the link cost functions of the network model.

In second-best road pricing, only a few of the links in the network can be charged. In our case, this is the links that cross the toll cordon. Furthermore, the charge must be the same on all these links. (It would however be interesting to study the efficiency and equity implication of relaxing this constraint.) To improve the situation, there might also be some other instruments available, like parking charges, a local fuel tax, public transport fares etc. We do not have the same knowledge about the structure of second-best solutions, but on the other hand, the number of policy instruments are restricted to a manageable handful. This permits another optimisation technique to be used without unreasonable demands on computer resources. (Our computer department may disagree to this statement.)

To facilitate the use of this technique, we have been forced to consider area-wide instruments only. That is, the charges at the toll ring are the same everywhere, as mentioned, and the *relative* changes in parking charges, public transport fares etc. will be the same throughout the area. These simplifications of the second-best policies considered are introduced to keep the demands on computer resources to a minimum, but it may also very well be that they correspond to real constraints on the available policy instruments. A bit of programming on the transport model is essential to allow us to use only one command to make simultaneous percentage changes in transport service levels and charges throughout the networks.

The optimisation technique for second-best pricing consists of a series of transport model runs, following each other automatically according to an algoritm that does not use derivatives (a DUD algoritm), and terminating when the changes from the last run becomes small enough. The Downhill Simplex algoritm was used in our study. Running on a HP9000 (D270) UNIX machine, the optimum solution for a particular scenario was found in approximately 3 days. Thus it seems possible to analyse slightly more complex problems than the ones studied here, allowing for more policy instruments to be included in the strategy, more time periods to be considered simultaneously or more zones in the transport model.

It is of course essential for the analysis of pricing strategies that the model is run to equilibrium (in the network and between supply and demand) at each iteration.

Problems

There will always be unresolved problems. We have tried to point them out for further study in the text and in some cases also in the conclusions. From a technical point of view, the two most troublesome problems we have met are:

1. How should we compute user benefits when the local transport model includes a car ownership model?

The problem is that cars are not only bought for use in the urban area, but also for longer trips, holidays and weekends etc. By definition, these trips are outside our model and so is the benefit derived from them. A pricing policy that affects car ownership is perhaps not to be evaluated in the urban transport markets alone. We have been forced to do so, but the results of optimisation when the car ownership model is included are obviously less trustworthy, and probably altogether useless when car taxes are included as policy instruments.

2. How should we take account of a positive shadow price of public funds in first-best optimisation?

The problem is how to include the benefits of saving taxpayers' money when the link cost functions are modified to make travellers face the real social costs of traversing the link. The theoretical soundness of the actual solution chosen in this study is open to debate.