Road Pricing

Effectiveness, Acceptance and Institutional Aspects

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Cover illustration:

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door

Barry Johan Ubbels

geboren te Monnickendam

promotoren: prof.dr. E.T. Verhoef
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Chapter 1

Introduction

1.1 Transport

Transport is an essential service in any society. Goods transportation ensures that products can be shipped from factories to markets. Passenger transport, both private and public, allows people to visit each other, go to work or school, and participate in a myriad of economic and social activities. The benefits of transport are many and varied: an efficient transport system is often a major precondition for economic growth, competitiveness and employment. Transport is mainly a derived activity, which means that for most individuals it is a way to facilitate other activities. Depending on the characteristics and requirements of these activities and the persons and goods involved, transportation can take place via the air, the sea, inland waterways, or the land. Transportation on land can take place by different means: walking, cycling, bus, train, truck or car. This thesis is concerned with the last option: private car transport.

Since the early 1950s all developed countries have witnessed a ‘mobility explosion’. The performance of the European transport sector has been in line with the expanding economy. For instance, from 1970 to 2000 total European goods transport in the (at that time) 15 Member States grew by 119% (from 1.4 million tkm to 3.1 million tkm) (Eurostat, 2003). Considering only inland transport, it appears that this considerable growth has been almost entirely realised by road transport (with a share of 74% in total freight transport). These figures show the growing road travel demand by the freight sector.

Trends in passenger transport also show the dominance and growth of road transport. Table 1.1 shows passenger travel demand for the first EU-15 countries between 1970 and 2000. Total transport demand increased by 126%, with passenger car transport progressing at an even higher pace. The average distance travelled per person per year has also increased rapidly, which is primarily due to people travelling further rather than travelling more frequently (Banister et al., 2000). Besides economic growth and increasing income levels, one of the main factors behind the increased demand for passenger mobility has been the geographical dispersion of economic activity, with a clear trend towards moving away from the urban centres. Consequently, there has been an ongoing separation of place of work and residential areas, leading to an increase in commuting.

Table 1.1: Passenger transport performance by mode in the EU-15 (1000 million pkm)

	Passenger cars	Buses and coaches	Tram and metro	Railway	Air (intra-EU and domestic)	Total
1970	1582	269	39	219	33	2142
1990	3199	369	48	268	157	4041
2000	3789	413	53	303	281	4839
1970-2000 (%)	+140	+53	+36	+38	+753	+126

Source: Eurostat (2003).

The demand for mobility has largely been satisfied by the increased use of private cars, which accounts today for roughly three-quarters of all trips. The car is attractive because it offers a high degree of independence and flexibility. Higher disposable incomes have resulted in a higher level of car ownership. The number of passenger cars per 1000

inhabitants has continuously increased from 1996 to 2001 in every EU-25 country, in total by 12% (Eurostat, 2004).
Unfortunately, the trend of increased road travel demand and automobile ownership has had negative consequences in terms of increasing congestion, environmental degradation and accidents. The rate of growth of car ownership was so fast that the supply of new infrastructure fell behind. The capacity of the existing road infrastructure became too small, particularly at specific sites during specific times of the day. Traffic congestion is nowadays a recurring ingredient of everyday life, making millions of car drivers suffer from significant time losses. Road transport is also one of the largest sources of environmental pollution in Europe. Environmental impacts associated with car use are considerable, and concern energy and mineral resources, land resources, air quality (emissions), noise and health (injuries and deaths from accidents). Estimates of these environmental costs of road use (excluding vehicle operating costs) amount on average to some 1.6% of GDP in Western Europe, including the external costs of accidents (0.5%), air pollution (0.6%), noise (0.3%) and global warming (0.2%) (UNITE, 2003). The total costs of road congestion amount to a further 1% according to this study.
Whilst the nature of this transport problem differs across regions, the calls for policy action are intensifying everywhere. Policy makers can choose from a range of policy instruments that deal with different transport externalities. Governments may influence the achievement of a more sustainable transport system by introducing regulations, imposing taxes, or providing subsidies (e.g. to stimulate the use and development of cleaner vehicles). In the present study, the focus is on one specific instrument that is available to policy makers: transport pricing.

1.2 Transport pricing

Transport economists have often claimed that price policies should be one of the main pillars of transport policy making. The idea would be that prices reflecting marginal costs would induce individuals to behave in a socially beneficial manner, and would thus lead to an efficiency improvement of the transport system, because in the present transport market prices are generally not optimal. In the competitive model, the equilibrium price of an object will normally equal its cost of production (including the amount needed to pay a firm's owner to stay in business rather than seek some other form of employment). Elementary economics tells us that, in the long run, price will then be equated with the marginal (and average) costs of each supplier. But the transport market is different. Simple market economic theory cannot directly be applied to transport for a variety of reasons (see Chapter 2 of this thesis). Transport prices do not simply result from the law of supply and demand. Consequently, transport system users currently do not perceive the full marginal social costs of their travel decisions. This leads to traffic volumes in excess of what is socially desirable, and it implies a suboptimal distribution of transport flows over time and space. Economic theory argues that prices should be corrected, and hence there is a role for governments to intervene in the market.
Although transport pricing seems to have found its way into both Dutch and European policy documents, the practical reality often appears quite different from the economically ideal situation. Governments have often objectives other than efficiency. Pricing measures in car transport are in many cases used to raise revenues, or assist in traffic control, and not so much to reduce congestion or internalise external costs. But the emerging problems in traffic, such as congestion, call for a possibly more efficient pricing strategy. It is of course important to know about the possible effects of new

pricing regimes. But it is also relevant to analyse the barriers to pricing measures, providing evidence why possibly more efficient solutions have not yet been introduced.

1.3 Aims and scope of the study

Transport pricing has been studied by (transport) economists for many decades now, but especially now that sophisticated electronic transport pricing schemes are increasingly becoming technically feasible and politically acceptable, it is fair to admit that there are many unsettled issues in our understanding of the economics of transport pricing. This is to a considerable extent due to the economists' 'habit' of presenting economic insights using highly simplified models of a very complicated multi-actor reality – and specifically – of human behaviour. Although this has a clear advantage in terms of exposition and communication of ideas, it may often leave policy makers empty handed as soon as the insights are to be implemented in reality. Blind spots in our knowledge and understanding of the optimal design and possible consequences of price policies in transport are also due to the complex nature of transport markets, in which actors' decision making and behaviour not only involves a great number of dimensions (e.g. mode, route, time of day) but in addition are closely interacting with behaviour in many other markets (e.g. spatial behaviour in terms of locational choice of living, working, shopping and recreating; labour supply decisions; telecommunication, etc.). But, as previously mentioned, there are not only uncertainties in the consequences, it is also very relevant to obtain knowledge about issues important to implementation (of which acceptance seems to be most relevant nowadays). This thesis aims to study these relevant aspects of transport pricing from the economic perspective in a multidisciplinary setting. We start with a more general approach of transport pricing, the applied work will focus on private road transport and road pricing in particular.

This study results from a multidisciplinary project (MultiDisciplinary research of Pricing in Transport: MD-PIT) that aims at providing a theoretical and empirical evaluation of the direct and indirect effects of practically feasible road pricing policies. The effects studied include behavioural responses and their consequences, as well as acceptability issues of various pricing and tax recycling schemes, and some specific institutional issues. The evaluation includes the derivation and formulation of policy implications. In order to accomplish this main research objective, we defined three different questions:

1. What behavioural responses to transport pricing can be expected to occur, and what does this mean for the design of first-best and second-best pricing schemes?
2. What implications can institutional issues have for the design and efficiency of road pricing? Since many institutional issues can be distinguished, we have identified two specific cases of interest: the case where private involvement in setting road pricing and road capacity is considered by a government; and secondly, the case where two different levels of government are involved in the design of road transport pricing schemes.
3. What factors determine the social acceptability of transport pricing; what role does the allocation of revenues play here; and what are the most important trade-offs that have to be made between the efficiency and social acceptability of pricing schemes and revenue allocation schemes?

Answering these questions requires a solid theoretical basis. Therefore, we begin with a literature review of the economics of transport pricing, explaining the motivation for transport pricing including efficiency and equity. For the evaluation and design of transport pricing strategies, it is of course important to have insight into the behavioural responses. This will to a considerable extent depend on the exact design of the pricing

scheme (e.g. a kilometre charge will most likely have more effect on kilometres driven than car ownership taxes to be paid yearly). Equally important, however, is the price sensitivity of car drivers for the various relevant dimensions of behaviour that together define transport behaviour. A literature review (Chapter 3) aims to identify relevant dimensions (e.g. departure time choice, mode choice etc.) and to assess their potential empirical relevance. The economic findings will be compared with those of psychologists and traffic engineers.
The results from this literature review (open issues, relevant policy measures) are then input for the design of the surveys. The empirical work aims to determine the behavioural responses to road pricing in the Netherlands. Since we evaluate new types of road pricing measures (not-yet existing in the Netherlands), we make use of stated preference techniques. Such techniques are considered especially useful when dealing with hypothetical situations where revealed preference measurement is not possible. The first survey asks the respondent to make choices between different hypothetical situations. The choice data have been analysed by estimating different choice models with the aim to determine the preferences of the respondents (commuters). The logit family of models is recognised as the essential toolkit for studying discrete choices. We present estimates from the multinomial logit model. These outcomes allow us also to derive estimates for important parameters such as the value of time, which provides a useful update for policy analysis. Unlike most other studies in this field, we also derive parameter estimates on an individual level. A second set of questions simply asked for the behavioural responses to different pricing measures. Effectiveness levels have been analysed qualitatively as well as quantitatively (in the form of a statistical analysis to explain the level of effectiveness). While most studies focused on trip suppression only, we analyse diverting behaviour (which alternative will be chosen).
One reason for optimal pricing being not very realistic is the existence of institutional constraints. The second question deals therefore with two (out of many) important institutional aspects of transport pricing. We use a small theoretical network model to investigate the implied efficiency effects of the inclusion of the private sector into road construction and operation, as well as the competition between different levels of governments in this. We consider different settings where capacity and roads are free to choose leading to interesting new insights.
In order to answer the third question, again a literature review is carried out that deals with the efficiency aspects and acceptability aspects of transport pricing measures with explicit attention for the use of revenues. Acceptance and revenue use will also be analysed empirically, and questions addressing these issues have been included in the surveys. Statistical methods are applied to assess issues that explain the level of acceptance. Unlike other studies we include information on individual's behavioural responses and link effectiveness and acceptance scores.

1.4 Structure of the study

The organisation of this thesis is shown schematically in Figure 1.1. The core of the analysis starts with a theoretical overview of the economics of transport pricing (Chapter 2). The economic principles discussed provide the basis for the three different research topics analysed in this thesis: the behavioural responses to transport pricing (Part I), the institutional issues of road pricing (Part II), and the acceptability of road pricing (Part III).
Part I focuses on the effectiveness of road pricing. It begins with an overview of the existing literature on behavioural responses to transport pricing, followed by an empirical evaluation of the direct and indirect effects of feasible pricing schemes. Part II

analyses the welfare consequences of situations where not one central government is responsible for road management, and prices are set by different (public or private) institutions. Parts I and II may show the attractiveness of transport pricing (in terms of effectiveness and welfare gains), but we should not forget that there are considerable barriers to implementation. Part III deals with what is recently considered as the most important hurdle: acceptance. Theoretical and empirical insights obtained in this part of the analysis may lead to a reformulation of (effective) pricing measures addressed in the previous parts. The final chapter (Chapter 10) synthesises the previous chapters, draws conclusions, and suggests further research and policy recommendations.
Looking more closely at the contents of this thesis, Chapter 2 deals with a literature review of the economics of transport pricing. Some key topics that are addressed include the economic motivation for transport pricing, efficiency and equity of transport pricing, and pricing in practice (first-best versus second-best pricing). Economic theory shows that optimal prices equal marginal social costs, but only under certain conditions. The chapter states that the transport market is far from this ideal, and therefore discusses some major second-best issues that have recently been studied in transport economic theory.

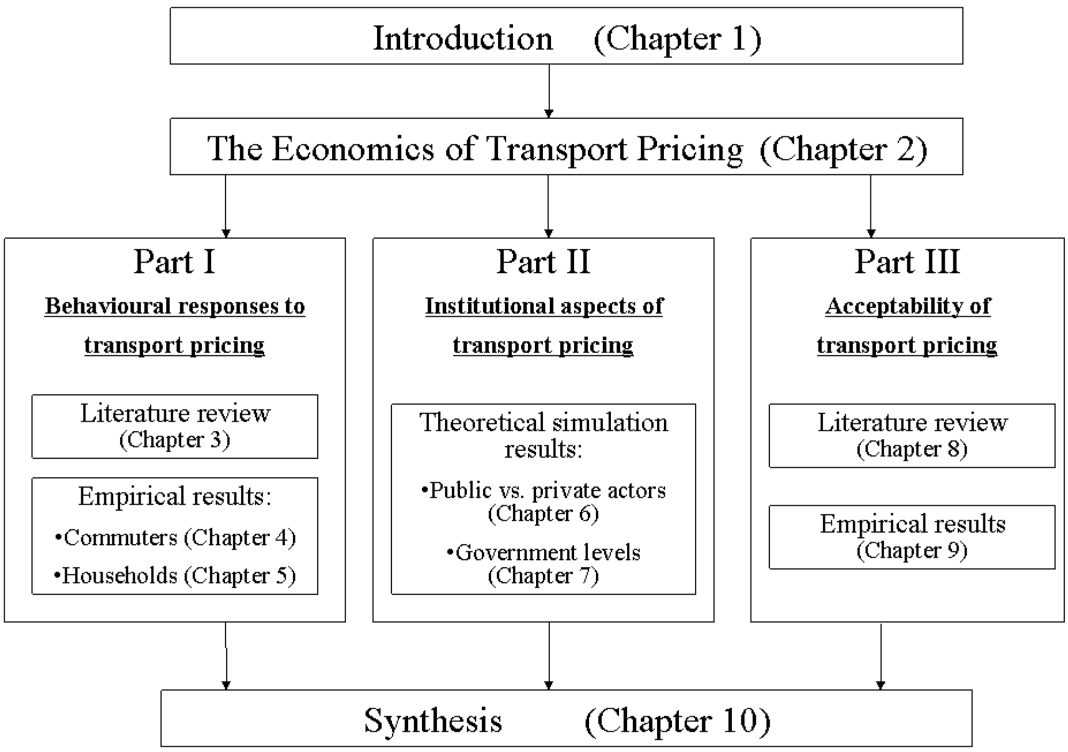

Figure 1.1: Outline of the research

Part I analyses the behavioural responses to transport pricing. For the evaluation and design of transport pricing strategies, it is of course important to have insight into the behavioural responses induced by transport pricing. It begins in Chapter 3 with a literature overview of the consequences of road pricing. Special emphasis is put on assessing the implications of varying sensitivities with respect to the different behavioural dimensions distinguished in the economics literature. Given the multidisciplinary approach, we move one step further and compare the results (in terms of methods applied and effect sizes found) from economic theory with those of the psychology discipline, possibly indicating (in)consistencies. Chapter 4 presents the empirical findings of an extensive survey conducted among Dutch commuters who regularly experience congestion. The respondents faced a choice experiment in which they distributed 10 trips over 4 constructed alternatives. The estimated choice models provide information on the behavioural responses of the commuters in terms of departure time, route choice and mode choice when confronted with road pricing. Moreover, we derive estimates for important transport policy concepts such as the value of time, value of schedule delay (early and late), and the value of uncertainty. This analysis focuses on the short-term responses of commuting traffic to road pricing. Chapter 5 presents the results from another survey with a different sample (car owners in general). It analyses the short-term responses of the respondents, but also includes the more long-term decision of car ownership. The data have been collected by a second questionnaire in which the respondents evaluated three different types of kilometre charges with varying use of revenues[1].

In Part II, two (out of many) important institutional aspects of transport pricing are considered. The first concerns pricing by private versus public operators (Chapter 6). This question is not only relevant for the foreseen privatisation of public transport systems, but may also soon become relevant for road transport, given the increasing interest in privately-operated pay-lanes or highways. The second aspect concerns the question of the level of government at which transport prices would be set (Chapter 7). Urban, regional, national, and transnational governments may frequently pursue different goals and would therefore often set different prices. Likewise, the use of revenues may be strongly dependent on the level of government at which prices are set.

Part III of the main analysis deals with acceptance issues of new road pricing measures. Economic theory has demonstrated (see Chapter 2) that the current pricing regimes are often not very efficient, and that there is scope for other types of measures. These more efficient measures have so far only seldom been implemented in practice. The low level of implementation is nowadays not so much caused by technical or administrative problems. Rather, the problem is that it is generally acknowledged that pricing measures meet public resistance and that acceptability is one of the major barriers to the successful implementation of new and more efficient pricing measures. Chapter 8 investigates the barriers to road pricing by means of a literature review. Explicit attention is paid to the role of revenue use. The spending of the revenues from road pricing may have considerable consequences not only in terms of public acceptance but also for the overall efficiency of the scheme. The results of this survey on the empirical and theoretical work available on this topic are then used as input for the design of both questionnaires described in Part I. The questionnaires distributed to commuters and households do not only focus on behavioural responses, but also address the issue of acceptability and revenue use. Chapter 9 presents the empirical results of the survey that was carried out. The aim is to identify important explanatory variables for the level of acceptance for different types of road pricing measures, and to score different types of revenue use in terms of acceptance.

Finally, Chapter 10 brings all the results together. It provides a synthesis of the theoretical and empirical findings, puts them into a policy perspective, and indicates which directions are most promising for further research.

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[1] The empirical part of this thesis analyses different types of road pricing measures. In most cases we have specified both the type of price measure and the type of revenue allocation. One of the measures includes variabilisation. This measure, policy relevant in the Netherlands, refers to the implementation of a kilometer charge together with the abolition of car taxation independent of car use (car ownership taxation and car purchase taxation).

Chapter 2

The economics of transport pricing

2.1 Introduction

Transport forms an important part of everyone's life. The spread of production, trade and ideas and the economic ascendancy of mankind all depend upon movement. Adequate transport is something that we tend to take for granted in the industrialised world, and if it is not available public concerns soon emerge. The reasons for this are not difficult to find. Comprehensive transport provision is perceived as an important input into the efficient functioning of modern industry and commerce. It also affords individuals and households the benefits of mobility.

Transport has some characteristics that makes it different from other goods. Possibly the most important characteristic of transport is that it is often not really demanded in its own right (Button, 1993). People wish, in general, to travel so that some benefit can be obtained at the final destination. Similarly, users of freight transport perceive transport as a cost in their overall production function and seek to minimise it wherever possible.

While the demand for transport has particular, if not unique, features, certain aspects of supply are also entirely peculiar to transport. More specifically, part of the supply is mobile – almost by definition – and is entirely different in its characteristics from the fixed infrastructure (for example, roads, airports, etc.). The fixed component is usually extremely long-lived and expensive to replace. Further, few elements of transport infrastructure have alternative uses.

Demand and supply work together to determine the market price in competitive markets. The price of a good or a service is what must be given in exchange for the good or service (Stiglitz and Driffill, 2000). In the competitive model, the equilibrium price of an object will normally equal its cost of production (including the amount needed to pay a firm's owner to stay in business rather than seek some other form of employment). Elementary economics tells us that, in the long run, price will then be equated with the marginal (and average) costs of each supplier. But the transport market is different. Simple market economic theory cannot directly be applied to transport for a variety of reasons. Since journeys are unique in space and time, monopoly is likely to arise in varying degrees, especially when technological change offers an advantage to a particular mode, or where economies of scale affect one mode more than another. This situation also affects the pricing of transport services. Transport prices do not simply result from the law of supply and demand. This chapter addresses a range of complexities that arise due to the nature of the cost structure and the different market conditions generally observed in the transport sector. Although general pricing issues in transport will be discussed, particular attention will be paid to the pricing of passenger car transport.

This chapter comprises several sections. We begin with a general discussion of pricing issues in transport. Section 2.3 focuses on marginal cost pricing, including equity and efficiency. We move on to market failures and pay special attention to externalities, monopoly and indivisibilities, which play an important role in transport pricing. Section 2.5 discusses some second-best pricing issues, since a great deal of research is nowadays focused on this topic. Finally some concluding remarks and lessons will be drawn from the issues raised in this chapter.

2.2 Transport pricing

Pricing is a method of resource allocation. Pricing strategies permit specified aims to be achieved; there is no such thing as the 'right' price. The pricing policy adopted by any transport undertaking depends upon its basic objectives. For example, optimal price aimed at achieving profit maximisation may differ from that needed to maximise social welfare or to ensure the highest sales revenue. In some cases, there is no attempt to devise a price to maximise or minimise anything, but instead prices are set that permit lower level objectives (for example, security, minimum market share) to be attained. Further, prices may be set to achieve certain objectives for the transport supplier in terms of his welfare. This is normally the case for private enterprise transport undertakings, while in other areas prices may be set to improve the welfare of consumers (as has been the case with publicly-owned transport undertakings). This distinction is important, as many undertakings consider that the employment of the pricing mechanisms to achieve their objectives is automatically for the benefit of customers.

It is clear that pricing objectives differ, depending on the provision of transport services (public or private) and market conditions. The following pricing objectives can be distinguished:

- Economic efficiency;
- Profit maximisation;
- Cost coverage;
- Environmental sustainability;
- Equity (including redistributive objectives);
- Objectives transcending the boundaries of transport markets, including macroeconomic objectives.

The objective of economic efficiency reflects the aim to maximise social welfare; this will be discussed in Section 2.3. Profitability is the traditional, classical economic assumption that firms set prices as to maximise profits. More recent variations on this theory suggest that many undertakings adopt prices that maximise sales revenues (Baumol, 1962) when in an expansive phase, or simply price to ensure that certain satisfactory levels of profit or market domination are achieved (Simon, 1959). A third possible objective is that of cost coverage. Most publicly-owned firms are focused not so much on making profits but to stay in business and recoup their costs, often induced to do so for political or fiscal reasons. Protection of the environment has become an important objective for governments in recent years. Transport in general, and road transport in particular, are widely recognised as an important source of pollution which threatens environmental sustainability. Pricing measures have been suggested or introduced to deal with these problems. Promoting environmental objectives may be consistent with the aim of securing welfare maximisation through economic efficiency, in particular when social welfare incorporates environmental social costs and benefits.

Equity objectives and the distribution of real incomes in society are important issues for a government, reflected in the pattern of taxation and public expenditures. Whilst transfer payments, such as benefits and pensions, are a major means of redistributing income, the provision of services, such as transport at subsidised prices, is often considered to be equally important (United Nations, 2001). Moreover, tax policies (or other policies) aimed at regulating transport and revenue recycling, will have distributional consequences that may or may not match more generally formulated distributional targets, and may therefore motivate adjustments in currently used (distortive) taxes. This, in turn, implies that indirect efficiency effects may occur elsewhere in the economy.

Finally, public bodies are concerned with macroeconomic policy objectives. Governments usually focus on four target variables: the level of unemployment; the rate of inflation, the balance of payments and the rate of growth of national output (see Stiglitz and Driffill, 2000). The level of investment in, and the pricing of, transport infrastructure and transport services both affects and is affected by macroeconomic policies.

The kinds of objectives mentioned above are complex and are often not compatible (see Table 2.1 below for some examples). Although there are many transport pricing objectives, economists often focus on the pursuance of economic efficiency in the transport sector alone. Prices that are socially optimal are seen as the first-best benchmark, which is in most cases politically desired.

Nevertheless, an expanding body of literature on transport pricing is emerging that considers pricing and revenue allocation in the context of a wider – general equilibrium – framework, in which (tax)distortions elsewhere in the economy and distributional objectives, as represented in social welfare functions, are considered explicitly (e.g. Mayeres and Proost, 1997; Parry and Bento, 2002).

Table 2.1: Pricing policy objectives and possible conflicts

Pricing Policy Objectives	**Conflicts**
Economic efficiency vs profit maximisation (or cost coverage)	Efficient pricing of the use of transport capacity may lead to financial losses for the infrastructure owner
Profitability vs income distribution	Pricing for profitability may lead to higher transport prices with adverse effects on poorer income groups
Economic efficiency vs macroeconomic policy	Macroeconomic price restraint policies may conflict with the need to increase transport prices during periods of congestion and excess demand

Source: Adapted from United Nations, 2001

So, efficient use of resources and optimising the welfare of society is clearly an important objective. It may even be the most important for governments involved in setting prices in mobility. In the following, the consequences of realising maximum welfare for price setting in general and transport pricing in particular will be discussed. We begin by considering what is often called a ‘first-best’ world: apart from the (transport) price to be determined, all other markets have efficient pricing, there are no other constraints on the transport prices, and no market failures to be considered. Second-best pricing issues will be discussed in Section 2.5.

2.3 Economic efficiency and equity in pricing

2.3.1 Efficiency: marginal cost pricing

The concept of economic efficiency is derived from the theory of welfare economics, and is concerned with the allocation of resources in an economy. Welfare economics takes a rather wide view of pricing, looking upon price as a method of resource allocation which maximises social welfare rather than simply the welfare of the supplier (Button, 1993). According to this view, prices should equate with marginal social cost to obtain maximal social welfare. Sometimes, public provision of the good or service may also result in maximising the suppliers’ welfare. Otherwise, regulatory policies may be applied to private companies so that their pricing policy is modified to maximise social rather than private welfare. This may take the form of price regulation, or taxing firms so that their prices become socially optimal. This will be explained below.

Deriving optimal prices needs an objective function. The most general form of this function is a social welfare function. Formally, a social welfare function $W = W\left(V^1 ... V^n\right)$ has as its arguments the indirect utility functions V^i of individuals $i, i = 1...N$ (Varian, 1999). These indirect utility functions indicate the maximum utility levels of the individuals. The utility levels depend on prices, income, and the magnitude of externalities such as congestion and pollution. The social welfare function incorporates welfare judgements with respect to the distribution of economic resources. These value judgements are reflected in the policy prescriptions based on the welfare function.

Several alternatives can be used as a target. These include: the search for local improvements to welfare (rather than a global optimum); Pareto improvements; potential Pareto improvements; compensating and equivalent variation; and social surplus. This last one is the most commonly used for applied welfare analysis. Social surplus is defined to be the sum of producers' surplus and consumers' surplus (CS). Consumers' surplus represents the benefit to consumers, as expressed by their willingness to pay, in excess of the cost of providing a particular quantity or level of output. Producers' surplus represents the revenue in excess of the cost of providing that level of output, i.e. profit. The principal advantage is that CS can be calculated using uncompensated aggregate demand curves. On the other hand, CS makes the implicit welfare judgement that welfare distributional concerns do not matter, by giving equal weight to the surplus of all individuals. Another drawback is that CS is not an exact measure of welfare when the utility function is not quasilinear.

Despite these disadvantages, the considerable practical advantages of CS make it attractive. CS is most commonly used to measure welfare changes associated with the change in the price of a good. Willig (1976) has shown that CS serves as a good approximation to the compensating and equivalent variation, which are exact measures of changes in welfare, as long as any one of three conditions hold:

1. the price change is not large;
2. expenditure on the commodity is not a large fraction of income;
3. the income elasticity of demand is not large.

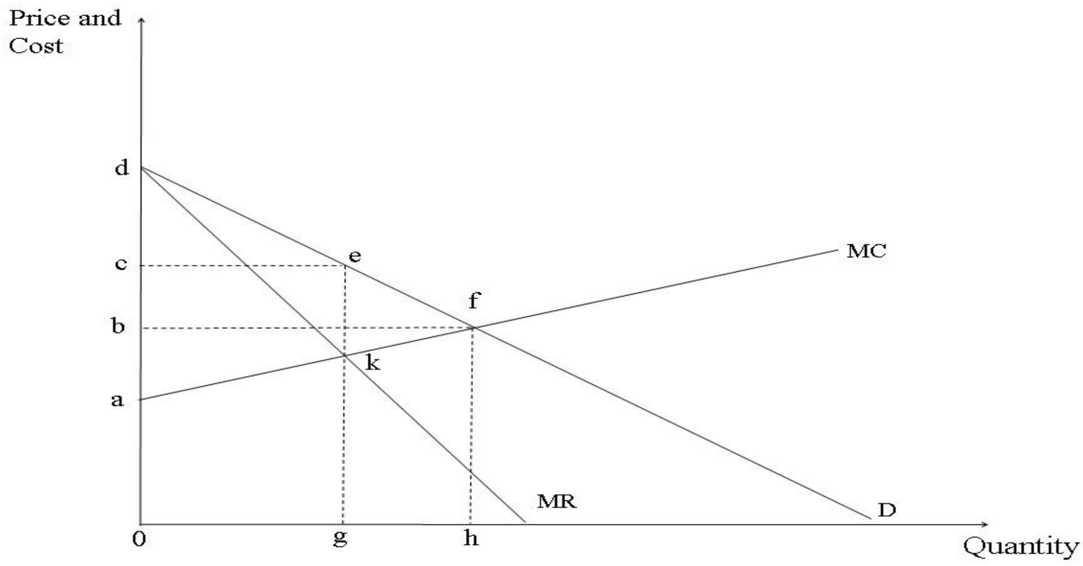


Figure 2.1: Welfare maximisation in a partial equilibrium setting

Welfare theory assumes that interpersonal utility comparisons can be made, and seeks to maximise the sum of consumers' and producers' surpluses. This can be illustrated diagrammatically as in Figure 2.1. In the diagram, MC is the marginal costs curve or supply function. Marginal costs are the increase in total costs that occurs from producing one more unit of output or service (Gomez-Ibanez, 1999). In the figure, it is assumed that marginal costs increase when output is increased. However, this is not necessarily the case in the transportation industry, where firms may face large fixed costs (see also Section 2.4.3 on this issue). D and MR represent the demand and marginal revenue curves, respectively. A profit maximising firm would produce the output *0g* at the price *0c*, where marginal revenues equal marginal costs (a monopolist is likely to choose this price: see Section 2.4.4 below). Consumers' surplus (assuming no income effects) is equal to the area *cde*, and producers' surplus is represented by the area *acek*, leading to a total of *adek* (social surplus level).
If this firm were to set its price equal to marginal costs, output would expand to *0h*, and price would fall to *0b*. Consumers' surplus would be given by area *bdf,* and producers' surplus by the area *abf*, resulting in a social surplus *adf.* When we compare this with the previously obtained aggregate, it appears that the triangle *kef* makes the difference. The sum of the two surpluses is at the maximum when price equals marginal costs. In other words, social welfare is maximised when price is equated with marginal social costs (Pareto optimum).
What marginal cost pricing does, in effect, is to result in transport services being provided up to the point where the benefit for the marginal unit is equated with the costs of providing that unit (Button, 1993). The traditional theory suggests that such a condition prevails in the long term when perfect competition exists, despite the fact that each firm is trying to maximise its own profits, i.e. producers' surplus. However, the ability to exercise any degree of monopoly power permits a firm to set prices above marginal costs, so that it can achieve additional profit at the expense of reduced output and at a cost to the consumer. This higher price, charged by the profit maximising monopolist, will deny some consumers the use of a service, even though

they are prepared to pay at least the marginal social costs involved. This fear has been explicitly high in the transport market leading to widespread price regulation in many sectors by numerous governments.
A ‘first-best optimum’, where all prices equate marginal social costs, will prevail as a market equilibrium under certain conditions, among which:

- perfect competition;
- no distortions in other market segments;
- no externalities;
- complete information about future prices, tastes and technology;
- no subsidies or indivisibilities of demand or supply.

An allocation is said to be first-best if it maximises social welfare subject to the irreducible technological constraints of production (Dreze and Stern, 1987). A first-best optimum in transport is an allocation defined by quantities of goods, including passenger and freight transport volumes, that maximises $W(.)$, given the prevailing technology, such as vehicle fuel consumption and emissions, and the capital stock, including transport infrastructure (MC-ICAM, 2002). This definition encompasses externalities if their costs are internalised in the decisions of agents who generate them and included in their utility functions. Economic efficiency then implies that the full costs of transport services are accounted for, including social and environmental costs (no externalities). Including these social and environmental costs in the welfare function is difficult, but estimates of the most important externalities exist (see also Section 2.4.2).

2.3.2 Social welfare and equity

From the previous discussions it becomes clear that, in a fully competitive and distortion free economy, each price equilibrium is a Pareto optimum. This means that the market mechanism is able to guarantee efficiency for any initial distribution of resources over the population. However, this distribution might not be consistent with policy objectives and the public may perceive it as unfair. This section deals with pricing and its consequences in terms of equity. Equity is important from the viewpoint of distribution of income (or other items) and for the acceptability of pricing policies by the public. Various types of equity concepts are important in transport and these will now be discussed, as well as strategies to deal with distributional issues.
Equity is important in the context of the acceptability of pricing. Many stakeholders raise objections about pricing measures that they perceive to be unfair. If a pricing measure is unfair either to themselves in relation to other people or to people perceived to be less well off in society, then there could be significant acceptability problems. Transport pricing can often be perceived to be a form of regressive taxation, allowing only those with enough money to access a resource (e.g. infrastructure) that was once considered free. Implementation strategies are therefore discussed that allow certain sections of the community to be exempted from pricing, or compensate some groups with a lump-sum transfer. The problem of who should receive extra benefits (e.g. tax exemption) and the wider problem of making sure price measures are both equitable and perceived to be so, are important issues to be included in any successful implementation strategy. Here the concept of price discrimination shows up. In public transport, for instance, it is common that different prices are charged for the same service. The fare policy of governments may benefit particular groups of society, e.g. the elderly.

The public finance and tax literature makes a distinction between horizontal equity and vertical equity. Horizontal equity refers to the principle which states that those who are in identical or similar circumstances should pay identical or similar amounts in taxes (Stiglitz and Driffill, 2000). It requires that those with equal status-whether measured by ability or some other appropriate scale-should be treated the same. If, for instance, income were the only measure of a person then two persons with equal incomes would be treated as equals. Vertical equity states that people who are better off should pay more taxes (Stiglitz and Driffill, 2000). This generally requires that those with less ability be treated favourably relative to those with greater ability.

The role of these concepts in transport can be illustrated by describing the implementation of road pricing and the use of the revenues. *Horizontal equity* implies that similar users should pay identical tolls. But the question who 'deserves' the benefit (or revenues) according to this criterion is matter of debate. It can be defined as those who actually pay the toll, or it could also include those who change their behaviour (travel pattern), thereby incurring costs in terms of inconvenience, and providing congestion reduction benefit to the toll payers. So the difficulty is that the initial users of the road have become 'unlike' after the implementation of the charge, and should be compensated. The use of road charges to fund public transport is an example. Horizontal equity is further complicated by the existence of externalities from motor vehicle use, including accident risk and environmental degradation. That vehicle use imposes costs on other people itself represents horizontal inequity. If the criterion is horizontal equity and external impacts are recognised, then revenues may be used to compensate for external costs (Litman, 1996). Funding candidates may include environmental and social programmes that mitigate the harm of motor vehicle use. However, compensation for external costs may, in turn, induce inefficient behaviour by the recipients of externalities, in the sense that insufficient incentive is provided to avoid incurring the externality (Oates, 1983; Verhoef, 1994). This implies that (also) from this perspective, there may be trade-offs between efficiency and equity in the regulation of externalities.

Vertical equity is concerned with the treatment of individuals and classes that are unlike. By this principle, the distribution of costs and benefits should reflect people's needs and abilities. Progressive tax rates, and need-based services such as programmes to help the poor, seniors, and disabled people, are examples of policies reflecting vertical equity. Vertical equity is often measured with respect to income. This is an imperfect metric, since people with the same income often have very different needs and abilities. Road pricing is usually considered vertically inequitable because charges impose a relatively larger burden on the poor. For example, a €2 per day toll might be horizontally equitable (everybody pays the same amount), but vertically inequitable because it represents a larger portion of income for a lower-income driver than for a high-income driver. This fact is tempered by the fact that lower-income people drive less on average than those with higher incomes.

Another equity issue refers to spatial or *geographical equity*, which is concerned with the treatment of individuals located in various regions or cities. Congestion pricing could be considered as unfair from this point of view, as charges (depending on time and place) will differ among regions. Another illustration of spatial equity concerns in transport is the experience of Sydney City Council, which decided that transport availability should not depend on the geographical area in which a person lives. Transport services should be available equally to people across the Sydney metropolitan region.

It should not be forgotten that it remains a political issue to decide what allocation of road pricing revenues is equitable. Political acceptability will reflect popular perceptions and the distribution of political power. When policy makers are not satisfied with the situation, the implementation of individual specific transfers can satisfy the distributional goals. If this redistribution can be realised without distorting the market mechanism, equity and efficiency can both be reached. The proper instrument for carrying out such transfers is a lump-sum tax, i.e. a tax that does not depend on any action of the individual: there is no way that he can change the tax liability (Atkinson and Stiglitz, 1980). A lump-sum tax would be one that induces income effects alone, no substitution effects. If such lump-sum transfers were possible there would be no reason to worry about distributional concerns in the transportation pricing policy domain. Unfortunately, in practice, it is almost impossible to effect transfers without distorting the market mechanism.

It appeared from the previous discussion that both the consumers' surplus and the social surplus weight monetary gains and costs equally for all individuals. The fact that these objective functions are so often used in transportation policy analysis does not imply that researchers deliberately want to ignore distributional issues. The main reason for using social surplus as the welfare measure is that it is easier to use, mainly because it requires only information at the market level.

Sometimes the term 'first-best' optimum is reserved for situations in which lump-sum taxes can be used to address distributional issues. In such circumstances, the marginal social value of the public good is, in the optimum, equal to the welfare weight of each traveller. In such a first-best optimum, prices are equal to marginal costs. This does not mean that there is no reason for government intervention because of the existence of externalities. Charges including the marginal external costs have to be introduced in order to guarantee that the travellers pay the full marginal cost associated with their actions.

This links to the 'user pays' concept, which states that all users of transport infrastructure should pay for the costs, including environmental and other external impacts. Protection of the environment has become an important objective for governments in recent years, and the 'polluter pays' principle is often proposed to reduce and control environmental pollution in a fair way. Marginal cost-based pricing can be regarded as being fully consistent with the user pays principle under first-best circumstances. However, all dimensions of travel behaviour must be priced at marginal social cost, and distortions elsewhere in the economy must be absent in a first-best optimum.

Under this interpretation, the 'user pays principle' implies that each user fully pays for the cost he imposes. But the principle can also be interpreted to mean that users together should cover the costs they collectively impose, implying average cost pricing, rather than marginal cost pricing. These two concepts are mutually inconsistent, unless marginal cost pricing just suffices to cover costs.

2.4 Deviations from first-best pricing

2.4.1 Deviations from marginal cost pricing

The previous section has shown us that equality of prices and marginal costs leads to an efficient use of resources in an otherwise ideal world. But the practical world is not ideal. Actual (market) prices may deviate from marginal costs for a number of reasons. Moreover, given the existence of such distortions, it is usually not optimal to set the other prices exactly equal to marginal costs. Most of these reasons result from market failures. The following reasons can be mentioned:

- Imperfect competition (e.g. monopoly);
- Increasing returns to scale (indivisibilities of supply: fixed capacity);
- Imperfect information;
- Indivisibilites of demand: peak load;
- Externalities;
- Difficulties with implementing marginal cost pricing (price instrument);
- Policies in favour of equity.

Imperfect competition implies that individual suppliers do not face a completely elastic demand curve. Profit maximisation then implies that a mark-up will be added to marginal costs. Only under conditions of perfect competition will market prices be equal to marginal costs.

If prices are equal to marginal costs, industries with *increasing returns to scale* (decreasing cost industries) will suffer losses, and are therefore unable to exist. In the absence of subsidies, it is impossible to have prices equal to marginal costs in such industries.

Imperfect information can reduce market efficiency: consumers need to have accurate information about their choices. For example, a rideshare programme could fail to attract users because there is little demand for the service, or it could be that potential users do not know about it or have an inaccurate impression of it.

Many parts of the transport industry experience a systematic pattern of *demand fluctuations* within a given period, with the pattern repeating itself from period to period. The duration of the fluctuations is too short to permit capacity to be varied to match them, while it is too expensive or physically impossible to store spare capacity to meet the requirements of the peak demand period. If sufficient capacity is provided to meet the peaks, then in the rest of the time varying amounts of it will be lying idle. On the other hand, the demand at each time will depend on the price that prevails at that time, as well as the prices set for all other times. In general, therefore, pricing policy could be used to flatten the peaks and raise the lows, so as to get a more even rate of capacity utilisation and a lower level of required capacity. The indivisibilities of demand is then that of determining an overall capacity level and optimal values for a sequence of prices over the demand cycle. The problem may be regarded as one of applying marginal cost pricing to a system with fluctuating demand.

In the presence of *external effects*, market prices will (even under conditions of perfect competition) not be equal to marginal costs. In order to make prices equal to marginal costs, they have to be adjusted appropriately by internalising the external effects. As we will see later, this requires tolls or subsidies, which are not always easy to implement.

Difficulties with implementing marginal cost pricing may arise when it is impossible to impose perfect competition or equality between prices and marginal costs by means of a governmental decree. Even if this were possible, it is doubtful whether it would be desirable. In modern economies, many markets are characterised by product differentiation which implies that producers can, to some extent, create their own markets and have some market power. Moreover, product differentiation is often to the benefit of the consumer. The development of new versions of a differentiated product usually requires large investments that are not reflected in the marginal costs of its production. Another kind of difficulty is related to the transaction costs incurred in setting prices equal to marginal costs. The administrative cost of collecting marginal cost fees, most of which are highly variable, can be rather high. This places

a limit on the precision with which rate structures can reflect specific costs, although new electronic pricing systems reduce transaction costs.
When governments are unable to impose marginal cost pricing in other markets than transport, marginal cost pricing in transport itself would typically no longer be optimal. A straightforward example concerns labour taxes that would distort the labour market. When these exist, it is to be expected that optimal congestion charges for road transport – mainly affecting commuters and hence affecting labour supply decisions – would not only reflect marginal external congestion costs but in addition would also reflect the current distortions on the labour market.
Social policy is not only concerned with efficiency, but also with *equity*. In the absence of instruments that enable the government to redistribute resources without distortions, this may require prices that deviate from marginal costs, for instance when luxury goods are taxed heavily (see also Section 2.3.2).
The implication of this list of reasons is that it should not be expected that in actual economies all prices will be (or can even be) equal to marginal costs. The transport market is characterised by several market imperfections which makes it very unlikely that the market, without regulation, will set transport prices equal to marginal social costs and, therefore, social welfare is not optimised. In the following, three specific market failures that play an import role in the transport market will be discussed; namely, externalities, cost-related issues (i.e. economies of scale, indivisibilities and common costs), and monopolies. In addition, some remarks will be made on the question of whether it is possible to correct for these market failures and in which way.

2.4.2 Externalities
The essence of an externality is that it involves (i) interdependence between two or more economic agents, and (ii) failure to price that interdependence. Formally, externalities exist when the activities of one group (either consumers or producers) unintentionally affect the welfare of another group, without any payment or compensation being made (Button, 1993). Most attention in transport is paid to the negative (costs) externalities, although also positive externalities (benefits) have been identified (for a discussion on this latter issue, see Verhoef (1996)). It is quite clear from everyday experience, that there are costs associated with transport that are not directly borne by those generating them. Transport generates many negative externalities, including noise, accidents, pollution, and congestion. Road travellers, for example, impose noise and vibration costs on those living adjacent to highways. In the introduction we noticed that these costs may be significant. Total congestion costs may be small compared with other externalities, but marginal congestion costs can be substantial in comparison to other marginal external costs (e.g. marginal external cost estimates from a Dutch study indicate that the external congestion costs exceed the other external cost categories by several orders of magnitude (CE, 1999)).
A result of the clear presence of externalities in transport is that the early neo-classical writers studying market failures frequently illustrated their viewpoints using transport examples. Dupuit was the one of the first in 1844 to illustrate efficient pricing of public goods (Button and Verhoef, 1998). Coase (1960) considered the absence of property rights in relation to the existence of externalities for a railway. Another well-known example is that of a congested road, including optimal congestion charges (Pigou in 1920). They all showed that the market mechanism fails to allocate resources efficiently.

It should be emphasised that optimality does not imply the total elimination of congestion and pollution, but rather the achievement of optimal levels of external costs. Ideally, externalities should be contained to the point where the costs of further reductions exceed the marginal social benefits. Let us analyse the problem of externalities by examining road traffic congestion together with the use of pricing methods. Similar analyses will also hold for other transport modes and other externalities, but road traffic congestion is, in a marginal sense, a very important externality, and offers a useful basis for analysis.

Congestion

The demand for transport is not constant over time. In large cities there are regular peaks in commuter travel, while on holiday routes, both within the country and to overseas destinations, there are seasonal peaks in demand. Transport infrastructure, although flexible in the long run, has a finite capacity at any given period of time. When users of a particular facility begin to interfere with other users because the capacity of the infrastructure is limited, then congestion externalities arise. It should be added that not only does congestion impose costs on the road user in terms of wasted time and fuel (also referred to as the 'pure congestion cost') but the stopping and starting it entails can also worsen atmospheric and other forms of pollution. This latter problem is particularly acute with local forms of pollution because road traffic congestion tends to be focused in urban areas.

One idea for optimising the level of congestion is to use the price mechanism to make road users more fully aware of how they impede on another. The idea that motorists should pay for the additional congestion they create, when entering a congested road was first suggested by Pigou (Pigou, 1920). Ideally they should pay the actual road users affected, but this is impossible in practice, so the idea is that an organisation (e.g. the relevant road authority) should be made responsible for collecting the charges.

The economic costs of road congestion can be calculated using the engineering concept of the speed-flow relationship. If we take a straight one-way street and consider traffic flows along it over a period of time at different speed levels, then the relationship between speed and flow would appear as in Figure 2.2. It shows that, as vehicle numbers entering a road increase, average speed does not at first significantly change as does the flow, measured by vehicles per hour. At low volumes of traffic, when vehicle impedance is zero, high speeds are possible, constrained only by the capability of the vehicle and legal speed limits, but, as the number of vehicles trying to enter the road increases (so they interact with existing traffic), drivers will slow one another down. Up to a point, flow will continue to rise because the effect of additional vehicle numbers outweighs the reduction in average speed. The maximum flow is reached when increased traffic volume ceases to offset the reduced speed (the road's engineering capacity). The absence of information causes motorists to continue to enter the road beyond this volume, thus leading to further drops in speed and resulting in the speed-flow relationship turning back on itself. These levels are known as 'forced flows', while economists often use the term 'hypercongestion'.

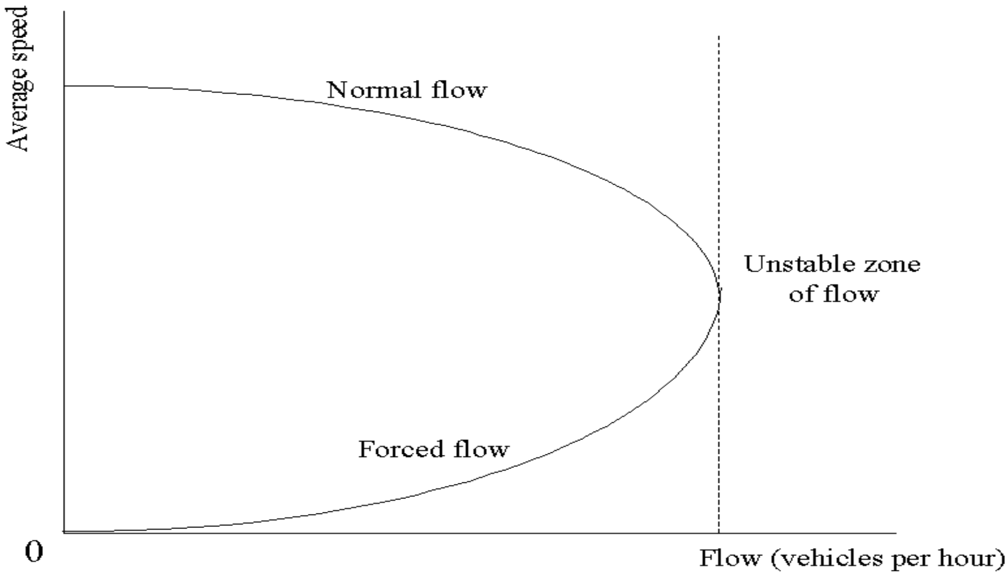


Figure 2.2: The speed-flow relationship
Source: Button, 1993.

Speed-flow curves can be used to measure the economic costs of congestion. Generalised travel costs include the motoring costs plus the travel time cost for a certain journey. Broadly, faster travel in urban areas means cheaper travel in terms of generalised cost – vehicles are used more effectively and travel times are reduced. The average generalised costs of a trip will increase as flow increases up to the maximum flow rate. It will continue to rise as hypercongestion sets in and produces a reduction in the rate of vehicle flow.

Pigou's economic analysis of road pricing and costs is explained as follows. We use a simplified framework and are not concerned with matters such as pollution and safety, and suppose a simple road without junctions. In these circumstances, road users are identical, apart from their marginal willingness to pay for a trip, represented by the demand curve D=MPB=MSB in Figure 2.3 (marginal private and social benefits, respectively). Individual users entering the road will only consider the costs they personally bear (marginal private costs, MPC), but not the external congestion costs (marginal social cost, MSC) they impose on other road users. The difference between marginal social costs and marginal private costs is caused by congestion. Individual motorists will only consider the average costs experienced by road users and take no account of the impact of their trip on other vehicles. Consequently, the marginal private cost is equal to the average social cost (ASC).

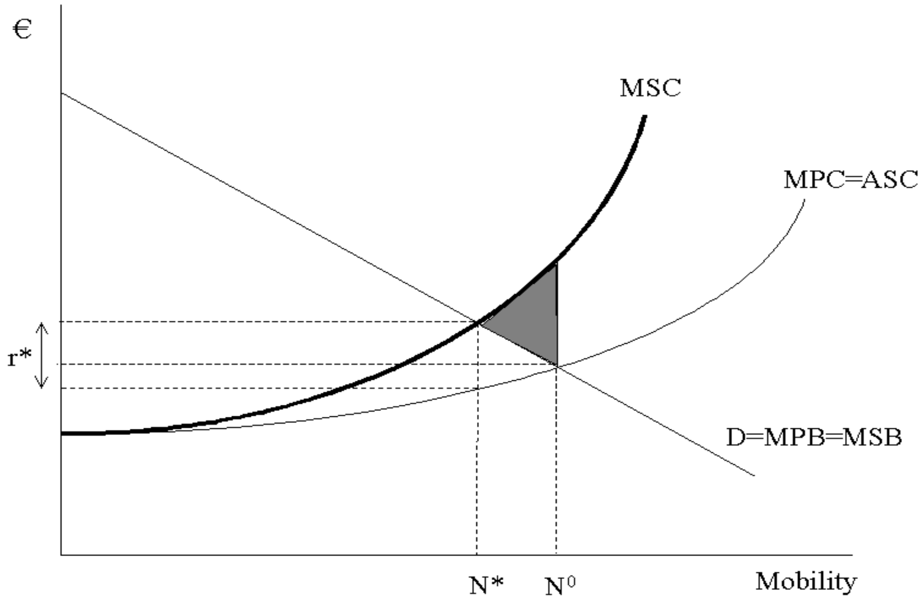


Figure 2.3: The economics of road pricing
Source: Button and Verhoef, 1998.

The fact that potential trip makers tend to consider only the private costs of any trip and ignore the external or social costs means that effectively ASC is the decision-making curve for private motorists. This means that road utilisation will be N^0, at which point, marginal private benefits equals marginal private costs (the free market equilibrium outcome). This is excessive from a social point of view, since at traffic flow N^0, the marginal social costs (including congestion costs) is (much) higher. The socially-optimal level of traffic flow is N^*. To internalise the externality or external costs of congestion, it would be necessary to impose a congestion tax. The charge that accomplishes this optimum is the Pigouvian charge r^*. This is equal to the difference between the marginal social costs and marginal private costs at the optimum, also known as the marginal external congestion costs. The shaded area reflects the welfare gain realised through introducing this charge. The Pigouvian tax is a charge imposed on the traveller or car driver, equal to the amount of the marginal external cost of the transport activity concerned, ensuring a Pareto-efficient allocation of resources. Theoretically, this policy strategy is preferable in a market system, but its implementation may encounter great difficulties as a result of high transaction costs caused by the 'large number' case and the circumnavigating behaviour of travellers.
Many parts of the transport industry experience a systematic pattern of demand fluctuations leading to congestion within a given time period, with the pattern repeating itself from period to period. The duration of the fluctuations is too short to permit capacity to be varied to match them, while it is too expensive to store spare capacity to meet the requirements of the peak demand period. This has led Vickrey (1969) to assume that traffic congestion takes the form of cars queuing behind a bottleneck. This model endogenised individuals' departure times which generated a

wealth of insights into urban rush-hour auto congestion (see for instance Arnott et al., 1998).

2.4.3 Economies of scale, indivisibilities and common costs

The presence of externalities, discussed above, is one of several peculiar characteristics of transportation which causes the failure to apply marginal cost pricing. Transportation facilities and services often require capital intensive infrastructure, and vehicle needs leading to certain industry specific characteristics may cause particular pricing problems. Specifically, the large fixed investment costs and the joint use of the facilities and services may result in necessary deviations from marginal cost pricing. We now discuss the presence of economies of scale in transport, the implications of indivisibilities, and the existence of common or joint costs.

Economies of scale

A characteristic of physical transport infrastructure is the considerable capital costs, which are often higher than the associated operating and maintenance costs for the infrastructure provider (especially on longer distance infrastructure), and can be very long lasting (see also Nijkamp and Rienstra, 1995). Once committed, infrastructure investment usually has few alternative uses and is normally regarded as sunk cost. This fixed component, such as roads, railways, bridges and runways normally give rise to significant economies of scale (marginal costs are below average costs). Once a rail track is laid, the marginal costs of using it falls until a certain capacity level is reached. Firms with large sunk costs and facing economies of scale have marginal costs that are lower than average costs, so that pricing at marginal costs does not generate enough revenue for the firm to be financially self-sufficient. In addition, transport vehicles, such as railcars and buses are also subject to scale economies in operation, though they are generally not as expensive as the infrastructure.

In the long run, however, congestion externalities may show up, resulting in an increase in marginal costs. A toll should be installed which optimally should equal the external costs (Pigouvian charge). A major contribution of Mohring and Harwitz (1962) was to show that the revenues from such a congestion toll will just cover the costs of the facility provider so long as there are no economies or diseconomies of scale in facility capacity, and the facility provider is investing optimally. This holds under certain conditions and concerns optimal highway investment in a first-best world (Lindsey and Verhoef, 2000).

Budgetary problems are especially common in transportation because transport services often exhibit economies of scale so that marginal cost pricing does not generate enough revenues to cover costs. Ramsey pricing is often suggested to be a solution in order not to deviate too much from efficient pricing. Ramsey pricing minimises the distorting effect of charging more than marginal cost by increasing prices more in those markets where demand is least sensitive to price (Nash, 2001). The basic idea is to charge those customers with the least price elastic demand the largest mark-ups necessary to cover marginal cost and thereby minimise the reduction in consumption that occurs from charging prices that are higher than marginal cost. Commuters, for instance, will be charged more than shoppers, and business travellers more than leisure passengers. It should be noted, however, that this form of price discrimination has itself often been regarded as unfair as it exploits market power to raise the price for the captive user. If the view of equity is that all users should contribute to the cost of that facility in proportion to their use of it, then some form of average-cost pricing is the only admissible pricing policy.

Indivisibilities

Problems arise when applying marginal cost pricing to transport infrastructure and services, because capacity can only be increased in relatively large indivisible units. There are many examples to be found in the transport sector: if the capacity of a railway coach is 60 passengers, then to carry 61 persons requires another coach. Existing airports at full capacity are another example: expansion requires a new runway and terminal facilities. It is often extremely costly to make (small) additions to physical capacity. The issue is one of optimal investment timing, since, under conditions of growing demand, there will come a point at which an increase in capacity will be worthwhile. This brings us to the distinction between short-run and long-run marginal costs.

In specifying the marginal cost-pricing rule, it is important to understand the distinction between short-run and long-run marginal costs. The distinction arises because different factors of production, used in providing transport services, have differing degrees of fixedness or variability over various business planning horizons. Airports, for example, facing increased demand may be able to increase throughput in the short term, whereas in the longer term the operator is forced to invest in new infrastructure (e.g. a terminal or runway). In the very short term, all inputs and costs are essentially fixed, and, conversely, in the long run, all inputs and costs are ultimately variable (Braeutigam, 1999). Over a planning horizon, it is important to identify those costs that can be varied (variable costs) and those which cannot be varied (fixed costs). Prices should normally be set in relation to short-run marginal costs, which may lie above, below, or be equal to long-run marginal costs.

What this means for optimal pricing and optimal investment can be illustrated with an airport example (investment in a terminal). The initial marginal costs of using a terminal will be very low, so the price is low when set according to short-run marginal costs (excluding investment costs). There is no need for new investment as there is spare capacity. If the demand function shifts outwards over time, the marginal costs will (sharply) increase due to congestion effects. A new terminal might be needed now. When the price in the peak period consists of operational costs (including that of additional investment), the corresponding demand will give a clear indication of the necessity of the investment. Continuation of excess demand with these LRMC charges justifies investment in a new terminal. In the long-run optimum, SRMC=LRMC may apply (Mohring-Harwitz type of equilibrium: see economies of scale).

This analysis implies that marginal cost pricing could produce market fluctuations in price before and after capacity adjustments are made. Further, whether or not the airport makes a profit depends on whether the price lies above or below the long-run marginal cost curve, LRMC. At any given point in time, the terminal might be profit or loss making; however, over its life, the net present value of the investment in additional capacity should be positive if it is to be worthwhile. Such fluctuations in prices and profits are likely to be undesirable, but unavoidable, because any other pricing pattern will produce welfare losses. If the price floor is raised above marginal running costs during times of excess capacity, then underutilisation will occur. If a price ceiling is set, during periods of excess demand, non-price rationing methods will be required. Similarly, premature investment in capacity is likely to represent a waste of capital resources. It will, however, keep marginal cost-based prices low.

Common and joint costs

A related set of pricing complications occurs because transportation firms often use the same facilities, equipment and labour to produce different services: they are multi-product firms. This leads to the conceptual and practical problems of determining transport prices associated with fixed and variable costs and choosing the relevant time period because many costs may also be 'joint' or 'common' to a number of users. Pricing in these circumstances may be difficult, as it is not always clear how to allocate costs between products. This may make it difficult to determine marginal costs. Joint costs exist when the provision of a specific service necessarily entails the output of some other service or product at little extra expense (Gomez-Ibanez, 1999). Jointness is a technical feature and exists at all points in time, that is, both before and after investment or capacity decisions are made. The classic example of jointness is the return trip, where the supply of a transport service in one direction normally implies the provision of a return service (Button, 1993).

Common costs are similar to joint costs, in that they are incurred as a result of providing services to a wide range of users, but differ, in that the resources used to provide one service do not unavoidably result in the production of other services (United Nations, 2001). An airport, for example, faces considerable common costs. A terminal is used by different types of users: terminal retailers and air passengers. The same holds for runways, these are used by different types of planes. The allocation of these common costs among users poses particular practical problems, which consequently also leads to pricing problems.

2.4.4 Monopoly

Firms facing the previous mentioned aspects such as high fixed costs and economies of scale, together with significant indivisibilities in the provision of capacity, have limited competition. These circumstances, often the case in the transport industry (particularly in terms of infrastructure), give rise to monopolies. Under these conditions, and a fairly small transport market relative to the optimal size, a good or a service can only be produced at least cost if only one firm is engaged in its production and a natural monopoly is likely to emerge. Public transport companies are often claimed to be a natural monopoly, although there may be little evidence of scale economies (Gomez-Ibanez, 1999). Constraints on competition are intended to avoid certain problems, but this tends to increase costs and does not provide an incentive for the development of alternatives, such as demand response transport and premium service commuter buses. A more competitive transport market may therefore result in benefits to consumers.

Imperfect competition creates a major distortion in the market for transport services. There is every risk that the monopolist will not provide optimal transport prices and, an unregulated market will therefore not lead to the maximisation of social welfare. In such circumstances, the government may decide to intervene either by directly providing the transport services or by regulating prices.

Hence, it is unlikely that prices equate marginal social costs under conditions of monopoly. Figure 2.4 illustrates how price and output would be determined under conditions of monopoly, and under competition within an industry subject to declining costs (e.g. the transit industry). The monopolist aiming to maximise profit will expand output up to the point at which marginal revenue is equal to marginal cost – point *a* in Figure 2.4. The corresponding level of output, Q_M, leads the monopolist to charge a price of P_M and supply the market at an average cost of C_M. The profit equals Q_M (P_M- C_M). Under perfect competition, demand and supply determine the price. The aggregate marginal cost curves are assumed to represent the industry supply curve which results in an equilibrium at point *b* in Figure 2.4 with output Q_C. Costs are higher than revenues and, at this point, the firms in the industry will make a financial loss. This is often the case in transport due to economies of scale.

The existence of declining average costs in the transport industry is an important reason for the emergence of natural monopolies in many sectors. The potential monopoly power and the possibility of abuse of this position may be reflected in high prices (or price discrimination) and has often led to government price regulation and public ownership. This is, for instance, the case in the airport industry. Governments are afraid of private airports setting inefficiently high prices. Therefore airports are often in public hands, or privatised airports are (price-)regulated. When governments take over, and prices are set equal to marginal costs, it is obvious that a subsidy is needed. It may also be possible to look for pricing policy options to assist cost recovery while at the same time minimising the resulting allocative efficiency losses. Two-part tariffs (consisting of a fixed charge per consumer and a variable charge per unit consumed) and Ramsey pricing have been suggested in these cases.

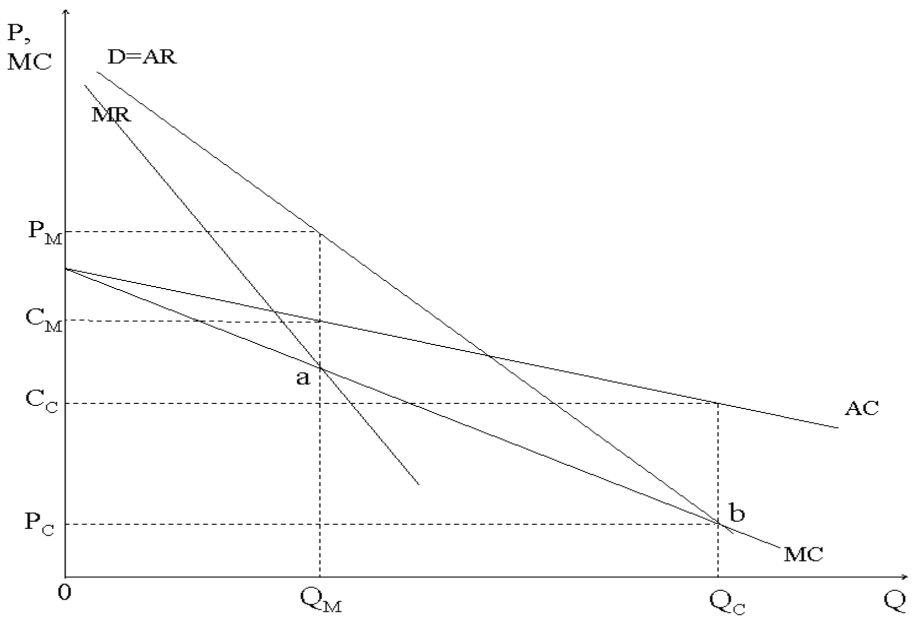


Figure 2.4: Price determination under monopoly vs perfect competition

2.5 Second-best pricing issues

From the previous discussion, it became clear that marginal cost pricing maximises social welfare. The standard exposition uses the well-known market diagram that identifies the free-market equilibrium at the intersection of the marginal benefit (demand) and the marginal private cost function (see Figure 2.1), and the optimum at the intersection of the marginal benefit and the marginal social cost function. When the existence of marginal external costs drives a wedge between marginal private and marginal social costs, the free market equilibrium and the optimum will not coincide. A ('Pigouvian') tax could then be used, equal to marginal external costs, which ensures that the consumers are confronted with all the costs of their decision. These pricing principles and a Pigouvian tax only hold in a theoretical first best world. This

first-best pricing is increasingly recognised as being of limited practical relevance, but it might serve as a useful theoretical benchmark.
We have seen that various market circumstances and characteristics hinder the transport market in setting prices based on marginal costs. In addition, various constraints and barriers may exist that prevent a regulator from determining prices that it ideally would like. Verhoef (2002) mentions the following important constraints:

- Technological and practical constraints: first-best pricing requires charges that vary continuously over time, place, route chosen, type of vehicle, driving style, etc, which might be too sophisticated and not understood by drivers or impossible to implement under available charging technologies;
- Acceptability constraints: there may be too much resistance and uncertainty (e.g. about the objective and necessity of the measure) that it may seem preferable to start with a few small-scale demonstration projects;
- Institutional constraints: one example is where local or regional governments cannot affect some transport charges that are set by a higher level government;
- Legal constraints: ideal prices might not be possible on the basis of legal arguments (e.g. when taxes should be predictable);
- Financial constraints: for instance, the prior definition of minimum or maximum tax revenue sums to be collected;
- Market interaction constraints: transport taxes will have many consequences for other markets, among the most important is the labour market;
- Political constraints: charges may become a political issue much more than an economic question.

This has led to some discussion on the practical relevance of marginal cost pricing. Rothengatter (2003) argues that marginal cost pricing is no longer optimal when aspects such as acceptability and institutional consequences are introduced into the analysis, and a real-world pricing system can therefore not be based on abstract economic theory. Nash (2003) replies that indeed difficulties and uncertainties remain (which should be carefully considered), but that there is no need for a totally different theoretical approach, marginal social costs are the correct starting point in the development of any efficient pricing policy.
Given these constraints and discussions, economic research has focused on setting prices that are available optimally, under the constraints applying: second-best prices. Examples of second-best tolling include the use of toll cordons around cities instead of tolling each road in the network, and the use of step tolls instead of smoothly time-varying tolls. It is safe to state that second-best pricing will be the rule for the implementation of marginal cost-based pricing in reality.

2.5.1 Second-best pricing: an overview of some results

It is clear that some aspects of the transport sector do not correspond to first-best conditions. We then enter the world of second-best, where the imperfectness of one variable has consequences for the optimal value of others. The conclusions that emerge from second-best analyses are dependent on the details of the situation under consideration, and it is hard to draw general conclusions. A substantial technical literature has emerged over the last decade that addresses various types of second-best pricing schemes (i.e. what do the tax rules look like, how do they deviate from Pigouvian charges), and analyses the relative efficiency of these schemes. Attention has turned in the recent literature to more realistic types of 'second-best' pricing, in which various costs or constraints deter or prevent the setting of first-best tolls. Much of this literature is reviewed in Lindsey and Verhoef (2001), whereas MC-ICAM (2002) gives insight into the kind of analysis. Drawing heavily on both these studies, three of the most relevant second-best problems that have been studied in transportation (congestion) pricing will now be presented.

Networks

First-best pricing in a network assumes that each link of a road network is efficiently priced. This is often impossible due to excessive costs, the requirement of toll-free alternatives by governments, and the likeliness of incremental implementation rather than at once. The question under study is then how second-best tolls should be set on toll roads, given unpriced congestion on untolled roads elsewhere in the network.

This network problem is one of the most widely studied where the simplest version concerns a simple network in which there are two links connecting the same origin and destination. Verhoef et al. (1996) demonstrate that if one of the links is often congested, the optimal second-best toll of the other link can be negative. This study also shows that the optimal toll depends on the relative free-flow travel times and capacities of two routes, and on the price elasticity of travel demand. Welfare gains from second-best pricing are, according to this study, a small fraction of the benefits from the first-best benchmark (only 10%). Other studies have looked at ways to enhance efficiency and have incorporated the possibility of dynamic (time varying) tolls, and sorting of drivers according to value of travel time. This does indeed yield higher absolute efficiency gains.

Most network studies assume a unimodal network. In reality, a traveller has the possibility to choose between modes. The leading example is the choice between public transport and the private car. Tabuchi (1993), for example, uses a second-best framework which is characterised by a road, subject to bottleneck congestion, that runs parallel to a railway. Assuming inelastic demand, and average cost pricing of rail trips (to stay in business), it is shown that the road share of travel is highest with an optimal (time-varying) road toll, and successively lower with a step toll, a uniform toll, and no toll. Another study that reviews second-best choices in a transport network with two modes is by Arnott and Yan (2000). The main difference between second-best problems on networks and those for mode choice is that, in the former case, an assumption of perfect substitutability is often made. Although, at first sight, the two-mode problem appears to be relatively simple, it has proved to be difficult to solve (MC-ICAM, 2002). Results are very much restricted by the assumptions made (such as fixed capacity and a fixed toll) and often complicated and difficult to interpret.

Second-best studies have not only addressed the issue of the level of second-best tolls in different types of networks, but recently the toll location has also been included. Verhoef (2002) examined the selection of individual toll links, and the determination of toll levels using some sensitivity indicators. Yang and Zhang (2002) considered selection of optimal toll levels and optimal locations for achieving maximum social welfare using a bi-level programming approach with both discrete and continuous variables. And Shepherd and Sumalee (2004) explored the usefulness of solving the optimal toll problem for a medium scale network.

Heterogeneity

Travellers and road vehicles differ in a number of characteristics. Vehicles vary, for example, in the road space they occupy, and in weight and acceleration capabilities.

Travellers have different values of time, desired speed, and so on. First-best pricing often makes it necessary to distinguish between different vehicle types and users (because of different marginal costs). It is important to know whether first-best congestion pricing can still be implemented, given these dimensions of heterogeneity, and if not, how second-best tolls are optimally determined. In this context a distinction is often made between anonymous tolling schemes (independent of vehicle type and driver) and non-anonymous (type-specific) tolls.
Many studies have been conducted on the implications of the problem of heterogeneity and pricing. The topics range from heterogeneity in drivers' values of time and trip-timing preferences to the heterogeneity in travel speed. Another example of a study that is of interest here is that of Verhoef and Small (2004), who consider a differentiation of tolls across parallel traffic lanes by using a static model. They show that an anonymous toll may still be optimal on each lane separately, and efficient segregation of drivers is achieved without regulation. It should be noted that the extra gains are rather small, so that a second-best single toll applied to the entire highway does not impose much of a welfare loss. Optimal anonymous tolling may entail segregation of vehicle or driver types onto separate routes.

Interactions with other sectors
Imperfections in other sectors of the economy have consequences for second-best optimal pricing of transport services. Modelling the transport sector typically assumes that the rest of the economy operates under first-best conditions. Although applied with the aim of simplifying the modelling exercise, it is not very realistic. For example, the existence of distortionary taxes on other markets (especially the labour market) and income distribution (which might be suboptimal) can be motivated by governmental objectives but have implications for pricing in transport. Intersectoral issues matter because transport pricing interacts with other markets that may be strongly distorted.
The existing literature on intersectoral issues shows their importance for optimal pricing: they are almost always relevant (MC-ICAM, 2002). The most relevant relation is with the labour market, which is heavily distorted: labour taxes exist mainly because the government needs revenues and for equity reasons, but strongly distort the labour-leisure choice. This implies that, whenever there is a reform in transport prices, the effect on the labour market distortion should be taken into account. Moreover, since distributional objectives can hardly be achieved by using distortionary labour taxes alone, the distributional concern will almost always be relevant in transport pricing.
In this context, the spending of revenues from pricing schemes is also important for the overall success of the measure. These revenues might be used to subsidise public transport, but also to reduce labour taxes, to increase government spending on other services, and so on. The effects for other sectors should not be neglected when looking at the effects of pricing. Parry and Bento (1999), for instance, show that the general equilibrium effects of road pricing schemes are sensitive to the spending of revenues, and may deviate considerably from partial equilibrium outcomes. This may have important implications for gaining social acceptance for congestion pricing schemes.

2.6 Conclusions
This chapter has aimed to give an overview of the economics of transport pricing and provide a basic understanding of the fundamental issues in transport pricing. It

addresses a range of complexities that arise due to the nature of the cost structure and different market conditions generally observed in the transport sector.

Pricing is a method of resource allocation: there is no 'right price', rather there are optimal pricing strategies to permit specified aims to be achieved. Several transport pricing objectives can be distinguished, such as economic efficiency, profitability, and cost coverage. Whilst there are many transport pricing objectives, economists will usually argue that the pursuance of economic efficiency should take precedence. Optimising the welfare of society may even be the most important to governments involved in setting prices in mobility. The concept of economic efficiency is derived from welfare economics, and is concerned with the allocation of resources in an economy. According to this theory, prices should equate with marginal social costs (throughout the economy) in order to obtain maximum social welfare. Marginal cost pricing results in transport services being provided up to the point where the benefit for the marginal unit is equated with the costs of providing that unit.

This efficient price will only prevail as a market equilibrium under certain conditions, i.e. all other markets also have efficient pricing, there are no constraints on transport prices, and market failures are non-existent. However, this optimal outcome may not reflect policy objectives. Distributional goals can be satisfied by making individual specific transfers, and, if these can be realised without distorting the market, equity and efficiency can both be reached.

In most cases, however, actual market prices deviate from marginal costs for several reasons. The transport market has some characteristics, which makes it very unlikely that the market, without regulation, will set transport prices equal to marginal social costs and, therefore, social welfare is not optimised. Examples of these reasons include imperfect competition (monopoly), increasing returns to scale and externalities. One of the most particular externalities in transport is congestion. Congestion is, in fact, caused by excessive demand exceeding capacity. The price is not equal to marginal costs because the externality is not reflected in the price to be paid by the users. A Pigouvian charge would, in a first-best world, be the optimal way to internalise the external costs of congestion resulting in optimal prices.

These characteristics make marginal cost pricing unrealistic in a free market. Governments may want to intervene and set more efficient prices. This is not straightforward, as the regulator may face several barriers and constraints preventing it from setting optimal prices (e.g. technical or political in nature). Obviously, the regulator has then to resort to 'second-best' pricing: setting prices that are available optimally under the constraints applying. Recent research has, therefore, focused on more realistic types of second-best pricing, in which various costs or constraints deter or prevent the setting of first-best tolls. This latter is often regarded as a useful benchmark. Examples of second-best problems discussed in this chapter include the problem of networks and the interactions with other markets or sectors. Under second-best conditions, optimal prices may be said to be marginal cost-based, rather than identical to marginal costs. It appears that second-best prices are more difficult to determine and implement, and may lead to considerably lower welfare gains compared with first-best prices.

Part I: Behavioural responses to transport pricing

Chapter 3

Behavioural responses to road pricing

3.1 Introduction

The previous chapter has outlined the economic principles of transport pricing. Economic theory argues that prices should equate marginal social costs to optimise welfare. Implicit assumptions on the behavioural changes of transport users to transport pricing lead to welfare changes. A Pigouvian charge, for instance, corrects for congestion costs and reduces demand for road space. This is only one type of response. This chapter discusses behavioural responses to road pricing more generally, not only theoretically but also empirically.

Prices reflect the direct, internal, perceived costs involved in consuming a good, that is, the factors that individual consumers must trade off when making purchase decisions. The term is sometimes limited to monetary costs, but it can include non-monetary costs such as time, discomfort, and risk. For example, the price of a public transport trip includes not only the financial cost of the ticket, but also expenses for getting to the bus-stop, plus the time and risk of travel. Price changes often affect consumption decisions. For example, one may consider a particular product too expensive at its regular price, but might buy it when it is discounted. Similarly, a price increase may motivate consumers to use less of a product or shift to another brand. Although individually these decisions may be quite variable and difficult to predict, in aggregate they tend to follow a rather predictable pattern: when prices decline consumption increases, and when prices increase consumption declines. This is called the "law of demand". Transportation activities tend to follow this pattern. When the monetary, time, discomfort, or risk costs of travel decline, the amount of mobility (measured in trips, person-miles, or ton-miles) tends to increase.

However, people's responses to transport pricing are not that straightforward. Price increases may also induce travellers to change their modal use or change their departure time, depending on the type of measure. A wide variety of pricing measures exists, having different consequences for travel behaviour. Hence, price measures are seen as one of the major tools for policy makers to influence transport development. The design of measures will generally depend on the objectives of the government to steer the development of transport in a more desired direction. It is, therefore, important for authorities to have clear insight into 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 the kilometrage of a given vehicle relatively weakly, compared with a kilometre charge). Equally important, however, is the price sensitivity (often indicated as elasticity by economists) of transport users for the various relevant types of behaviour that together define transport behaviour. People will react differently to various pricing schemes.

The main aim of this chapter is to present an overview of the literature on road pricing effects and identify the relevant dimensions of behaviour and assess their potential empirical relevance. It serves as input for the empirical work reported later in Chapters 4 and 5. We will mostly discuss the effects from the economic perspective, but the effects of road pricing have also been studied by other disciplines such as psychology and traffic engineering. The work of traffic engineers on road pricing effects is, in terms of underlying theoretical concepts and methods used, very much related to that of economists. We have, therefore, decided to compare the work of economists and traffic engineers on the one hand, with that of psychologists on the other. It is interesting to compare the research methods that have predominantly been used, the underlying models of/or motivations for behaviour, and the relevant dimensions of behaviour. Besides a fundamental understanding of the possible effects that road pricing might have, we may also identify possible (in)consistencies (between disciplines) and open issues.

The link between car costs and behaviour is central in this paper. We will focus on pricing in car transport and provide first an overview of possible measures and the ways people may respond to these price changes. Section 3.3 provides an overview of modelling results for various behavioural dimensions. Section 3.4 proceeds with an overview of empirical findings. Elasticities and practical experiences provide valuable knowledge about the effects of road prices and price sensitivity. These two sections have a strong economic perspective. Section 3.5 continues with a brief overview of interesting psychological research and compares the findings of both approaches. Finally, Section 3.6 concludes.

3.2 The price of car use and behavioural response

Governments are very much involved in the transport market. Hence, transport prices are often set or influenced by the public sector. Governments may have several reasons or objectives for changing prices. Pricing measures are often used to raise revenues, they assist in traffic control and contribute towards the internalisation of external costs. Most often it is a combination of these objectives that is behind the implementation of a pricing scheme. Transport pricing measures can be very diverse and very much targeted towards a certain type of behaviour. Broadly speaking, transport pricing measures can be divided into five different types, according to the way charges and payments are applied (CAPRI, 1998):

- Vehicle pricing, related to car ownership and usage (independent of the roads used);
- Road pricing, related to use of specific roads and areas (possibly at specific times);
- Parking pricing, related to use of parking spaces;
- Public transport pricing, related to use of public transport;
- Special taxes or subsidies, for instance related to commuting (e.g. tax allowance to deduct commuting costs when using public transport), real estate, or particular locations (e.g. near public transport facilities).

This offers governments a wide range of direct and indirect price instruments that can be implemented as part of a policy to ensure correct charging for transport. Transport system users currently do not perceive the full marginal social costs of their travel decisions. This leads to traffic volumes in excess of what is socially desirable, and it implies a suboptimal distribution of transport flows over time and space. For dealing with the various types of externalities (congestion, noise, and so on) economic theory argues that prices should be set according to marginal social costs. For various (practical) reasons, this first-best type of pricing is generally not used or even feasible in transport (see also Chapter 2). However, there are several policy instruments available to governments which can be used to deal with the various externalities. 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. The opposite of charging, viz. subsidising, is also 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; some people change behaviour, others don't. When people decide to change, 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 relocation;
- change in driving style (e.g. speed choice);
- vehicle ownership;
- type of vehicle/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 predictability of the effect of a certain measure rather difficult. The following sections discuss various behavioural responses to transport pricing, including effect sizes and important factors that affect this price sensitivity. We begin with results from the theoretical (economic and traffic engineering) literature, where models are used to assess the impact of a certain price measure on one of the distinguished dimensions above, and continue with an overview of important empirical findings. Finally, results from the psychological literature will be evaluated.

3.3 Behavioural responses in theoretical and empirical models

Transport modelling focuses on ways to simplify and abstract important relationships underlying the provision and use of transport. It is concerned with the methods, be they quantitative or qualitative, which allow us to study the relationships that underlie transportation decision making. In some cases, models can be purely descriptive, but more often there is the explicit aim of seeking the key links between causes and effects in transport decision making either by the providers of transport services or by the users. This is particularly important in practice because transport models are used not only by researchers but also often by policy makers. They need to know the likely implications of their actions on transport behaviour. Hence, models are mainly used to examine the impacts (in terms of efficiency or profits, for example) of particular policy measures, and to determine the behavioural responses of transport users.

A wide variety of modelling approaches has been proposed for particular problems. Road traffic congestion, for instance, is one of the transport problems that has been extensively modelled (for an overview of models used to study traffic congestion, see Lindsey and Verhoef, 2000). One reason is that different (policy) questions related to traffic congestion require different types of models. Moreover, traffic congestion is a complex phenomenon, involving complicated temporal and spatial dynamics. Economists, however, seek manageable analytical formulations to characterise the problem studied and to derive (optimal) results for policy makers.

We are particularly interested in the behavioural responses of transport users to pricing measures. The effects of a pricing measure can be simulated by using a model that tries to capture most of the forces and interrelationships determining transport patterns. Model parameters, elasticities and functional forms are most often taken from observed data, as discussed in the following section. This should ensure that both the qualitative and, to a certain extent, the quantitative conclusions are applicable in reality, and not just confined to the particular computer simulation.

Models, developed by economists or traffic engineers, have to make assumptions on the behavioural responses of transport users in order to estimate the effects of particular pricing measures. It is interesting to investigate how this is done and what the particular results of these modelling experiments are for the various types of behavioural responses mentioned in Section 3.2. We provide a brief overview of the treatment of behavioural issues in the modelling literature, and try to gain insight in the direction and size of the expected effects of the measures. Variabilisation (replacement of fixed car taxation by a kilometre charge) will be treated separately given its relevance to our empirical work that will be discussed later in Chapters 4 and 5. Note that completeness is not the aim: the following subsections only provide some illustrative research examples of those behavioural responses that are also included in our empirical survey to be discussed in the next two chapters.

3.3.1 Trip suppression

Demand modelling for person travel has been dominated by the four-step model (see for an overall reference Ortuzar and Willumsen, 1994). The first stage of this model, trip generation, defines the magnitude of total daily traffic. Since we focus on pricing, we discuss trip suppression, rather than trip generation. Models including an elastic demand function assume that the number of trips made (or kilometres driven) will decline with an increase in prices. Most static models use an elastic demand function, whereas dynamic models (discussed later to predict departure time choices) often have inelastic demand functions. Static-stationary state economic models have in common that traffic speeds, flows and densities are uniform across drivers and constant along the road and – as it were – over time, in the sense that they do not change during a driver's trip (Verhoef, 2002). The models proposed differ particularly in terms of the argument deployed in the specification of cost (normally a generalised cost function) and inverse demand functions used for the characterisation of free-market and efficient market equilibria. The demand curve is often assumed to slope downwards to reflect the fact that, as for most commodities, the number of trips people want to make decreases with the price. In such a setting, Pigou, for instance, derived his optimal toll tax equal to the marginal congestion costs (Pigou, 1920).

3.3.2 Departure time choice

The choice of departure time by road users has been studied using dynamic models. These time-dependent models of congestion build on time-independent models by adding two elements: a specification of how travel demand depends on time, and a specification of how traffic flows evolve over time and space (Lindsey and Verhoef, 2001). In these models, road users typically have a desired arrival time at work, deviations from which imply that schedule delay costs will be incurred. Each individual decides when to depart from home, so as to minimise trip price, which, in the absence of a toll, consists of travel time costs and schedule delay costs. Equilibrium requires that the trip price be uniform over the departure period and higher outside this period. In the simplest version of the model, each morning commuter travels from home to work along a single road which has a bottleneck of fixed flow capacity. Originally proposed by Vickrey (1969), this specific congestion technology (endogenising individuals' departure times) has been made popular especially by the work of authors such as Arnott et al. (1993, 1998) and Small (1992). The bottleneck model is simplified by the assumption that commuters have the same value of time, and demand is price inelastic: N individuals commute, one per vehicle, regardless of the trip cost. This implies that the overall demand for transport will not change when the price changes. The price may only affect the departure time of commuters, ideally in such a way that road capacity meets demand throughout the peak period. The demand is then equally distributed over time.

In a two-route setting, Arnott et al. (1990) show that in equilibrium without tolls, wasteful queuing occurs, although the number of drivers on each route is the same as in the system optimum. An optimal time-varying toll eliminates queuing without affecting route usage. Uniform and step tolls alter route usage, but only slightly. Step tolls generally yield much greater efficiency gains than uniform tolls because they reduce queuing by altering departure times.

3.3.3 Route choice behaviour

Research has been carried out on the effectiveness of pricing measures in reallocating traffic volumes over a network. Economists often focus on the implications of congestion pricing on social welfare. For example, Arnott et al. (1990) study user equilibrium, system optimum, and various pricing regimes for a network of two routes in parallel. They use the bottleneck model in which traffic flow is either uncongested or fixed at a capacity independent of traffic density. Besides departure time, that paper also considers route choices which are assumed to be governed by the trade-offs between travel time and schedule delay costs. As usual, demand is inelastic in this model; hence, gross benefits cannot be evaluated using demand functions. The study focuses on first-best analysis and does not consider the case in which efficient tolls cannot be imposed on both routes. Another study, by Liu and McDonald (1999), considers an urban highway network consisting of two routes connecting an origin and a destination and analyses travellers' route choice behaviour. One route is tolled, and on account of technical and/or political constraints, the other route must remain untolled. In addition, the study considers two time periods: peak and off-peak, to describe travellers' departure time choice. Travel costs consist of travel time costs (caused by congestion) and schedule-related costs. The demand for transport in one period is a function of trip prices in both peak and pre-peak periods. The results show that the optimum second-best tolls can vary appreciably from the optimal first-best tolls imposed on all routes. Second-best congestion pricing is found to have three major impacts on the allocation of traffic volume: (1) diversion of peak period traffic to the free route; (2) shift of peak period traffic to the off-peak period; and (3) reduction in total traffic volume (Liu and McDonald, 1999). Furthermore, it is found that second-best tolls are less effective in reallocating traffic volume than first-best prices.

3.3.4 Modal split choice

Pricing of car travelling may induce people to use other modes of transport. Tabuchi (1993), for example, models a setting in which travellers have a choice between driving and using public transit. This second-best framework is characterised by a road, subject to bottleneck congestion, that runs parallel to a railway. Railway operating costs include a fixed cost and a constant marginal cost per traveller. The railway is congestion free, but uneconomic to run at a low number of passengers. Assuming inelastic demand, and average cost pricing of rail trips (to stay in business), it is shown that the road share of travel is highest with an optimal (time-varying) road toll and successively lower with a step toll, a uniform toll, and no toll. But having an uncongested railway as the alternative mode, rather than a congested highway, changes the relative efficiency gains of the various road tolls. At sufficiently high levels of demand, a uniform toll yields more than half the efficiency gains of the optimal toll. These benefits result from diverting people from the congested road to the uncongested rail network. In estimating location effects, Eliasson and Mattsson (2001) (for more detail of the model, see Section 3.3.6 on location effects) include a public transport system in their simulation model of a generic city. This study also provides estimated effects of congestion pricing on travel patterns. The implementation of general congestion pricing leads to less car traffic in terms of total distance travelled (about 24% less) and total travel time (about 57% less). The use of public transport is assumed to increase (by 4 to 5 percentage units higher than without congestion pricing), whereas car shares decline.

3.3.5 Vehicle occupancy

Whereas congestion pricing and the derivation of optimal tolls have received ample attention, the issue of carpooling has largely been neglected in the literature. For instance, Daganzo (1982) made a first attempt to incorporate carpooling in equilibrium traffic assignment in general networks, but the demand for carpools is assumed to be fixed. This means that the model fails to include the mode choice behaviour of commuters. Yang and Huang (1999), however, use a deterministic equilibrium mode choice model with overall elastic demand. Their analysis concerns the carpooling and congestion pricing problem in a multi-lane highway with HOV (high-occupancy vehicle) lanes. Numerical examples show the efficiency of HOV lanes, first- and second-best pricing and their combinations. Despite the fact that the model is highly simplified, the findings may be relevant for the design and operations of combined congestion pricing and HOV lanes in practice, such as in California. They found that marginal cost pricing provides the most efficient policy option under either elastic or inelastic demand. Reserving one or more entire lanes for carpooling vehicles rarely reduces total costs and nor does it improve social welfare, given marginal cost prices. Nevertheless, conventional carpool lanes alone can be justified at reasonably high congestion levels. Differentiation of tolls across commuting modes should be cautiously implemented. The optimal uniform second-best toll is a weighted sum of the marginal external congestion costs between non-carpooling and carpooling commuters.

3.3.6 Location choices

The effects of road pricing on transport and location patterns have been much discussed. Simulation models for a typical city can be used to examine the impacts of road pricing on transport and location patterns. The model city should then be calibrated to replicate typical observed location and travel patterns. Model parameters, elasticities, functional forms, and so on can be taken from land use and transport models estimated on observed data. This should ensure that the conclusions are also applicable in reality. The first studies on this issue date back to the 1970s when Solow and Vickrey (1971) look at traffic patterns, congestion costs, and land use. They show that, without congestion tolls, the market value of land may be a poor guide to land-use decisions, and lead to an overallocation of land to transportation. Solow (1973) confirms this result by using a simulation model of urban activity including the congestion costs of transportation. He shows that rents nearer the city are too low to properly reflect the social worth of transportation costs in the absence of congestion tolls. This will result in more land to be taken for use as roads than is socially desirable. It remains unknown what the consequences are for location patterns. Another topical contribution from this period compares a model of equilibrium land use patterns in the residential ring of an urban area with an optimal one (Oron et al., 1973). They show that scarce resources can be saved by households moving from the periphery to more central locations in a distorted situation with suboptimal congestion tolls. Proper pricing of transportation will most probably lead to less suburbanisation.

More recently, Eliasson and Mattsson (2001) have developed a simulation model of a generic city to study the effects of general congestion pricing and more specific toll ring pricing. The city, consisting of homogenous zones, contains four types of actors: households, employers, shops, and service establishments. The location of households is determined by their value of plot size and accessibility to workplace, shops and service establishments. Firms locate only according to accessibility to households. Shops and service establishments locate according to the accessibility to households with this difference – that they evaluate the expected number of customers in each zone. They also take into account the proximity to working places and the size of the plot. It would go too far to discuss all other assumptions of the model at this point; rather we focus on the outcomes. It appears that the location effects of congestion pricing are quite small when compared with the effects on the travel pattern. This is related to the assumption that a well-functioning public transport system is available. According to their results, congestion pricing makes the city less dispersed. However, it is not primarily the city centre that grows denser, but the innermost ring of suburbs, which gain about 2% more households and workplaces and about 5% more shops at full congestion pricing. The authors claim that the findings are consistent with findings of various empirical model studies. The location effects of a toll ring are fairly small and depend strongly on where the toll ring is located.

3.3.7 Driving behaviour (speed choice)

Most economic models assume traffic congestion to be caused by a technical, exogenously-given speed-flow relation. The speed-flow relationship is regarded as a reflection of what may be called 'traffic technology'. Driver behaviour does not determine this relationship in conventional modelling. The speed choice can, however, have important implications for the level of congestion and, for this reason should not be ignored. Verhoef and Rouwendal (2004) have included driving behaviour in their analysis by developing a model, in which road users choose an optimal speed, given the situation, so as to minimise generalised travel costs (including monetary costs (fuel), time costs, and expected accident costs). Road users are heterogeneous with respect to their willingness to pay for making a trip, so that the demand function is generally not perfectly inelastic. All road users choose a speed so as to minimise their private generalised cost function. The overall welfare optimum in their model requires tolls to be either accompanied by speed policies, or set as a function of speed. This suggests that speed policies may be a strong instrument in the regulation of flow congestion.

3.3.8 Vehicle ownership

It is generally acknowledged that the level of car ownership depends on, *inter alia*, the available income, basic travel demand due to household structure and the costs of car use and car ownership. However, the relationship between pricing and car ownership has only rarely been studied. The vehicle ownership decision is usually not included in simulation modelling, and the few studies that do incorporate it do so in a rather fragmented way (De Borger, 2001). One of the exemptions is variabilisation modelling, which analyses the consequences of decreased fixed prices (e.g. ownership taxes) and increased variable charges (e.g. fuel prices). Variabilisation will be discussed separately because of its relevance for our empirical work.

Van Dender (1996) finds of a strong expansion of car ownership (and, consequently, a small decrease of mileage) when replacing all fixed type of taxes by variable taxes and using a dynamic model. These rather indecisive results on the effects of changes in price structures on car ownership are confirmed by Bates (2000), who concludes, on the basis of a review of the international literature that it has been difficult to introduce price terms in car ownership models. Since the variability of prices is usually rather low, it appears difficult to estimate models that are able to simulate the effects of changes in price structures on overall car ownership. It can be concluded, therefore, that there are some contradictory results concerning car ownership following from the above-mentioned studies. However, more research in this field is recommended.

3.3.9 Technology choice

Transport in general, and road transport in particular, causes a variety of external effects, environmental effects being one of these. The basic concept of marginal external cost pricing is straightforward: wherever efficient prices appear to be lacking, apply the price mechanism and set appropriate prices. In order to include environmental effects, such as noise or emissions, in prices, cars should be taxed differently and according to the costs they cause.

The choice for a certain type of technology can be influenced by different prices. Verhoef (2000) demonstrates that marginal external cost pricing provides optimal incentives, in both the short and the long run and, when choosing environmental technology, in the choice of vehicle. The environmental performance of the car stock also depends on the type of fuel that cars use. Depending on the differentiation in the price, the composition of the car fleet can be influenced. A variable charge per kilometre may (partly) be based upon the environmental performance (e.g. emissions) of a car. But the system of fixed charges at the moment of purchase can also influence this aspect. The price of a car can be based upon its relative or absolute environmental performance. More environmentally friendly cars will be purchased when the costs of environmentally-unfriendly cars are increased and/or the costs of environmentally friendly cars are decreased. Modelling studies including this type of behaviour are scarce in the literature. The study of MuConsult (1998) outlines that, depending on the way of variabilisation, a bigger car is more often replaced than an average-sized or small car. These effects are stronger when the charge is higher or differentiated according to the weight of the car. In addition, this study shows that some car drivers will replace their car by a more fuel efficient one. Depending again on the way of variabilisation, between 1.1% and 2.7% of the total vehicle stock will be replaced by a more fuel-efficient type of car.

3.3.10 Variabilisation

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

One of the first studies on 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 €cents, 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 are replaced by bicycle use and car-pooling. Effects are less strong when the charge is lower. A charge of 3 €cents is estimated to decrease commuting traffic by 5% and social traffic by 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 both car owners and non-car owners reported in MuConsult (2002) has also analysed the behavioural responses to different types of a kilometre charge with the abolition of fixed taxes. Here, we will discuss their predicted effects of the replacement of the Dutch car ownership tax (the ‘MRB’) only, and of both the MRB and the tax on car purchase (the ‘BPM’).[2] The charges were differentiated according to fuel type, the MRB-only scenario included a charge of 2.4 €cents per kilometre for petrol-using cars (with slightly higher charges for cars running on diesel and gas), whereas the MRB+BPM scenario included a charge of 4.9 €cents (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 stronger growth under the MRB-only scenario compared with the MRB+BPM scenario (2.8% vs. 1.2%). The higher

[2] Dutch car taxation consists of a fuel tax and two taxes that are independent of car use: a car ownership tax (motorrijtuigenbelasting (MRB)) and a tax to be paid at purchase of a new car (belasting op personenauto’s en motorrijwielen (BPM)).

charges in this latter scenario induce relatively more car owners to sell their car (4.6% vs. 1.3%). The effect on the second-hand market, where car prices may go down, 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 who indicate they would purchase a new car (estimated around 2% for both scenarios). In particular, social, shopping and recreational trips will be adjusted, whereas business traffic and kilometres driven for school or educational purposes remain almost unchanged. About 30% of the commuting trips will be adjusted, but less often than the social and shopping trips.

Recently (in a study 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) model developed for the Netherlands (AVV, 2005). This is a network model, whereas previously mentioned model results are mostly limited to isolated road segments. A network can be represented as a set of origin-destination pairs, a set of routes connecting each OD pair, and a set of directed links for each route, where links may be shared by more than one route. This type of models may be used to forecast traffic flows for a certain region or country. They enable the effects of various policy scenarios (on mobility) to be predicted taking into account the zonal characteristics such as income and size of the working population. The model shows the effects on the number of trips on particular roads, departure time choice, modal choice (train, bus/underground, slow traffic, car, and car occupancy), and destination choice both in the short run and the long run. One of the drawbacks of the model is that it is not a dynamic model. It only shows the end situation; it is unclear how behaviour is adjusting to new measures in-between.

Of the ten different alternatives that have been evaluated with this model, 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 €cents, and depended on fuel type and weight of the car. The level of congestion in 2020 is assumed to be reduced by 40% (in terms of vehicle hours lost). People will change mode (use of train, bus/metro, and slow transport increases in terms of kilometres by about 6%), and there will especially be an increase in 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 €cents) than the previous measure, but an additional charge of 0.11 €cents was levied on locations and times with severe congestion. The LMS model outcomes suggest that growth of congestion will be reduced by about 45% (with 5% more reduction in peak periods than the rest of the day). Trip distances will decrease. This effect is limited for commuting trips but larger for social trips. Business traffic (6%) and freight traffic (1%) are predicted to increase, but total traffic demand will decrease (by 10%) as a result of 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 because of differences in the types of measures (e.g. differentiation according to weight versus fuel type) that have been evaluated and their 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.

3.4 Behavioural responses: empirical findings

When policy makers consider the implementation of any type of measure, they want to be informed about the effects. In the case of road pricing, they might have different possibilities to obtain knowledge. A set of elasticities based on the existing literature, and empirical experiences elsewhere, can provide indicative answers to the questions about the effectiveness of pricing measures. We will discuss both issues in the following subsections.

3.4.1 Elasticities

Changes in prices will normally lead to changes in demand for goods or products. The extent of this behavioural response depends on the steepness or flatness of the demand curve. The sensitivity to price changes is expressed by economists in the concept of elasticity. 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). The elasticity concept is a dimensionless measure of the sensitivity of a dependent variable to changes in an independent variable. So the unit of measurement (be it euros or cents and metres or kilometres) of the variables does not make a difference. The elasticity value will be the same, regardless of how the variables are expressed, which is an advantage of the elasticity concept over other measures of sensitivity. It measures the responsiveness of demand to a change in price. An elasticity can be positive or negative. Price elasticities are usually negative. The dependent variable is called elastic with regard to the independent variable when the absolute value of the elasticity exceeds 1. In other cases, the dependent variable is inelastic, while a fixed 'dependent' variable is said to be perfectly inelastic.

Although it is possible to derive elasticities directly from empirical data (e.g. a before-and-after study of an infrastructure project), normally models are used to derive elasticities. Practically all elasticities found in the literature are based on models of some kind (De Jong et al., 1998).

The most important distinctions within travel demand models that are used in practice to derive elasticities, are distinctions with regard to the choice that is modelled and the type of data used. Models for the following choices can be found in the literature (De Jong and Gunn, 2001):

- Mode choice;
- Car use;
- Fuel consumption;
- Departure time choice;
- Destination choice;
- Travel frequency choice;
- Car ownership;
- Residential choice.

It is clear from the previous discussion that a wide variety of elasticities can be computed, in view of the various pricing regimes possible and the large number of effects that can be studied. Moreover, one can analyse long-term or short-term effects, but it is also possible to compare different countries, as elasticities are likely to differ from a geographical perspective. Many studies have been conducted providing many estimates of very specific types of elasticities. It is not the aim to give a complete overview of all transport demand elasticities that have appeared in the literature in the past (for international reviews of travel demand elasticities, see, e.g., Oum et al., 1992, and Goodwin, 1992). Hence, we will focus on particular estimates relevant to our study. Therefore we will have a look at:

- Recent studies;
- Both long-term and short-term elasticities;
- Elasticities of fuel price changes, annual charges, vehicle kilometre charges, and purchase taxes;
- Effects on car stock, fuel consumption, car use, route choice, and modal split.

The studies included here give a general impression of some international estimates (Table 3.2) and particular European estimates found in the literature (Table 3.1). The TRACE project collected many European car cost elasticities of demand for car travel and public transport for different trip purposes. The main findings of the literature review on these elasticities have been reported in De Jong and Gunn (2001). These elasticities are unweighted means from different studies.

Fuel price elasticities

The most widely studied elasticities are the direct fuel price elasticities, which indicate the effects of an increase or decrease in fuel price. Most studies have looked at the effect of fuel prices on car stock, fuel consumption, and car use.

Looking at the effect of an increase in fuel price on fuel consumption, it appears that less fuel will be used. Note that fuel consumption can be reduced without reducing car use, as a result of changes in driving behaviour or fuel efficiency. This explains larger elasticities related to fuel consumption than those related to car use (car mileage) or car stock. Brons (2006) reports, for instance, a large effect on fuel efficiency in a meta-analysis of various studies. He finds a mean of -0.53 (both in the short and long run) for the price elasticity of demand for gasoline, which is caused by responses in fuel efficiency (0.22) and car ownership (-0.22), and to a lesser degree to a response in car use (-0.1).

Summarising international research, Goodwin (1992) estimates the price elasticity of gasoline demand to be -0.27 in the short run and -0.71 in the long run (see Table 3.2). He predicts that a 10% increase in vehicle fuel prices will have the following effects:

- In the short run, it reduces fuel consumption by 2.7%, in part as a result of more fuel efficient driving (such as shifting more driving to a household's most fuel-efficient car);
- In the long run, it reduces petroleum consumption by 7% or more, in part as a result of the purchase of more fuel-efficient vehicles.

Increased fuel prices cause a combination of reduced driving and increased fuel efficiency. Short-term fuel savings consist of reduced driving, and a shift toward using more fuel-efficient vehicles, particularly in multi-vehicle households where drivers have short-term choices. Long-term fuel savings consist primarily of purchases of more fuel-efficient vehicles.

Other researchers report similar results in both the short term and the long term. Espey (1998), for instance, summarises a large number of studies and finds that short-run price elasticity estimates for the demand for fuel range from 0 to -1.36, averaging -0.26.

An increase in fuel prices also has effects on car use and car ownership as can be seen from both Table 3.1 and Table 3.2. Goodwin finds a long run price elasticity of kilometres driven with respect to fuel price of –0.33, in the short run this is –0.16. This means that a 10% fuel price increase is likely to reduce driving by 1.6% in the short run, and by 3.3% over the long run. These results are consistent with other international research (e.g. Johansson and Schipper (1997) find an effect of –0.3 on the mean annual driving distance per car (best guess)). European estimates (totals) tend to be the same for the short run, but slightly lower in the long-run (car kilometres with respect to fuel price, see Table 3.1). Car trips are likely to be less elastic in the long run (elasticity of –0.19).

Much international research has been done on the effects of fuel prices on car stock. The effects are likely to be modest and lower than the effects on fuel consumption. Several

estimates are around –0.2, indicating a decrease of 2% in car ownership when fuel prices are increased by 10%. The effects are only significant in the long run; short-term elasticities are hardly available.
Cross-fuel-price elasticities with respect to public transport use have been found in the literature. The international literature review by Goodwin (1992) contains evidence on the impact of petrol price on public transport demand (both short and long term and in terms of traveller kilometres). The quoted elasticity of +0.34 is the mean of five results from three studies. European estimates from the TRACE project are considerably lower and range from +0.07 to +0.10 (see Table 3.1). The fuel price elasticity expressed in number of public transport trips is considerably higher in the short run: +0.33.

Elasticities of annual charges
The effects of annual charges on car stock, fuel consumption, etc., are less often studied than fuel price effects and mostly calculated only for the long term (since no short-run impact can be expected). Johansson and Schipper (1997) estimate the effects of a change in annual charges consisting of the purchase tax, the import fees, and the present value of the annual tax (on ownership) for a car (average age of the car is 15 with an interest rate of 6%). The long-term effect according to them (depending on the estimation technique) on the vehicle stock is about –0.06. In relation to fuel consumption, they found an elasticity of –0.11. Also interesting is the possibility of a positive impact of annual charges on the mean annual driving distance per car. This can be explained by the fact that fixed charges have little effect on the use of the vehicle. Some people argue that it may even encourage people to drive because they have already paid for it. The fixed car costs in the study of Geurs and van Wee (1997) consist of depreciation charges, insurance fees, road or car ownership tax and a part of the costs of repair and spare parts. They found an elasticity of these annual charges of –0.1 on vehicle kilometres. Table 3.2 also shows that the effect of annual charges on the car stock, on car use and on fuel consumption is considerably lower than the effect of fuel taxation. This is due to the direct effect of fuel prices on fuel consumption and car use. The small effect of annual charges on car stock can partly be explained by the lack of awareness of annual costs when the decision to own a car is made.

Elasticities of vehicle kilometre charges
Road pricing can take several forms, such as a cordon charge, a charge per kilometre, and a charge based on the level of congestion. The travel impacts depend on the price structure. The consequences of road pricing schemes on car use can be expressed in elasticities of vehicle kilometre charges. 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. It can be expected that kilometre charges have an effect on alternative routes chosen by travellers. An elasticity of 0.43 has been found in one city, namely Milan, but has not been included in Table 3.2 as it is unclear what this suggests. It may be that travelling on the supporting road network is increased (and results in more kilometres) but the explanation of this number is unknown. Nevertheless, the evasive reactions of car drivers are important and may reduce the overall impact of the measure.

Geurs and van Wee (1997) report the results of a variable costs elasticity by using the FACTS model. They simulate the effects of a kilometre charge by increasing the variable maintenance costs by 5 €cents per kilometre. This results in an elasticity of around –0,20.

Elasticities of purchase taxes

Elasticities of purchase taxes are difficult to find, but different studies have analysed the effects of car price on car use and car ownership. An increase of purchase tax is often equal to an increase of the price of the car, and therefore it may be expected that individuals react to a car price increase exactly in the same way as to an increase of purchase taxes. However, the car price affects the car stock in the long term much more than taxes do (INFRAS, 2000). It is interesting that the reactions (car use, fuel consumption) to car price changes seem to be rather significant in comparison with annual vehicle charges. This has to do with the definition of an elasticity. Annual vehicle taxes are just a small part of the annual capital costs of a vehicle, and thus it seems plausible that the corresponding elasticities differ in the reported manner.

Table 3.1: European Travel Elasticities

Term/ Purpose	**Car-trips with respect to fuel price**	**Car-kms with respect to fuel price**	**Traveller kilometres by public transport with respect to fuel price**	**Number of public transport trips with respect to fuel price**
Short-term:				
Commuting	–0.20	–0.12		
Home based business	–0.06	–0.02		0.17
Non-home based business	–0.06	–0.02		0.17
Education	–0.22	–0.09		
Other	–0.20	–0.20		0.48
Total	–0.16	–0.16	0.07	0.33
Long term:				
Commuting	–0.14	–0.23	0.26	0.12
Home-based business	–0.07	–0.20		0.03
Non-home based business	–0.17	–0.26		
Education	–0.40	–0.41		0.14
Other	–0.15	–0.29		0.07
Total	–0.19	–0.26	0.10	0.07

Source: De Jong and Gunn (2001)

Table 3.2: Selected price elasticities for changes of different charges

Effect on	**Fuel price/taxes**		**Annual charges**		**Vehicle km charges**		**Car price**	
	Short-term	**Long-term**	**Short-term**	**Long-term**	**Short-term**	**Long-term**	**Short-term**	**Long-term**
Car stock	-0.05[k]	-0.3[a] -0.15/-0.41[b] -0.2/-0.4[c] -0.2 (-0.1)[d] -0.18/0.36[h] -0.18/0.36[j]		-0.081[f] -0.08/-0.04(-0.06)[d]	-0.17/-0.20[k]	-0.11/-0.20[k]	-0.38[i]	-0.89[e] -0.253[f] -0.77[i] -0.6[i] -0.28/-0.57[j]
Fuel consumption	-0.27/-0.28[a] -0.20/-0.25[g] -0.26[l]	-0.71/-0.84[a] -0.702[f] -0.54/-0.96[g] -1/-0.4(-0.7)[d] -0.58[l]		-0.55[f] -0.16/-0.02(-0.11)[d]				-0.529[f]
Car use (km)	-0.16[a] -0.10/-0.50[k]	-0.33[a] -0.262[f] -0.55/-0.05(-0.3)[d]		-0.04/0.8[d] -0.05/-0.15[h] -0.1[k]	-0.1/-0.8[h] -0.14/-0.22[k]			-0.287[f]
Modal split	0.34[a](0.08/0.8) (public transport vehicle km's)				0.05/0.4[h]			

Source: INFRAS (2000), adjusted.
a Goodwin (1992) average values of different international studies, all time periods and all travel purposes.
b Hensher (1987, in Goodwin, 1992), no explicit distinction between short and long-term.
c Tanner (1981-1983, in Goodwin (1992)), no explicit distinction between short and long-term
d Johansson and Schipper (1997), in brackets= best guess; annual charges=taxation other than fuel (sum of purchase taxes and annual taxes).
e Harbour (1987 in Goodwin (1992)), average of more than 90 estimates reviewed.
f Storchmann (1998) as quoted in INFRAS (2000), effects of annual charges and annual depreciation on car stock and on fuel demand per capita.
g Sterner et al. (1992).
h European Commission (1996), elasticity depends on purpose of the trip, transport mode, level of road pricing.
i Vaes (1982, as quoted in European Commission (1996))/Bland (1994, as quoted in European Commission (1996)).
j Dargay (1998), elasticities for different income classes, differentiated in purchase costs and running costs (used as fuel price elasticity).
k Geurs and van Wee (1997), overview of ranges of different price elasticities presented in the Dutch and the international literature.
l Espey (1998), averages of 277 long-run price elasticity estimates for gasoline demand and of 363 short- or medium-run estimates.

Parking price elasticities

Parking pricing means that motorists pay directly for using parking facilities. Parking pricing may be implemented as a demand management strategy (to reduce vehicular traffic in an area), as a parking management strategy (to reduce parking problems in a particular location), to recover parking facility costs, to generate revenue for other purposes (such as a local transportation programme or downtown improvement district), or for a combination of these objectives. Most vehicle parking (especially in non-urban areas) is provided free or significantly subsidised. When parking is priced, there are often substantial discounts for long-term leases, and sometimes there is no hourly or daily rental option, leaving motorists with little financial incentive to use alternative modes part-time.

Motorists appear to be sensitive to parking prices because they are such a direct charge. Compared with other out-of-pocket expenses, parking fees are found to have a greater effect on vehicle trips, typically by a factor of 1.5 to 2.0 (USEPA, 1998). Several studies (see VTPI, 2002 for an overview) provide detailed reviews of parking price elasticities. These studies indicate that the elasticity of parking is typically in the –0.1 to –0.3 range, with significant variation depending on demographic, geographic, mode choice and trip characteristics (which makes comparison difficult). De Jong et al. (1999) provide detailed estimates of the elasticity of various types of travel (car-trips, car-kilometres, transit travel, walking/cycling, commuting, business trips, etc.) with respect to parking price under various conditions (e.g. level of vehicle ownership and transit use, type of trip, etc.). The table below summarises long-term elasticities for relatively automobile-oriented urban regions. Table 3.3 can be used to obtain the following impacts in terms of trips and kilometres (of trips to destination zones with paid parking) after a 10% increase in the parking charge (total effect):

- Car travel: –1.6% in the long run in terms of trips, –0.7% in terms of kilometres;
- Car passengers (other persons in the car than the car driver): +0.3% (trips) and +0.2% (kilometres): this means that a parking cost increase will stimulate carpooling;
- Public transport use will increase +0.2% (trips) and +0.1% (kilometres);
- Slow modes (walking, cycling): +0.3% in terms of both trips and kilometres.

Table 3.3 also shows the difference in sensitivity for the various purposes. Business travellers and educational trips tend to be less sensitive to price changes compared with other purposes.

Table 3.3: Long term parking price elasticities

Term/Purpose	**Car Driver**	**Car Passenger**	**Public Transport**	**Slow Modes (walking and cycling)**
Trips				
Commuting	–0.08	+0.02	+0.02	+0.02
Business	–0.02	+0.01	+0.01	+0.01
Education	–0.10	+0.00	+0.00	+0.00
Other	–0.30	+0.04	+0.04	+0.05
Total	–0.16	+0.03	+0.02	+0.03
Kilometres				
Commuting	–0.04	+0.01	+0.01	+0.02
Business	–0.03	+0.01	+0.00	+0.01
Education	–0.02	+0.00	+0.00	+0.00
Other	–0.15	+0.03	+0.02	+0.05
Total	–0.07	+0.02	+0.01	+0.03

Source: De Jong et al. (1999)

3.4.2 Results from some practical experiences worldwide

For many years, the only example of congestion pricing was in Singapore. Today, there is more experience, coming from Norwegian toll cordons and express lanes in the U.S. Singapore and Orange County, for instance, are interesting and valuable examples of situations where road pricing is actually implemented. We will briefly explain the schemes and discuss some interesting behavioural responses from these two schemes.

In 1975 *Singapore* implemented the Area Licence scheme to restrict car ownership and car use. The size and the structure of the fee have changed over years. At first, the fee was only imposed during the morning peak, but in 1989 this was extended to include the afternoon peak. Public transport was exempted from the charge. Tolls were collected manually from the very beginning, but recently the tolls were automated and made more variable. The effects on traffic have been very significant. Of the commuters travelling to jobs in the restricted zone, the share commuting in cars with less than four passengers (carpools carrying four or more people were exempted until 1989) dropped from 48% to 27% during the first few months of operation, while the combined modal shares of carpools and buses rose from 41% to 62% (Small and Gomez-Ibanez, 1998). Moreover, the number of vehicles of all types entering the zone during peak hours declined, while traffic rose during the half-hour period preceding the toll period. This shows that the congestion prices clearly affected the departure time choice of car users.

Recently (as of 1998), 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 3.4 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 home in the evening can be postponed to avoid the high peak charge. This suggests that time of day charging may lead to considerable departure time and mode choice effects, but much depends on local situations (e.g. public transport availability).

Table 3.4: Elasticities of traffic entering the restricted zone by time interval

Time period	*Cars*	*Other vehicles (motorcycles, taxis, LGVs, HGVs, buses)*	*All vehicles*
7:30-9:30	–0.106	–0.019	–0.069
9:30-15:00	–0.082	–0.080	–0.083
15:30-17:30	–0.123	–0.151	–0.143
17:30-19:00	–0.324	–0.189	–0.265
7:30-19:00	–0.123	–0.106	–0.118

Source: Olszewski and Xie (2005)

State Route 91 in Orange County (California) has 10 miles of express toll lanes, privately constructed and built, and funded by variable electronic tolls. These tolls vary throughout the day in relation to demand and to congestion on the parallel freeway, ranging from \$0.75 to \$3.50 per trip. Users need to be registered customers and carry transponders. There are discounted tolls for high-occupancy vehicles (3+). Field data collection included traffic measurements, vehicle occupancy counts, transit ridership data, and comprehensive travel surveys with current and former commuters. Data analysis included, inter alia, the time-of-

day choices of commuters as well as vehicle occupancy. The express lane is located in what had been one of the most heavily congested freeway corridors of California, with typical peak period delays of 30-45 minutes before the project.
It appeared that the traveller's decision to use the toll lanes is very closely related to hour-by-hour variations in traffic conditions (Sullivan, 2000). The analysis shows that peak period commuters on SR 91 value time at approximately $13-16 per hour, and that demand is moderately price-sensitive. New toll schedules implemented in 1997 introduce hour-by-hour toll differences in peak periods. As yet, the fairly small differences in these tolls have not been accompanied by much flattening of the peak period traffic distributions. Within three months after the opening, peak traffic observations showed a greater than 40% jump in high occupancy vehicles carrying three or more people. At that time, the lanes were free of charge. When carpool users were charged a 50% toll in January 1998, about a third (about 2000 vehicles a day) of the HOV3+ traffic left the lanes.
Models have been used to measure the responses to change in tolls. The price elasticity for use of the toll lanes during the 6-hour period of heaviest use (morning westbound or afternoon eastbound) is consistently about –0.7 to –0.8 based on response to uniform percentage toll changes. This indicates that a 10% across-the-board toll increase would result in about a 7% or 8% decrease in toll facility use. Table 3.5 shows the expected mode shifts from raising the tolls. It is shown that doubling all the tolls causes just 0.7% of all SOV vehicles to switch to other modes in the morning. This increases the number of higher-occupied vehicles. Responsiveness in the afternoon is slightly greater. These calculations understate the true effects of a toll increase on vehicle demand because they do not include trip generation. Table 3.6 shows that time-of-day shifts are small. Increasing the peak of the peak tolls (that is at 7-8 a.m. and 5-6 p.m.) by 10%, results in overall shifts out of those time periods of just 0.5% in the morning and 0.74% in the afternoon. This illustrates the weak effect of imposing a charge on a paylane on total trips made on the whole road.

Table 3.5: Estimated mode response to increase in all tolls on route 91 Express lanes

	10% increase in tolls	**50% increase in tolls**	**100% increase in tolls**
Morning westbound			
SOV vehicles	–0.09	–0.4	–0.7
HOV2 vehicles	0.26	1.1	1.9
HOV3+ vehicles	0.55	2.47	4.39
Total vehicles	–0.05	–0.2	–0.35
Afternoon eastbound			
SOV vehicles	–0.11	–0.47	–0.77
HOV2 vehicles	0.34	1.37	2.18
HOV3+ vehicles	0.8	3.54	6.09
Total vehicles	–0.06	–0.24	–0.4

Source: Sullivan (2000)

Table 3.6: Estimated time of day response to peak single hour toll increase on route 91 Express lanes (in % change of total vehicle volumes)

	10% increase in peak of peak tolls	**50% increase in peak of peak tolls**	**100% increase in peak of peak tolls**
Morning westbound			
4-5 a.m.	0.12	0.54	0.97
5-7 a.m.	0.14	0.64	1.16
7-8 a.m.	–0.50	–2.26	–4.05
8-9 a.m.	0.12	0.52	0.93
9-10 a.m.	0.11	0.50	0.89
peak period (5-9 a.m.)	–0.04	–0.19	–0.34
Afternoon eastbound			
2-3 p.m.	0.21	0.92	1.60
3-5 p.m.	0.21	0.93	1.61
5-6 p.m.	–0.74	–3.25	–5.62
6-7 p.m.	0.23	1.00	1.73
7-8 p.m.	0.22	0.98	1.69
peak period (3-7 p.m.)	–0.06	–0.24	–0.47

Source: Sullivan (2000)

3.4.3 Overview

On the basis of this overview, we can define the following important factors affecting price sensitivity:

- Type of price change: the different types of pricing measures can have different impacts on travel behaviour. Parking charges and road tolls may affect travel routes and destinations. A time-variable fee probably shifts some trips to other times. Fuel price increases tend to affect the type of vehicles purchased more than vehicle usage;
- Type of trip and traveller: De Jong and Gunn (2001) find, for instance, that commuting and business travel is less sensitive to changes in fuel prices than travel for other purposes;
- Quality and price of alternatives (e.g. routes, modes, and destinations): price sensitivity tends to increase if alternative routes, modes and destinations are of good quality and affordable;
- Price level: the results from variabilisation studies and some empirical case studies have shown that large price increases tend to have more effect;
- Time period: we have seen that there is a difference between short-term and long-term price elasticities. 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., 1992). Button (1993) reports that short-term elasticities are typically one-third of long-term elasticities. Dargay and Gately (1997) conclude that about 30% of the response to a price change takes place within 1 year, and that virtually all response takes place within 13 years.

Elasticities can provide indicative and useful answers to the questions about the effectiveness of policy measures. However, policy makers must realise *the* elasticity of some measure does not exist. Elasticities of travel demand will vary with circumstances and very much depend on the contexts. Relevant contexts include geographical scale of the study, the short-term or long-term, existing price levels and alternatives, and the composition of the population. The types of change in travel times and costs might also be relevant (e.g. small or big change, increase or decrease, and gradual or drastic change). This makes it difficult to compare and interpret different elasticities. Comparison of elasticities only makes sense when there is a clear description of the dependent and independent variables (which price changes and what kind of demand are affected).

3.5 Behavioural responses to road pricing: comparison of psychological and economic perspectives

The previous sections have provided an overview of road pricing effects studied in the economic literature. It is now interesting to compare these findings with those of another discipline. Differences between disciplines in research methods and theoretical underpinnings may lead to considerable differences in effects and effect sizes. This section aims to give a brief review of the results from the (theoretical and empirical) psychology literature, and compare these with the previously discussed economic results. We include issues such as underlying theoretical concepts and methods used, as these may be relevant for explaining any differences. We begin with a discussion on the psychological results, followed by a comparative review identifying differences and similarities.

3.5.1 Results from psychology

Chapter 2 stated that economists use utility theory to explain the changes in transport behaviour. Psychologists look at the background of behavioural determinants, such as social norms and personal values, in addition to transport environmental pressures and opportunities. Variations in these determinants form the basis for people's variations in price sensitivity (in both the short and the long term) and in their expected utility of adopting various transport alternatives. Moreover, characteristics of pricing measures (such as type of payment, level of charge, push or pull measures) have also been identified as important.

In psychological studies, the actual effectiveness of transport pricing policies in changing behaviour has hardly been examined. The focus is more on the identification of those personal (underlying) factors that affect or explain responses to pricing measures, such as abilities, motivations, and perceptions. First, we will discuss some theoretical concepts that psychologists use when trying to explain the effects of pricing on transport behaviour. This is followed by a brief overview of empirical studies in this field.

Psychological factors affecting transport behaviour

Psychological research explains behavioural responses by searching for factors that may explain people's choices. The effectiveness of pricing policies to change people's transport behaviour depends partly on individual characteristics. Different behavioural processes and determinants may underlie the choices that people make. The focus is on internal (personal) factors that affect behavioural responses. These factors may explain if, why, and how financial incentives (such as pricing or subsidising) will result in behavioural changes. They may also explain which behavioural processes might undermine the assumed effectiveness of financial incentives. In the following we discuss two theories (the theory of planned behaviour and the norm activation model) and the role of habits to explain behaviour.

According to the theory of planned behaviour (see Ajzen, 1991) people's intentions drive behaviour. Attitudes, relevant subjective norms, and perceived behavioural control, all influence these intentions. The relevance of these three issues will subsequently be discussed.

People have a stronger intention to exhibit behaviour that they evaluate favourably (positive attitude) than behaviour that they evaluate unfavourably (negative attitude). People's attitudes may be affected by pricing policies, because attitudes are based on the weighing of the (perceived) costs and benefits of various alternatives. However, besides the financial costs of various behavioural options, other aspects (such as comfort, travel time or congestion) of car driving may be important as well. In general, the attitude towards car driving is rather positive (e.g. Aarts, 1996; Steg, 1991).

Subjective norms refer to people's perception of the expectations and opinions of relevant others (e.g. friends or family). Social norms are especially influential when people are uncertain about which behaviour to perform. Since many people travel by car, car use may be seen as the social norm. In a situation where people tend to adapt their behaviour to this social norm, it is unlikely that pricing policies will affect people's behaviour strongly. The concept of social comparison is also important in this context. People tend to compare their own opinions, abilities and performances with those of others (Festinger, 1954). People do not want to differ too much from others, but they do want to be a bit better. People also use cars to compare themselves with others (Steg et al., 2001). The car has become a status symbol (Slotegraaf et al., 1997). To the extent that people perceive cars as a status symbol, pricing policies will not greatly affect transport behaviour. Pricing policies will probably generate resistance because they hinder people from expressing themselves socially.

Perceived behavioural control refers to a person's perception of the extent to which certain behaviour is within his or her control or is easy or difficult (Bamberg, 2002). Pricing policies will be less effective when people perceive behavioural changes as impossible (reflecting little personal control). If for example a rush-hour charge is introduced, and people perceive no possibilities to change their trip (e.g. because of fixed working hours), they are likely to pay the charge. Behavioural control refers to the actual and perceived opportunities that people have. For example, if people judge the quality of public transport unfavourably, public transport will not be perceived as a reasonable option, even though it might be a feasible alternative.

According to the norm activation model of altruistic behaviour (Schwartz, 1977), behaviour is influenced by personal norms. Personal norms are self-expectations for specific actions in particular situations, as constructed by the individual (Schwartz, 1977). They refer to a feeling of moral obligation to behave in a certain way. People feel guilty if they do not act in line with their personal norms. Because of this, personal norms may have a strong effect on behaviour.

Personal norms depend on problem awareness and the ascription of responsibility. The first of these factors is the extent to which people are aware of the negative consequences of their transport behaviour for others, e.g. congestion or CO_2-emissions. If people are aware of the environmental consequences of transport, they are more likely to feel obliged to manifest behaviour consistent with these concerns (e.g. by purchasing a more energy-efficient car). The importance of problem awareness in transport behaviour has also been stressed by other researchers (Garvill, 1999; Vlek et al., 1997). If people are more aware of the problems caused by transport, pricing policies aimed at reducing these problems, might be more effective. In that case, people better understand the long-term benefits that pricing policies are aiming for, such as less congestion or CO_2-emissions. The second factor in Schwartz's model (1977) is the ascription of responsibility. The more a person feels responsible for the negative consequences of a certain behaviour (e.g. congestion), the more he/she is likely to feel obliged to change this behaviour (e.g. plan a trip at another time of the day). The amount of responsibility that someone feels depends on the number of people involved. The effect on congestion of one person giving up driving a car is negligible, which results in a low (experienced) responsibility for each individual.

The cognitive capacity of people is limited. Therefore, people use simplifying ways to facilitate decision making. One of these ways is to repeat choices that have satisfying outcomes. In other words, people form *habits* and subsequently rely on them. Previous decisions may have been based on careful deliberation of the advantages and disadvantages of the behaviour, and on preferences (Aarts et al., 1997). Behaviour becomes automated when people no longer explicitly reason about its advantages and disadvantages and their preferences (the previously mentioned determinants of behaviour are no longer seriously considered). Even if (dis)advantages or circumstances change somewhat, people stick to their habits and will not change their behaviour as long as the outcomes remain satisfying (but may no longer be optimal). Transport behaviour is often habitual (see, e.g., Aarts and Dijksterhuis, 2000). To change habitual behaviour by means of pricing policies, the amount of price change is important. It appears that a small price increase is hardly noticed by most people (Steg, 1996). However, a large price increase does affect people's behaviour (Linderhof, 2001), because the outcomes of their behaviour are no longer satisfying. A drastic price increase may cause a shock reaction, which may result in renewed reasoning about behaviour. However, the main reason for avoiding drastic price rises is that they are usually politically unacceptable (Steg, 2003).

Empirical research

It appears that little empirical psychological research is available on the effectiveness of transport pricing policies. Most studies address the effects of pricing measures in general, and focus on their perceived effectiveness. There are studies that deal with the effects of policy measures (including pricing) on transport behaviour. These focus on car use and often distinguish between push and pull measures (e.g. Steg, 1996). Push measures are aimed at making car use or car ownership less attractive, whereas pull measures stimulate alternatives for car use. We will briefly describe the results from two empirical studies that explicitly addressed the effectiveness of transport pricing.

The first study is by Cavalini et al. (1996), who examined the effectiveness of several transport policy measures (including financial measures) for private drivers, commuters, and business drivers, respectively. Almost 25% of the respondents indicated that they would be able to give up their car, but less than 10% were willing to do so. Although people were less willing to give up their car, the findings suggest that price measures, like doubling motor vehicle tax, would be more effective (self-reported) to reduce car ownership than other policy measures that try to restrain car use (such as information provision on the disadvantages of the car). In particular, changes in type of car would result from organisational measures (e.g. the introduction of smaller cars with similar performance) and less from price measures (doubling tax on vehicle ownership, free public transport, and tax on heavy cars or subsidy on smaller cars). So, price measures do not seem the most effective way to influence the type of car that people purchase. More than half of the people indicated that they would be able to reduce their number of kilometres driven. One third of the respondents indicated that they would actually do so if the included price measures (fuel-price increment and free public transport) were introduced. Trips made for business reasons appeared to be less sensitive than trips made for other purposes (private and commuting). Commuters and business drivers indicated that legal measures (such as staggered working hours and a ban on private car use during rush hours) would be most effective. All car users indicated that they were willing to change their travel route. This would best be accomplished by information measures (e.g. an electronic signpost system) and price measures (e.g. road pricing). Finally, people indicated that they were capable and willing to change their driving style. Legal and organisational measures (e.g. speed delimiter in car) were more effective in changing driving style than price measures (e.g. high fines for speed violations).

The second study is by Jakobsson et al. (2002), who conducted a quasi-experimental study on the effectiveness of increasing costs per kilometre driven by car. Three groups were charged and compared with a control group. Respondents had to report behaviour in a log and payment (budgets) was fictitious. Each participant was offered a sum of money necessary to cover expenses for the usual transport demand in a week. If their number of kilometres driven decreased they could keep the remaining amount of money, but if their kilometres driven increased they did not have to pay more money than the offered sum. The general conclusion of this study was that even substantial economic disincentives are unlikely to result in any significant reduction in private car use in the short term. Reductions of car use were mainly due to a reduction both in the number of trips and in driving distance, in particular for shopping purposes.

3.5.2 Comparison with economic findings

We have discussed the findings from two different disciplines; it makes sense to compare them. Despite the relatively short description of the psychological approach and results, it is interesting to address issues such as the methods that are predominantly used, the underlying models or motivations for behaviour, and the anticipated effectiveness as shown by the research results.

Table 3.7 provides an overview of concepts, methods, and behavioural dimensions studied by economists and psychologists. Where economists and traffic engineers use utility theory to explain these changes in transport behaviour, psychologists look at a broader range of behavioural determinants such as beliefs, attitudes, and social norms, in addition to transport environmental pressures and opportunities. Psychologists also assume that people do not always make rational choices: habits are important. Economists and engineers try to explain behaviour by looking more at observable and measurable factors.

The disciplines also differ in the methods used to study behavioural responses. Economists study behavioural responses to pricing from both a theoretical and an empirical perspective. Theoretical/conceptual models have been developed mainly to analyse the effects of prices on welfare (i.e. optimal versus second-best pricing policies). Empirical research (stated and revealed preference techniques) has been used to determine price sensitivity (in terms of elasticities) of transport users. Engineers and economists use their models to forecast future situations. Psychologists do not apply modelling techniques: they rely more on individual questionnaires and quasi-experimental surveys to analyse the present situation.

The range of responses that are studied varies considerably. Transport economists have probably studied many of the possible behavioural responses compared with psychologists. Psychologists have hardly (empirically) studied the effects of transport pricing policies. But when analysing the effects of road pricing, they mainly focus on the decision whether or not to own a car, and whether or not to use it.

The relatively few psychological studies suggest that the effectiveness of transport pricing may be low, although dependent on the type of measure and individual characteristics. Studies often focus on the use of the car and vehicle ownership, which may be those dimensions where the effect may be relatively small (compared, for instance, with trip timing, destination choice, etc.). In contrast, the economic discipline shows the potential effectiveness of road pricing measures. Economic (and traffic engineering) model outcomes, as well as empirical estimates show that road pricing may be rather effective and may result in (depending of the type of measure) considerable welfare gains. A possible explanation for this large effectiveness may be hidden in the concept of utility maximisation and the marginal costs and benefits of the use of a road that underlie economic models. Road pricing will increase the costs and affects those drivers who have a relatively low willingness to pay. Economic theory now assumes that these drivers will change behaviour and decide not to use the road anymore. Psychologists focus in general on the ‘average’ user, who is relatively less inclined to change. Moreover, economists and engineers tend to focus more strongly on those behavioural dimensions where adaptations are largest, such as departure time and route choice.

Finally, the disciplines under study differ in terms of the social objectives that are typically considered. Economists focus on social welfare, whereas psychologists study the effects of pricing measures in terms of changing behaviour and quality of life (this may be defined as the extent to which the important values and needs of people are fulfilled (see, e.g., Steg and Gifford, 2005). Note that there is a difference between the traffic engineering discipline and economics on this issue, because engineers are mainly interested in the effects that transport prices will have on the use of the transportation system. They use relatively large network models compared with economists.

Table 3.7: Comparison of research methods used to analyse behavioural responses to road pricing

	Economics/traffic engineers	Psychology
Underlying theoretical concepts	Utility maximisation	Theory based on behavioural determinants (e.g. attitudes, norms)
Methods	Theoretical models, stated and revealed preference	Stated preference, individual questionnaires, experimental surveys, theoretical reasoning
Dimensions of behaviour studied	Many (in theoretical models)	Few (mainly car use and car ownership)
Empirical research	Considerable	Limited
Conclusions on effectiveness of pricing	Possibly considerable	Possibly low, depending on type of measure and individual characteristics
Social objectives typically considered	Welfare maximisation/network benefits	Effectiveness and quality of life

3.6 Conclusions

This chapter has dealt with the behavioural responses of transport users induced by transport prices. It is important to have an adequate overview of the literature on this issue before we begin our own empirical research. We did not restrict ourselves to the economic discipline – the results from psychology have also been briefly addressed. Both reviews and the comparison have resulted in the following important insights.

Economists have paid considerable attention to the behavioural responses to transport pricing, theoretically as well as empirically. The empirical literature suggests that road pricing can be very effective, but much depends on the type of price measure. Parking charges and road tolls affect travel routes and destinations, while a time-dependent fee seems to have a considerable effect on the departure time of road users. Price sensitivity is also influenced by other factors such as the quality and price of alternative modes and destinations and the type of trip and traveller (e.g. business trips are relatively less elastic than social trips). The effectiveness of pricing measures is also demonstrated by theoretical modelling: they can lead to large welfare gains. It appeared that different types of behaviour have been studied by using simulation models. Many types of models have been used to examine the key links between causes and effects in transport decision making either by the providers of transport services or by the users.

While economists might be convinced about the effectiveness of road pricing, psychologists tend to be more sceptical. The psychology literature addresses the effects of pricing, but focuses on a smaller set of behavioural responses. It also has a different type of underlying theoretical concept: the background of behavioural determinants, such as basic needs, social norms, and personal values, is considered, in addition to transport environmental pressures and opportunities. Economists focus on utility maximising behaviour and try to forecast future situations. According to psychologists, the effectiveness of pricing measures depends not only on the characteristics of these measures, but also on individual aspects such as motivations, habits, and perceptions. A possible explanation for the difference in effectiveness may be hidden in the concept of utility maximisation and the marginal costs and benefits of the use of a road that underlie economic models. Road pricing will increase the costs, and affects those drivers that have a relatively low willingness to pay. Economic theory now assumes that these drivers will change behaviour and decide not to use the road anymore. Psychologists focus in general on the 'average' user, who is relatively less inclined to change. Economists and engineers tend to focus more strongly on those behavioural dimensions where adaptations are largest, such as departure time and route choice.

Chapter 4

Valuing time, scheduling, and uncertainty: estimations from discrete choice modelling

4.1 Introduction

The previous chapter has shown the different behavioural consequences road pricing might have. It is now interesting to explore the potential responses of Dutch car drivers to relevant road pricing measures considered by policy makers to deal with traffic problems. A kilometre charge, possibly differentiated according to time, is such a relevant measure, at least in the Netherlands. Since we do not have revealed preference data available on the effects of such a measure, we decided to use a stated preference (SP) type of approach. The stated preference method is a general and widely applied method for measuring valuations and preferences, and for predicting choices between alternatives or goods, especially when it comes to hypothetical situations. A typical SP experiment confronts the respondent with the choice between two or more alternatives which differ in one or several aspects. By constructing the characteristics of the alternatives in a judicious manner, the relative value of the variables can be measured through statistical analysis. Models can be estimated on the respondents' choice data that incorporate the attributes of the alternatives, as well as contextual effects (external factors) that influence choices. The resulting models are not primarily used to predict demand but instead make it possible to find trade-offs between paying and travelling under preferred conditions (in terms of specific attributes, e.g. departure time or travel time) versus paying less or nothing and facing less attractive travel conditions. The preferences (and hence the behavioural responses) of travellers can be determined including substitution rates between different parameters, which may be cost and time, for instance. This means that important concepts in transport, such as the value of time (VOT) of certain groups can be measured.

Traditionally, value of travel time is considered to be one of the largest cost components in cost-benefit analysis of transportation projects, and the reduction of travel time is usually regarded as the main source of benefits that travellers receive from the improvement of a transport facility. However, when the seriousness of road congestion rises considerably, the reliability of travel time may be more important than the savings of travel time for the travellers, particularly when travellers have a schedule constraint. Several reliability-related components, such as standard deviation of travel time, have been considered in mode or route choice modelling. Numerous studies have shown the importance of these reliability factors in travellers' choice behaviour, and in some cases reliability becomes an even higher value than travel time savings (see, e.g., Small et al., 1999; Lam and Small, 2001).

Empirical studies on the monetary VOT are large in number and the results show convergence. However, the monetary value of uncertainty (VUNC) has been studied less often, and is therefore less certain, in particular for the Dutch situation. There is also still a lack of a common definition and accurate measurement of reliability. Moreover, the model specifications of travellers' responses to changes in reliability differ over studies. Our research contributes by providing useful new insights into relatively unknown concepts such as the value of scheduling costs (at least for the Dutch situation), by updating the value of time for an important target group (i.e. commuters), and by providing insight into the valuation of uncertainty.

In this chapter, we present outcomes from a stated choice experiment among Dutch car commuters who experience congestion on a regular basis. Respondents were offered two different types of stated choice questions. The first four choice sets contained simple choice structures, of varying one single attribute and the cost term, enabling us to estimate interval values for time, schedule delay (late and early), and uncertainty (or reliability) for each individual. The second set of choice alternatives included more attributes, which were varied in a systematic way, and more choices that had to be made by the respondents (11 screens were shown). The data from both types of questions are different in nature and hence require a different type of analysis. We start with the more simple analysis of the interval estimates resulting from the first four choice sets. Next, we will analyse the second set of choice data by estimating different types of models. This allows us to compare estimates from both approaches.

The aim of this study is twofold. First, it is useful to derive (up-to-date) estimates of important transport concepts such as the VOT and VUNC for this particular group of car drivers who experience congestion. Since we obtain estimates at an individual level it is possible to include this parameter as an explanatory variable for other type of analyses (e.g. when explaining the level of effectiveness in Chapter 9). Secondly, we study the impact of the individual characteristics on these estimates. By allowing those trait variables to interact with travel time and reliability related attributes, we are able to assess the estimates for different groups of travellers.

The remainder of this chapter is organised as follows. Section 4.2 describes the choice experiment and the data used in our empirical assessment. Section 4.3 presents the results from the first part of the stated choice experiment, the interval estimates. It includes a short statistical analysis in order to search for explanatory variables. Section 4.4 provides some background by discussing the theoretical framework of discrete choice analysis. The estimated choice models will be presented in Section 4.5. Finally, Section 4.6 concludes.

4.2 Data sources and survey description

4.2.1 Data collection

The data have been obtained by conducting an (interactive) computer-based survey among Dutch commuters. The questionnaire can roughly be divided into three parts. First, we asked for some socio-economic characteristics concerning the respondent (such as education and income). Next, the two stated choice experiments were presented to the respondents. And, finally, we asked for their opinion (on issues such as acceptance and effectiveness) about different types of road pricing measures. This chapter presents the data analysis of the stated choice experiments.

The data collection was carried out by a specialised firm (NIPO), which has a panel of over 50,000 respondents. Since the survey was aimed at respondents who use a car for their commuting journey and also experience congestion on a regular basis, we selected working respondents, who drive to work by car two or more times per week, and who experience congestion of 10 minutes or more at least two times a week. An initial analysis revealed that a random sample would result in a relatively low number of women and lower income groups. Therefore, in order to investigate the role of income, it was decided to ‘over-sample’ the lower income groups and create an equal number of respondents over the various income classes. The final sample includes 1115 respondents. The data were collected during three weeks in June 2004.

4.2.2 Survey

As previously explained, the survey started with some general questions asking for important explanatory variables concerning the characteristics of the respondent (such as income, gender, and education). This provided us with a profile of the Dutch commuter who experiences congestion. However, we should not forget that an Internet survey is used, which attracts younger people and respondents who are higher educated. Our sample indicates that most commuters are men (76%) and relatively highly educated (about 44% have a bachelor's or higher degree). The characteristics of our database have been compared with the general profile of the Dutch car driver facing congestion, in order to check representativeness. Research by Goudappel Coffeng (1997) suggests that about 75% of all drivers in congestion are men (almost equal to our findings). Our sample includes more respondents aged between 26 and 35 (about 10%), whereas the share of persons older than 45 years is lower (as expected). Moreover, drivers in congestion tend to have a high income and be higher educated (our sample includes more persons with bachelor's and master's degrees (8%) and less junior secondary general than the Goudappel survey). The effect of the "over-sampling" of lower income is clearly present. About 21% of the drivers in this sample have an income below €28,500, whereas only 8% drivers of the 1997 sample earned an income below the average of that time.

Each respondent was asked to distribute 10 (commuting) trips amongst four alternatives in the choice experiment. The attribute levels of the alternatives were based on the answers of respondents about their current travel behaviour. In total, respondents are confronted with 15 (4+11) screens in the experiment.

The first four screens were simpler versions of the choice experiment, in which we only changed the road pricing fee and one other attribute (travel time, shift to earlier arrival time, shift to later arrival time, or uncertainty in travel time). These choice questions were designed in such a way that we can infer interval estimates for individuals' values of time (VOT), values of schedule delay early (VSDE), values of schedule delay late (VSDL), and values of uncertainty (or reliability, VUNC) from the allocation of 10 trips over four alternatives. The units for all parameter values are €/hour. The choice for a particular trip implies an interval in which VOT, VSDE, VSDL or VUNC must lie for that particular choice situation. The more concentrated the ten trips are allocated to a particular alternative, the less dispersed that individual's VOT, VSDE, VSDL or VUNC apparently is. The design of the alternatives developed to derive the VOT estimate is then as follows.

The VOT for car commuting trips in the Netherlands, as used by the Dutch government for 2004, was about € 8.3 per hour (see AVV, 2006). Given this value, the following four intervals were identified:

1. € 0 – 4
2. € 4 – 8
3. € 8 – 12
4. > € 12

In order to allocate responses to the above categories, a choice was offered to the respondent as presented in Table 4.1.

Table 4.1: Design of the first screen: four alternatives to estimate an individual's VOT

	A (group 4)	B (group 3)	C (group 2)	D (group 1)
Departure time	T_D	T_D – 15 min.	T_D – 30 min.	T_D – 45 min.
Travel time	T_F	T_F + 15 min.	T_F + 30 min.	T_F + 45 min.
Arrival time	T_A	T_A	T_A	T_A
Toll	€ 6	€ 3	€ 1	€ 0

Note: T_D stands for the departure time, T_A for the arrival time, and T_F for the travel time.

If the respondent chooses alternative C, we can infer that he is willing to pay € 1 to save 15 minutes of travel time (C is preferred over D, implying a VOT of at least € 4 per hour), but not more than € 8 per hour (C is preferred over B, indicating that the respondent is not willing to pay € 2 to save 15 minutes). The calculation of the interval estimates based on the data will be explained in Section 4.3. We have developed scenarios to estimate the other parameters in a similar way: these can be found in Appendix 4a. Note that the simplicity of the design in Table 4.1 comes at a price: we are unable to study the question of whether the VOT (and other valuations) depends on the size of the travel time gain.

The second part of the choice experiment consisted of 11 screens. This has been developed by the MD-PIT project consortium[3]. The design has 44 choice sets, but can be blocked into 4 sets of 11. Each respondent was assigned a block randomly, and the order of the 11 treatments in a block was randomised as well. The levels of attributes of the constructed alternatives are based on a fractional factorial design (orthogonal non-linear main effects design) using 4 levels for 13 of the attributes and 2 levels for two of the attributes. The attributes are based on the current behaviour of respondents with the aim to design alternatives as close to the reality of the individual respondent as possible (see Appendix 4b for an example). Each of the attributes has a limited number of values (levels) and these levels are combined in a systematic way, such that each attribute is independent of one another. Each screen consists of 4 alternatives with separate attributes (alternative specific attributes, see Table 4.2). Three alternatives are car-specific; and the remaining alternative is always public transport (even in cases where the respondent indicated that there is no public transport alternative available; the choice sets concern hypothesised situations). The attribute levels are such that the first car alternative (A) is based on the preferred travel conditions of the respondent paying a relatively high price. Expected arrival times are relatively close to the preferred arrival time, a large part of the trip is free flow, and uncertainty margins are small compared to alternatives B and C. The other road possibilities (alternative B and C) have lower road pricing fees, but in return the travel conditions (in terms of arrival time, travel time, uncertainty and trip length (C)) are less attractive.

Table 4.2: Design of the second part of the stated choice experiment (11 screens)

Alternative	Attribute	Levels
A: car (pay)	Expected arrival time	4 (-10, -5, PAT, +5)
	Travel time	4 (85% of trip length free flow, 90%, 95% and 100%)
	Uncertainty (max. delay)	4 (uncertainty margin * 0.2, 0.4, 0.6 and 0.8)
	Trip costs (fuel + charge)	4 (charge depends on distance, distance*0.08, 0.1, 0.12, and 0.14)
B: car (change departure time)	Expected arrival time	4 (-50, -30, -10, +10)
	Travel time	4 (65% of trip length free flow, 70%, 75% and 80%)
	Uncertainty (max. delay)	4 (uncertainty margin * 0.8, 1, 1.2 and 1.4)
	Trip costs	4 (charge depends on distance, distance * 0.03, 0.04, 0.05, and 0.06)
C: car (change route)	Expected arrival time	4 (-30, -20, -10, PAT)
	Travel time	4 (55% of trip length free flow, 60%, 65% and 70%)
	Uncertainty (max. delay)	4 (uncertainty margin * 0.6, 0.8, 1, and 1.2)
	Trip costs	4 (charge depends on distance, distance * 0, 0.01, 0.02, and 0.03)
	Trip length	2 (distance * 1.2, and 1.4)
D: public transport (change mode)	Arrival time	4 (-30, -10, +10, +30 compared with PAT)
	Travel time	2 (based on reported travel time with public transport if available (if not: 1.3 * mean car travel time), no change, and reported travel time * 1.2)

Notes: PAT = preferred arrival time, travel time consists of a free flow and a congested part; uncertainty margin = difference between reported mean travel time and free flow travel time

[3] The development was coordinated by the Technical University of Delft; for a detailed description of the experiment we refer to Amelsfort (2004).

4.3 Analysis of interval estimates

4.3.1 How to derive interval estimates

The previous section described the interval values defined and the design of the first four screens. In order to calculate an average interval estimate for an individual, we need an expected value for each of the four intervals. It is not plausible to assume that the expected values are the exact middle points of their interval, and this is not even defined for the fourth interval. We therefore hypothesise that there is an underlying statistical distribution that can be fitted to the actual aggregated trip allocation over the intervals, and approximate the expected interval values based on this presumed distribution. We have chosen to use the Gamma distribution. This distribution has been chosen for pragmatic reasons (in particular because only two parameters have to be estimated) and its non-negativity which is appropriate here. Note that the distribution is used only to determine the expected value within each interval, not the expected value for the entire distribution. In order to find the parameters of the best-fitting Gamma distribution, we have applied the ordinary least squares method over the pooled choice probabilities (finding the minimum difference between actual and simulated distribution).

Table 4.3: Actual frequency of choices and the fitted Gamma distribution (parameters of the distribution in brackets)

VOT	**€ 0-4**	**€ 4-8**	**€ 8-12**	**> € 12**	**Total**
Actual probability	0.2	0.2	0.32	0.27	1.0
Gamma distribution (2.0; 0.2)	0.19	0.28	0.22	0.31	1.0
VSDE	**€ 0-2**	**€ 2-4**	**€ 4-6**	**> € 6**	**Total**
Actual probability	0.27	0.2	0.27	0.25	1.0
Gamma distribution (1.5; 0.32)	0.27	0.27	0.18	0.28	1.0
VSDL	**€ 0-8**	**€ 8-16**	**€ 16-24**	**> € 24**	**Total**
Actual probability	0.44	0.18	0.18	0.19	1.0
Gamma distribution (1.0; 0.07)	0.43	0.24	0.14	0.19	1.0
VUNC	**€ 0-3**	**€ 3-6**	**€ 6-9**	**> € 9**	**Total**
Actual probability	0.36	0.24	0.26	0.14	1.0
Gamma distribution (1.7; 0.31)	0.33	0.32	0.18	0.17	1.0

Table 4.3 shows the frequencies of choices over the four intervals and the Gamma distribution that could be fitted to these observations. With the parameters estimated, the mean interval values can be determined. Note that the probabilities from the Gamma distribution may deviate from the observed probabilities. It is therefore important to emphasise that the Gamma distribution was only used to determine the expected values for each choice. Choice probabilities used in further calculations are the observed probabilities. It appeared that the distributions were (slightly) different for income, so that the mean interval value also depends on the income of the respondent. Table 4.4 presents the mean average values for VOT, VSDE, VSDL, and VUNC for the different income groups.

Table 4.4: The expected values for VOT, VSDE, VSDL and VUNC, for each interval for the different income groups (€/hour)

Income (gross yearly)	VOT				VSDE				VSDL				VUNC			
	0-4	**4-8**	**8-12**	**>12**	**0-2**	**2-4**	**4-6**	**>6**	**0-8**	**8-16**	**16-24**	**>24**	**0-3**	**3-6**	**6-9**	**>9**
<€28,500	2.4	5.9	9.8	18.5	1.1	2.9	4.9	9.6	3.5	11.7	19.7	44.1	1.6	4.4	7.3	13.4
€28,500-45,000	2.4	5.9	9.8	18.1	1.1	2.9	4.9	9.5	3.4	11.6	19.6	40.2	1.6	4.4	7.3	13.1
€45,000-68,000	2.7	6.0	9.9	17.6	1.1	2.9	4.9	9.5	3.5	11.6	19.7	40.2	1.6	4.4	7.3	13.3
>€68,000	2.7	6.0	9.9	17.9	1.1	2.9	4.9	9.5	3.2	11.6	19.6	38.9	1.6	4.4	7.3	12.9

It is now possible to determine an individual's VOT as the weighted average of the intervals' expected values, where the individual's weights are determined by the number of trips allocated to each interval. For instance, when a respondent with an income of less than €28,500 allocates 5 trips to B and 5 trips to C, a VOT estimate of 7.8 results ((5*5.9+5*9.8)/10). The VSDE, VSDL, and VUNC have been estimated in a similar way, only the interval values and attribute values were different (see Appendix 4a for the screens and interval values). Note that the interval boundaries calculated in this way refer to average VOT, over discrete (non-marginal) travel time gains or losses. This is different from the conventional definition, which refers to the marginal rate of substitution between time and money.

4.3.2 Results and statistical analysis

Table 4.5 shows the mean values for the various estimates. The mean value of time is about €10, which is somewhat higher than the current value that is used in policy documents, of about €8.3. The 95% confidence interval is between €9.6 and €10.1 which indicates that there is a significant difference. It is comparable to a recent (median) U.S. estimate of \$11.9 obtained from a stated preference experiment (Small et al. (2005)). The interval estimate of the VSDE is considerably lower than the VSDL. This confirms the expectation that people normally prefer early arrivals over late arrivals. It is rather plausible that the VSDE is lower than the VOT; otherwise people prefer to stay in the car and drive around, over arriving early. The VUNC has a mean value of €5.4. It is difficult to compare this estimate with other international estimates, given the variety in definitions of uncertainty used (see Tseng et al. 2005 for a meta-analysis on reliability ratio's). AVV (2006) gives a reliability ratio (VOR/VOT) for the Netherlands of 0.8, we find a ratio of 0.6. In our case, uncertainty is measured in units of travel time (difference between the maximum and minimum travel time). It is evident that this ratio is different when the units of uncertainty are based on the standard deviation. The minimum and maximum values and the standard deviation shown in Table 4.5 indicate the considerable level of variation (especially for the VSDL).

The reported VUNC in Table 4.5 is derived from the scenario presented in Appendix 4a. Uncertainty involves a minimum and maximum arrival time, and hence a (equal) chance of arriving earlier or later than the preferred arrival time. As a consequence, the value of uncertainty implicitly includes scheduling costs. It therefore makes sense to distinguish between two different concepts of VUNC (with and without correction for expected scheduling costs), not only for conceptual reasons, but also for comparability with the stated choice experiment discussed in Section 4.4. We can calculate the pure VUNC (VUNC2 in Table 4.5) for each individual by reducing the present interval estimate (VUNC) with the estimated scheduling costs. For the calculation of these latter costs we use the individual VSDE and VSDL. The probability of arriving earlier is greater than the probability of arriving later, 0.75 versus 0.25. These probabilities are multiplied by 0.5 since there is an equal chance of arriving at a certain time for both early and late schedules. So, the VSDE estimates are multiplied by 0.375, and the VSDL estimates by 0.125. Both costs are then the expected schedule costs for being late and early, which are deducted from the VUNC for each individual. The average equals 1.82, considerably lower than the VUNC estimate but positive. The minimum value shows that for some respondents the pure VUNC may actually be negative.

Table 4.5: Descriptive statistics of interval estimates for VOT, VSDE, VSDL, and VUNC (€/hour)

	N	Minimum	Maximum	Mean	Std. Deviation
VOT	1115	2.5	18.5	9.8	5.0
VSDE	1115	1.1	9.6	4.7	2.8
VSDL	1115	3.6	38.3	14.5	11.8
VUNC	1115	1.7	12.8	5.4	3.3
VUNC2	1115	-7.0	12.4	1.8	2.7

It is then interesting to search for explanatory variables. Since we have information on the socio-economic characteristics of the respondent, it is possible to analyse its impact on the estimates. The literature indicates, for instance, that higher income people tend to have a higher VOT. Table 4.6 shows the estimates for four different income categories. The results are, however, somewhat ambiguous. As would be expected, the highest income group has the highest VOT, but the high estimate for the lowest income group is more difficult to explain.

Table 4.6: The average values of the VOT, the VSDE, the VSDL, and the VUNC for the different income groups (€/hour)

	VOT	VSDE	VSDL	VUNC
<€28,500	9.9	4.6	18.6	5.8
€28,500-€45,000	9.2	4.3	14.9	5.0
€45.000-€68.000	9.8	4.7	13.6	5.3
>€68.000	10.5	5.0	12.6	5.2

The effect of income and other possibly important explanatory variables has been tested statistically. We conducted a regression analysis with the interval estimates as the dependent variable. Table 4.7 shows the results for the four regressions. Despite the very low overall fit of the models, the significance and sign of the coefficients give a tentative indication of the impact of the various variables. When we first look at income, the previous conclusion for VOT is confirmed: the impact is not significant (at the 10% level). This is not in line with previous Dutch findings (1998 estimations in Gunn, 2001). A possible explanation is that people with higher incomes can nowadays be more productive in the car, due to improved technical possibilities. Next, those with a very high VOT may already avoid congested times and are therefore not included in the sample. We hope to be careful with such explanations, however because the results in Table 4.11 below do show the expected pattern where VOT rises with income. The effect of income is only significant at this level for the respondents' VSDL (with a negative coefficient, which confirms the result of Table 4.6). Income and education (also negatively significant) may be correlated here. A possible explanation for the negative impact of education and income on VSDL is that lower-educated people more often have jobs with less flexible working hours.

When we look at the results for VSDE, gender has a significant impact (at the 10% level), with females having a higher VSDE than male respondents. Respondents who are higher

educated tend to have a lower VSDE. The explanation may be the same as for VSDL. The impact of travel-cost compensation by the employer (higher VOT and VSDE for respondents who are fully compensated) may be explained by the respondents' assumption that their employer will also pay for future toll costs. The number of working hours during a week does not have an impact on any of the dependent variables. The composition of the household may have an impact on the different concepts discussed here. Table 4.7 shows, however, that the impact is rather marginal. Single-person households with children are likely to have a higher VOT, families without children tend to have a higher VSDE, while single-person households seem to have a lower VUNC than other type of households.
It seems that the variation in the estimations is much more caused by non-observable factors than the observed factors that have been included in the regressions. This is confirmed by the very low overall fit.

Table 4.7: Regression results for VOT, VSDE, VSDL, and VUNC

	VOT		VSDE		VSDL		VUNC	
	B	t stat.	B	t stat.	B	t stat.	B	t. stat
Constant	8.90	8.9***	4.013	6.9***	25.17	9.6***	7.258	10.3***
Gender (dummy, female=1)	.517	1.3	.427	1.8*	.236	.22	.355	1.2
Education	-.156	-1.5	.-.137	-2.3**	-.933	-3.4***	-.164	-2.2**
Gross yearly income	.095	1.6	.055	1.6	-.478	-3.1***	-.068	-1.6
Cost comp1 (dummy)	-.791	-1.6	-.111	-.38	2.293	1.7*	-.134	.38
Cost comp2 (dummy)	-.657	-2.0**	-.370	-1.9**	.092	.11	7.04E-05	.00
Household comp1 (dummy)	-.029	-.07	.174	.69	-1.773	-1.6	-.609	-1.9**
Household comp2 (dummy)	2.072	2.3**	.574	1.1	-.543	-.23	-.156	-.24
Household comp3 (dummy)	.521	1.5	.348	1.8*	1.263	1.4	.170	.71
Working hours a week	.038	.31	.086	1.2	.161	.49	-.073	-.82
R square	.017		.018		.040		.016	

Notes: Cost comp1: respondents receive no compensation from employer, cost comp2: respondents are partly compensated, cost comp3 respondents are fully compensated by employer; household composition1 = single, household 2 = single with child, household 3 = couple without children, household 4 = couple with child(ren). Significance is indicated by ***, **, and *, referring to significance at the 99%, 95%, and 90% levels, respectively.

4.4 Stated choice experiment: theoretical framework

4.4.1 Discrete choice models

The individual traveller's choice behaviour is commonly analysed using discrete choice models (e.g. Ben-Akiva and Lerman, 1987). Most models used in practice are based on random utility theory (RUT), which assumes that the individual's preference/taste can be described by a deterministic (systematic) part of utility, V_{ij}, and a stochastic component, ε_{ij}. The conventional random utility specification in the case of respondent *i* choosing among *J* alternatives is expressed in Eq. (1).

$$U\left(choice\ j\ for\ individual\ i\right) = U_{ij} = V_{ij} + \varepsilon_{ij}, \quad j = 1,...,J. \qquad (1)$$

The systematic component is assumed to be the part of utility contributed by attributes that can be observed by researchers, while the random component is the part of utility contributed by attributes unobserved by researchers. The observed part of systematic utility V_{ij} is a function of attributes in the alternative and characteristics of the decision maker. A linear function, which is specified by a vector of the decision maker's taste β, can be denoted as $\mathrm{V}_{ij} = \sum_{k=1}^{K} \beta_k X_{ijk}$ in the case of generic parameters (Ben-Akiva and Lerman, 1987). Utility

maximisation theory assumes that an individual chooses the alternative that yields the highest utility level.
The empirical specification of V_{ij} is crucial to modelling the individual's choice behaviour because the utility function not only reflects the individual's decision-making process given the socio-economic environment, but also determines the predictive capability of the choice model.
In making the choice model operational, the random terms (unobserved by the analysts), also play a crucial role. Different assumptions on the joint distribution of random terms in the utility function result in different models. The most extensively used model in transportation studies is the Multinomial Logit (MNL) model, which assumes that the random terms are independently and identically distributed according to an extreme value type I distribution. Under these assumptions, the choice probability for respondent i to choose alternative j becomes:

$$\Pr ob_{ij} = \frac{\exp(V_{ij})}{\sum_{l=1}^{J} \exp(V_{ij})} \tag{2}$$

The above assumption is most restrictive in that it does not allow for the error components of different alternatives to be correlated. However, in a situation of repeated choices by individuals this is not the case. For each choice situation n, the specification then becomes:

$$U_{ijn} = V_{ijn} + \varepsilon_{ijn}, \text{ with} \tag{3}$$

$$\mathrm{V}_{ijn} = \sum_{k=1}^{K} \beta_k X_{ijnk}$$

This model can be solved using a maximum likelihood estimation method. The log likelihood function is given as:

$$\log L = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{n=1}^{N} d_{ijn} \log \Pr ob_{ijn} \tag{4}$$

In this present study, the dependent variable is the choice proportions allocated among four alternatives. Thus, d_{ijn} is defined as the choice proportion distributed by respondent *i* to alternative *j* in each choice *n*, and we have $\sum_j d_{ijn} = 1$ under each choice profile (Greene, 1993). The respondent makes several choices in 11 choice situations.

4.4.2 Choice model specification

Apart from travel time and travel-cost elements, scheduling (trip-timing) convenience is also found to be one of the important determinants of commuters' travel behaviour. Utility functions with explicit scheduling delay costs specification (see, e.g., Small (1982); Hendrickson and Plank (1984); Wilson (1989); Chin (1990)) have been tested extensively in modelling travellers' route/mode and departure time choices.
Small (1982) introduced the schedule delay (SD) variable to measure the difference between the traveler's actual arrival time and preferred arrival time (PAT). Since people may value early and late arrivals differently due to their different consequences, the SD variable can be evaluated as two separate terms, schedule delay early (SDE) and schedule delay late (SDL). SDE is defined as the amount of time arriving earlier at the destination than the PAT, while SDL is the amount of time arriving later than the PAT. This gives the relationship in the utility expression (V) as follows:

$$V = \beta_T \cdot T + \beta_C \cdot C + \beta_E \cdot SDE + \beta_L \cdot SDL + \theta \cdot D_L, \tag{5}$$

where T denotes the travel time, and C gives the travel cost. Travel cost may include fuel cost and/or toll cost. SDE is defined as Max(0, PAT minus actual arrival time), SDL is defined as

Max(0, actual arrival time minus PAT); and D_L is the lateness dummy, which is equal to 1 when $SDL \geq 0$, and 0 otherwise. The coefficients of β and θ measure the marginal disutilities of being early and late, while θ represents a fixed penalty for late arrival. Since C, T, SDE and SDL are disutilities, the coefficients are assumed to be negative. Small's (1982) empirical finding is that $|\beta_L| > |\beta_T| > |\beta_E|$, which means that people prefer early arrival to additional travel time, and prefer additional travel time to late arrival (similar to the findings in Section 4.3 above).

The model proposed by Noland and Small in 1995 extended Small's 1982 trip-scheduling model (see Eq.(5)) by considering the probability distribution of travel time and adding an additional random component depicting the uncertainty effect, that is, apart from the scheduling constraint. The result is presented as Eq.(6), this is called *Maximum Expected Utility* (MEU) theory.

$$E(U) = \beta_T \cdot E(T) + \beta_C \cdot C + \beta_E \cdot E(SDE) + \beta_L \cdot E(SDL) + \theta \cdot P_L \qquad (6)$$

where $E(T)$ is the expected travel time; $E(SDE)$ is the expected schedule delay early; $E(SDL)$ is the expected schedule delay late, and $P_L \equiv E(D_L)$ is the expected lateness. Note that, with a random arrival time, expected schedule delay early and late can both be positive when the expected arrival time is at the PAT.

Once the model is estimated, it is possible to derive the marginal rate of substitution between any pair of the attributes in the bundle. Obtaining such measures is a common objective in the use of discrete choice models. For example, the monetary value of travel time (VOT), an important economic indicator in transportation studies, is defined as the marginal substitution rate between travel time and costs, and, hence, as the ratio of the respective coefficients (see Eq.(7)). It is important to define the cost component. A VOT based on toll costs is typically different from one based on fuel costs, given a difference in attitude of respondents.

$$VOT = \frac{\partial U / \partial T}{\partial U / \partial C} = \frac{\beta_T}{\beta_C} \qquad (7)$$

Similarly, the VSDE, VSDL, and VUNC can be derived.

4.5 Estimation results of stated choice experiment (SCE) data

The previous section described the basics of maximum likelihood estimation of the utility parameters of one discrete choice model: the MNL model. This section discusses the application to our data. We study the trade-offs between paying and travelling under preferred conditions versus paying less and facing less attractive travel conditions in terms of departure time, uncertainty, route length, travel time, and mode of transport. We have estimated various specifications of this choice model, and will only present those estimates that have a clear interpretation. First, the basic model is outlined, including the resulting estimates of VOT, VSDE, VSDL, and VUNC. Next, we will include heterogeneity into the estimation of the models.

4.5.1 The basic multinomial logit (MNL) model

As a starting point, we analyse the respondents' overall trade-offs for mean travel time, uncertainty of travel time, and travel cost. This is similar to the 'mean-variance' modelling approach proposed by Jackson and Jucker (1981), where travellers were supposed to make a trade-off between mean travel time and variance of travel time. This gives estimates of how people evaluate travel time and uncertainty with respect to the monetary cost. The choice experiment included three different car alternatives and one public transport alternative. It makes sense to assume that all car alternatives have the same parameters. This is not the case for the public transport alternative compared with the car alternative. Therefore, we have defined two utility expressions: one for the car alternatives, and one for public transport. The utility expressions of car (V_C) and public transport modes (V_{PT}) are given by:

$$
\begin{aligned}
V_{CAR} &= \beta_C \cdot C + \beta_T \cdot E[T] + \beta_{UNC} \cdot UNC + EDT + VEDT + VVEDT \\
V_{PT} &= ASC_{PT} + \beta_C \cdot C + \beta_T \cdot E[T] + EDT + VEDT + VVEDT
\end{aligned}
\qquad (8)
$$

where *C* is the travel cost (in our experiment consisting of both fuel and toll costs for the car, and ticket price for public transport); *E[T]* is the mean travel time, and *UNC* is the amount of uncertain travel time[4]. ASC_{PT} is the alternative specific constant of public transport, added to capture the effect of respondents' difference in preference for car or public transport. Our experiment also involves different departure time conditions implied by different mode and route alternatives. Therefore, we specify a set of dummy variables, *EDT*, *VEDT*, and *VVEDT*, to explain the utility difference incurred by chosen different departure time slots. *EDT* denotes the dummy for 'early departure', and captures the disutility when the respondent's departure time is 30 to 60 minutes earlier than his/her preferred departure time (PDT); *VEDT* is the dummy of 'very early departure', accounting for the disutility when the respondent's departure time is 60-90 minutes earlier than his/her *PDT*; and *VVEDT* gives the 'very very early departure' dummy when the departure time is more than 90 minutes earlier than the *PDT*. Here, we use effects coding for the early departure variables of EDT, VEDT, and VVEDT. This implies that, instead of coding the base level[5] 0 across the newly created variables, the base level is -1 across each of these new variables. Since the basis is different between ASC and the early departure variables, we are able to distinguish the estimated ASC and the value of these early departure variables[6].
Next, we estimate a more complete model incorporating the scheduling variables based on Eq.(6). This model illustrates that the individual accounts for the following attributes in their decision making: travel cost, *C*; mean travel time *E[T]*; expected schedule delay early*, E[SDE]*; expected schedule delay late, *E[SDL]*; probability of arriving later than the preferred arrival time, P_L[7]; and amount of uncertain travel time (*UNC)*. We include both schedule delay early and early departure time. The early departure "dummies" capture the extra penalty that travelers depart too earlier than their (reported) preferred departure time, which differs over respondents. These are dummy (discrete) variables (and not time unites as is the case with schedule delay); correlation between travel time, early departure time and schedule delay is therefore not much of an issue.
The generic indirect utility functions of car (V_{CAR}) and public transport modes (V_{PT}) are given as follows:

$$
\begin{aligned}
V_{CAR} &= \beta_C \cdot C + \beta_T \cdot E[T] + \beta_{SDE} \cdot E[SDE] + \beta_{SDL} \cdot E[SDL] + \beta_{P_L} \cdot P_L + \beta_{UNC} \cdot UNC \\
&\quad + EDT + VEDT + VVEDT \\
V_{PT} &= ASC_{PT} + \beta_C \cdot C + \beta_T \cdot E[T] + \beta_{SDE} \cdot E[SDE] + \beta_{SDL} \cdot E[SDL] + \beta_{P_L} \cdot P_L \\
&\quad + EDT + VEDT + VVEDT
\end{aligned}
\qquad (9)
$$

4 The mean travel time is defined as the 'mean value of minimum and maximum total travel time in the choice experiment', while uncertainty is the 'difference between maximum and minimum total travel time'.

5 The base level of early departure variables is set as: the departure time is less than 30 minutes earlier than the PDT.

6 Interpreting the parameters with effects coding is different from doing so with dummy coding because the base level of effect coding variables is no longer zero. The positive coefficient for EDT can still be interpreted as a disutility.

7 The computation of E[SDE], E[SDL], and P_L is given in Appendix 4c.

Uncertainty of travel time is also included as an independent variable in this model. However, it is likely to be of limited relevance, since most of the uncertainty effects are captured by *E(SDE)*, *E(SDL)*, and P_L (recall the discussion about VUNC and VUNC2 in Section 4.3).
The first two columns of Table 4.8 show the MNL estimates of the mean-variance modelling and the trip-scheduling modelling approach. The unit of all time-related attributes is in minutes, and travel cost is in euros. A general finding obtained from these two models is the negative sign for the alternative specific public transport coefficient. This suggests that, in general, respondents prefer the car over the public transport alternative, because the ASC represents individuals' taste in choosing that alternative. A possible explanation for this phenomenon is that the sample consists of car users, who implicitly have a preference for the car. Shifting departure time to earlier time periods is less preferred for all models.

Table 4.8: Estimation results of the basic models for SCE data

Explanatory variables	Model 1	Model 2	Model 3	Model 4	Model 5
ASC of public transport alternative	-1.07***	-0.77***	-0.78***	-0.78***	-0.75***
A_PT	(-22.0)	(-14.8)	(-7.8)	(-14.9)	(-8.2)
Travel cost	-0.09***	-0.09***	-0.09***	-0.09***	-0.09***
C	(-16.7)	(-16.5)	(-16.6)	(-16.5)	(-16.5)
Mean travel time E[T]	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
E[T]	(-11.5)	(-9.6)	(-8.9)	(-9.6)	(-8.8)
E[T]*Public transport dummy			-0.002**		-0.002**
E[T]*PT			(-2.2)		(-2.1)
Expected schedule delay early		-0.02***	-0.02***	-0.008	
E[SDE]		(-8.6)	(-8.7)	(-1.2)	
Expected schedule delay early squared				-0.0002*	-0.0004***
$E[(SDE)^2]$				(-1.6)	(-8.6)
E[SDE]*Public transport dummy			0.009**		
E[SDE]*PT			(2.4)		
Expected schedule delay early squared*public transport dummy					0.0003**
$E[(SDE)^2]$*PT					(2.3)
Expected schedule delay late		-0.02***	-0.02***	-0.02***	-0.02***
E[SDL]		(-9.4)	(-9.2)	(-5.6)	(-9.6)
Expected schedule delay late squared				0.0001	
$E[(SDL)^2]$				(0.97)	
E[SDL]*Public transport dummy			0.01**		0.009**
E[SDL]*PT			(2.5)		(2.5)
Probability of late arrival (later than PAT)		-0.09*	-0.07	0.007	0.05
P_L		(-1.9)	(-1.4)	(0.1)	(1.3)
Uncertainty	-0.007***	0.002	0.001	0.002	0.002
UNC	(-5.2)	(1.3)	(1.0)	(1.1)	(1.1)
Dummy for departing 30-59 min earlier than preferred departure time (PDT)	0.34***	0.29***	0.29***	0.28***	0.28***
EDT	(12.1)	(8.9)	(8.7)	(8.5)	(8.2)
Dummy for departing 60-89 min earlier than PDT	-0.21***	-0.14***	-0.15***	-0.13***	-0.14***
VEDT	(-6.4)	(-3.7)	(-3.8)	(-3.6)	(-3.8)
Dummy for departing more than 90 min PDT	-0.53***	-0.52***	-0.51***	-0.52***	-0.53
VVEDT	(-7.3)	(-5.9)	(-5.8)	(-6.0)	(-6.3)
Log likelihood	-15549.72	-15420.39	-15413.53	-15418.60	-15413.53
R-sqrd Adjusted	0.08	0.09	0.09	0.09	0.09

Note: t-statistics are shown in parenthesis. Significance is indicated by ***, **, and *, referring to significance at the 99%, 95%, and 90% levels, respectively.

When comparing these first two model estimations, we see that uncertainty is only significant in Model 1. In Model 2, with the work scheduling consideration taken into account, uncertainty is no longer significant. This result suggests that uncertainty may be explained by the scheduling constraints. Small et al. (1999) obtained a similar result for the estimate of

standard deviation of travel time in the scheduling specification utility function. The authors argue that when the scheduling costs are fully specified in a model, it is unnecessary to add an additional cost for unreliability (uncertainty) of travel. Our results confirm this.
Based on the specification in Equation (9), we extend our analysis and investigate the mode-specific effects by interacting the travel time and scheduling variables with a public transport dummy. This leads to the following general specification:

$$\begin{aligned} V = PT \cdot ASC + \beta_C \cdot C + \beta_T \cdot E[T] + \beta_{SDE} \cdot E[SDE] + \beta_{SDL} \cdot E[SDL] + \beta_{P_L} \cdot P_L + \beta_{UNC} \cdot UNC \\ + \beta_{PT} \cdot PT \cdot E[T] + \beta_{PSDE} \cdot PT \cdot E[SDE] + \beta_{PSDL} \cdot PT \cdot E[SDL] + EDT + VEDT + VVEDT \end{aligned} \quad (10)$$

where $PT = 1$ if the alternative is public transport, and 0 otherwise.
The aim is to analyse whether respondents evaluate the attributes of public transport and road transport with different values. By checking the significance of the coefficients of these interaction terms, we can examine whether the valuation of public transport significantly differs from road transport. The results of Model 3 (Table 4.8) do indeed show that there is a difference in the disutility attributed to travel time and schedule delay. Surprisingly, travel time becomes more important and scheduling deviations less important for public transport relative to the car.
Finally, we considered the nonlinear effects of scheduling variables, such as *E[SDE]* and *E[SDL]*, by including the quadratic terms of these variables in our indirect utility function (Models 4 and 5). The coefficient of this quadratic term of SDE is negative and significant, indicating the non-linear effect. It indicates that people's aversion to arriving early is increasing non-linearly as their schedule delay early time increases. Based on the findings of Model 4, the public transport interaction terms are re-inserted in Model 5. Because there is almost no explanatory power of the variables *E[SDE]* and $E[(SDL)^2]$ in Model 4, we omit these two variables in Model 5.

Table 4.9: The VOT, VSDE,VSDL, and VUNC of Models 1-5(€/hour)

	Model 1	Model 2	Model 3	Model 4	Model 5
VOT generic	8.87	8.88	-	8.94	-
VOT for car	-	-	8.35*	-	8.35*
VOT for public transport	-	-	9.66*	-	9.63*
VSDE generic	-	12.01	-		-
At SDE=10 min				3.17	
At SDE=20 min				6.34	
At SDE=30 min				9.51	
VSDE for car	-		12.30*	-	
At SDE=10 min					5.52*
At SDE=20 min					11.04*
At SDE=30 min					16.56*
VSDE for public transport	-		6.43*	-	
At SDE=10 min					2.29*
At SDE=20 min					4.59*
At SDE=30 min					6.88*
VSDL generic	-	14.58	-	17.29	-
VSDL for car	-	-	16.07*	-	16.60*
VSDL for public transport	-	-	9.69*	-	10.73*
VUNC generic	4.24	-	-	-	-

Note: all monetary values given in this table have significance levels within the 90% interval, whereas * is the indication to show that the difference between car and public transport is significant at the 90% level.

The resulting parameter values (VOT, VSDE, VSDL, and VUNC) from these models are summarised in Table 4.9. The generic VOT values of around € 8.9 seem reasonable and in between the value used in Dutch policy documents and the (mean) interval estimates presented in Section 4.3. Similar results are found for VSDL. The value of uncertainty is somewhat lower than the interval estimate (only significant when scheduling costs are excluded).

The results for Model 2 indicate a considerable higher estimate for VSDE than the interval estimate. This value (12.07) is even higher than VOT, which is rather implausible. People would then prefer extra travel time over early arrival at work. The high VSDE may be explained by the non-linear effect of the SDE variable. We have seen that inclusion of the quadratic terms of SDE (Model 4) leads to a coefficient of $E[(SDE)^2]$ that is negative and significant. Because expected SDE appears as a quadratic term in the utility function, the marginal cost of SDE rises with SDE. Consequently, VSDE is within a reasonable range when the expected schedule delay early time is within 20 minutes. This finding is plausible, as similar results are also obtained in previous studies (Hendrickson and Plank, 1984; Small et al. 1999). It is also in line with the interval estimate.

The estimated coefficients of the interaction terms in Model 3 and Model 5 indicate that the valuations of travel time and scheduling attributes in public transport are significantly different from those in car transport. Figures for VOT, derived from Models 3 and 5, are significantly higher for public transport than for road transport. Jiang and Morikawa (2004) theoretically analysed the variation of VOT and they find that the value of travel time savings is higher for a slower mode if the marginal utility decreases with travel time. This is the case in our experiment. Public transport is designed as a slower mode and marginal utility is likely to decrease when travel time rises. Another possible explanation is that public transport is generally less comfortable, people are willing to pay relatively more to reduce public transport travel time than time spent in a car. It is in this context of importance to emphasise that we are dealing here with valuations of car users. For VSDE and VSDL, car transport has (significantly) higher estimates than public transport. A possible explanation is that public transport usage may be perceived as a relatively easy excuse to arrive early or late at work compared with the car alternative. Private car users may therefore be willing to pay more to save early or late arrival time.

4.5.2 Observed heterogeneity: multinomial logit model with a set of covariates

This section elaborates the analysis by allowing the travel time and scheduling related attributes to interact with behavioural indicators, such as restriction of work starting time and restriction of home departure time, and with some socio-economic indicators, such as gender, income, education, and travel cost compensation. The sample characteristics of these variables can be found in Appendix 4f. Our starting point is the scheduling specification of Model 2 (Eq.(9)).

Behavioural indicators: effects of departure and arrival time restrictions

Intuitively, individuals' flexibility of arrival time at work and departure time from home will have some impact on VOT and scheduling costs. Numerous empirical studies have confirmed that work starting time flexibility has a significant impact on the schedule delay estimates (e.g. Small 1982; Small et al. 1999). Most studies have focused on arrival time restrictions; less studies have explicitly addressed the impact of departure time flexibility on schedule delay costs. Our data contains information on both issues. We have therefore specified the interaction terms for these restriction dummies with time and scheduling attributes, and analyse the significance of both effects.

Table 4.10: Monetary values implied by Model 10 (shown in appendix 4d) (€/hour)

	VOT	VSDE	VSDL	Penalty (later or earlier than restriction)
No restriction [a]	8.47	9.80	11.25	-
Cannot arrive at work later than restriction	7.57	12.61*	15.34**	6.39***
Cannot depart from home before restriction	10.29	18.29***	11.22	1.49
Cannot depart from home after restriction	13.25***	7.87	10.57	3.13**

Note: ***, **, and *, indicate that the difference between one particular group and the reference group is significant at the 99%, 95%, and 90% levels, respectively. [a] No restriction on departure and arrival time is taken as the reference group for comparison.

Table 4.10 shows the VOT, VSDE, and VSDL (the underlying MNL models can be found in Appendix 4d). It appears that restrictions do matter as may be expected. Respondents with restricted starting times at work have a significantly higher VSDE and VSDL, and they also incur a penalty for arriving later than the restricted time (included by means of a dummy variable). These respondents are willing to pay about €6.4 to arrive before the restriction. For the restrictions of individuals' departure time, the effects are different between early and late departure constraints. Commuters tend to have a higher VSDE when it is impossible to change their departure time to an earlier time slot. Commuters who cannot change departure time to a later moment have a higher VOT.

Travel environment and socio-economic indicators

There is ample evidence that VOT, VSDE, and VSDL vary with travel environment and socio-economic variables such as trip length, income, and gender (see, e.g., Small et al., 1999; Lam and Small, 2001). Here, we investigate the effects of trip length, income, gender, education, and travel cost compensation by the employer on our estimates of interest. The estimation results can be found in Appendix 4e, while the summarised monetary values are given in Table 4.11.

Table 4.11: Monetary values implied by Models 11 to 15 (€/hour)

	VOT	VSDE	VSDL
Trip length 30 km or less [a]	6.66	14.85	19.57
Trip length 30-60 km	6.57	9.51***	10.91***
Trip length 60 km or more	11.09***	11.11*	9.06***
Household yearly income €28,500 or less [a]	5.29	14.27	18.47
Household yearly income €28,500-45,000	6.49	11.22	16.48
Household yearly income €45,000-68,000	12.72***	9.72**	10.26***
Household yearly income €68,000 or more	10.48***	12.35	11.74***
Male [a]	8.51	10.35	15.02
Female	10.72**	17.31***	14.37
Lower education (HAVO or less) [a]	8.91	11.20	16.94
Higher education (HBO or above)	8.95	13.24	12.05**
No travel cost compensation [a]	- [b]	11.00	15.74
Partial travel cost compensation	9.74***	8.54	10.88*
Full travel cost compensation	12.50***	13.03	13.06

Note: ***, **, and *, indicate that the difference between one particular group and the reference group are significant at the 99%, 95%, and 90% levels, respectively.
[a] This is taken as the reference group for comparison.
[b] The travel time coefficient is not significant.

Most of the findings are in line with the literature, such as a positive trip length effect on values of time (Gunn, 2001); positive income effects on values of time (Small et al, 1999) and positive female effects on schedule delay cost (Lam and Small, 2001). Particularly, we also find that scheduling costs are lower for respondents with a higher income and a higher educational level (similar to what we found with the interval estimates). This may be explained by the fact that higher educated people have higher status jobs, which generally have less restricted working times. The impact of income on VOT is different from the interval estimates where we did not find a positive relation. The compensation of travel costs by the employer seems most relevant for the VOT. Compensated commuters tend to have a higher VOT than uncompensated drivers. The results of the interval estimates were less strong on this issue; there was only a difference between fully and partially compensated respondents.

4.6 Conclusions

Policy makers are usually very interested in the up-to-date VOT of road users. This concept is an important input to the cost-benefit analysis of new roads. Recently, with the increasing levels of congestion, other concepts have also gained in importance in the policy arena. Reliability (reaching a destination within a certain period of time), for instance, has recently been proposed as an important indicator for the performance of the Dutch road infrastructure. In addition, the estimated choice models can be integrated in models, which predict car drivers' responses to changing travel times or to the imposition of road user charging.

The aim was to find trade-offs between paying and travelling under attractive conditions (in terms of arrival time, travel time, etc.) versus paying less (or nothing) and facing less attractive travel conditions in terms of departure time, route length, and mode. We estimated choice models to estimate values for the above mentioned concepts and assessed the impact of individual characteristics on these.

Two different types of choice experiments were carried out. The first, relatively simple, choice experiment was developed to find individual (interval) estimates for each type of parameter value. In line with other empirical results, we found that VSDL has the highest value (a mean value of €14), followed by the VOT (about €10). However, this latter value is slightly higher than the value used in 2004 for commuting traffic (€8.3) by Dutch policy makers. Commuters seem to attach less value to arriving too early and uncertain travel times. The importance of socio-economic characteristics is rather modest. Income, often cited as important for VOT, only explains some of the variation in the VSDL estimate. Whether employers compensate for travel costs or not influences some of the parameter values. VOT and VSDE tend to be higher for fully-compensated respondents. Those respondents probably think that the road tolls will also be compensated by their employer.

The second experiment consisted of 11 choice sets, and again respondents were asked to allocate 10 trips over four alternatives. It was a labelled experiment in which the alternatives consisted of different attributes (15 in total), which were based on the current behaviour of each individual. We estimated various choice models by using the choice proportions set-up. The respondents preferred the car alternative over the public transport alternative. When we include scheduling costs into the estimations, "pure uncertainty" becomes insignificant. This has also been found by others, and it suggests that it is unnecessary to add an additional cost for unreliability (or uncertainty) of travel when scheduling costs are fully specified. The nonlinear effects of scheduling variables have also been addressed in our model estimations. The analysis indicates that people's aversion to arriving early increases non-linearly as their schedule delay early time increases.

The resulting parameter values for VOT and VSDL seem rather plausible. The size is comparable to the interval estimates, with the VOT being somewhat lower (comparable with the previously mentioned 2004 value used in policy documents). The generic VSDE estimates for car and public transport were rather high. This may be explained by the non-linear effect of the SDE variable. VSDE decreases (to a more reasonable value) when the expected schedule delay early time is within 20 minutes. Note that VOT, VSDE and VSDL of public transport are significantly different from those in car transport. The VOT of car users is lower, whereas their VSDE and VSDL is significantly higher.

We have also included personal variables in the utility functions to study heterogeneity. It is found that the presence of departure or arrival time restrictions is important for the parameter values. People with restricted starting times at work have higher VSDE and VSDL, and they also incur a penalty for arriving later than the restricted time. For the restrictions of individuals' commuting departure time, the effects are different between early and late departure constraints. Moreover, trip length seems to have an impact, especially on VSDE and VSDL. Respondents making longer commuting trips generally attach a lower value to arriving earlier or later than the preferred time. The VSDL is lower for people with a higher income, which is similar to the findings with the interval estimates. Travel cost compensation only seems to have an impact on VOT, with fully-compensated commuters generally having a higher VOT. This is similar to what we found with the first experiment. These respondents may assume that future road charged will also be compensated by their employers, which can explain their willingness to pay for travel time savings.

Appendix 4A

Scenarios to obtain VSDE, VSDL, and VUNC interval estimates

The literature suggests that the **VSDE** is about half of the VOT. Therefore, we defined the following 4 intervals:

1. € 0 – 2
2. € 2 – 4
3. € 4 – 6
4. > € 6

	A (group 4)	B (group 3)	C (group 2)	D (group 1)
Departure time	T_D	T_D – 15 min.	T_D – 30 min.	T_D – 45 min.
Travel time	T_f	T_f	T_f	T_f
Arrival time	T_A	T_A – 15 min.	T_A – 30 min.	T_A – 45 min.
Toll	€ 3	€ 1.50	€ 0.50	€ 0

According to the literature **VSDL** is about twice the VOT. Therefore, we defined the following 4 intervals:

1. € 0 – 8
2. € 8 – 16
3. € 16 – 24
4. > € 24

	A (group 4)	B (group 3)	C (group 2)	D (group 1)
Departure time	T_D	T_D + 10 min.	T_D + 20 min.	T_D + 30 min.
Travel time	T_f	T_f	T_f	T_f
Arrival time	T_A	T_A + 10 min.	T_A + 20 min.	T_A + 30 min.
Toll	€ 8	€ 4	€ 1.33	€ 0

We have defined, rather arbitrarily, the following intervals for the **VUNC**:

1. € 0 – 3
2. € 3 – 6
3. € 6 – 9
4. > € 9

	A (group 4)	B (group 3)	C (group 2)	D (group 1)
Departure time	T_D – 30 min.	T_D – 30 min.	T_D – 30 min.	T_D – 30 min.
Min. travel time	T_f + 30 min.	T_f + 5 min.	T_f + 0 min.	T_f
Max. travel time	T_f + 30 min.	T_f + 35 min.	T_f + 40 min.	T_f + 55 min.
Min. arrival time	T_A	T_A – 15 min.	T_A – 30 min.	T_A – 45 min.
Max. arrival time	T_A	T_A + 5 min.	T_A + 10 min.	T_A + 15 min.
Tol	€ 6	€ 3	€ 1	€ 0

Appendix 4B

Example of one screen (with 4 alternatives) of the second part of the SC-experiment as presented to the respondent (levels are indicative)

Alternative A	Alternative B	Alternative C	Alternative D
Mode of transport: car	Mode of transport: car	Mode of transport: car	Mode of transport: public transport
Trip length : 35 km	Trip length: 35 km	Trip length: 49 km	Trip length: 35 km
Travel costs: € 8.10 of which: – fuel: €3.20 – charge: €4.90	Travel costs: € 4.60 of which: – fuel: €3.20 – charge: €1.40	Travel costs: € 6.20 of which: – fuel: €4.20 – charge: €2.00	Price of a ticket: € 3.18
Departure time: 08.10	Departure time: 08.25	Departure time: 08.00	Departure time: 07.25
Total travel time between 40 and 50 minutes of which: – free flow: 25 min. – minimum time in congestion: 15 min. – maximum time in congestion: 25 min.	Total travel time between 50 and 60 minutes of which: – free flow: 25 min. – minimum time in congestion: 25 min. – maximum time in congestion: 35 min.	Total travel time between 55 and 65 minutes of which: – free flow: 40 min. – minimum time in congestion: 15 min. – maximum time in congestion: 25 min.	Total travel time: 72 minutes
Arrival time is hence between: 8.50 and 9.00	Arrival time is hence between: 9.15 and 9.25	Arrival time is hence between: 8.55 and 9.05	Arrival time: 08.37
Number of trips …..	Number of trips ….	Number of trips …	Number of trips …

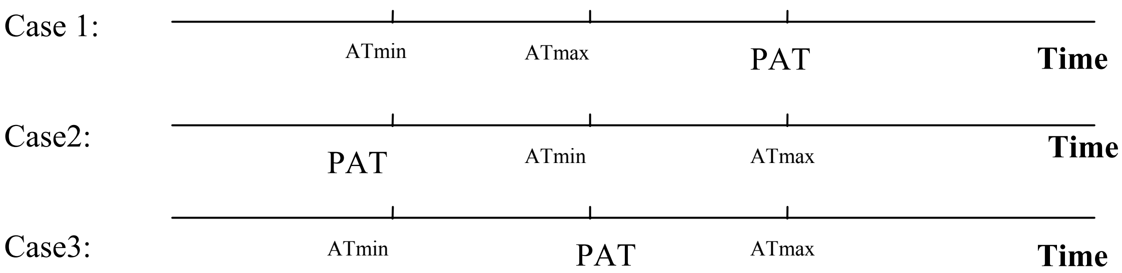
Appendix 4C

Computation of E[SDE] and E[SDL]

SDE is defined to be positive for early arrivals and zero otherwise; while SDL is positive for late arrivals and zero otherwise. P_L represents the probability of arriving later than the preferred arrival time.

$$SDE(AT) = \max\{PAT - AT, 0\}$$
$$SDL(AT) = \max\{AT - PAT, 0\}$$
$$P_L = \Pr ob(AT > PAT),$$

where AT denotes the arrival time and PAT is the preferred arrival time.
To compute the E[SDE], E[SDL], and P_L we can distinguish the following three cases:



where ATmin is the earliest arrival time and ATmax is the latest arrival time

Case 1: $AT\max \le PAT$

$$E[SDE] = PAT - \frac{1}{2}\left(AT\min + AT\max\right)$$
$$E[SDL] = 0$$
$$P_L = 0 \,.$$

Case 2: $AT\min \ge PAT$

$$E[SDE] = 0$$
$$E[SDL] = \frac{1}{2}\left(AT\min + AT\max\right) - PAT$$
$$P_L = 1 \,.$$

Case 3: $AT\min < PAT \;\&\; AT\max > PAT$

$$E[SDE] = \frac{1}{2}\left(PAT - AT\min\right) * \left(1 - P_L\right)$$
$$E[SDL] = \frac{1}{2}\left(AT\max - PAT\right) * P_L$$
$$P_L = \frac{AT\max - PAT}{AT\max - AT\min} \,.$$

Appendix 4D

Estimation results of scheduling restriction effects based on Model 2

Explanatory variables	Model 6	Model 7	Model 8	Model 9	Model 10
ASC of public transport alternative	-0.77*** (-14.9)	-0.77*** (-14.9)	-0.77*** (-14.8)	-0.77*** (-14.9)	-0.78*** (-14.9)
Travel cost C	-0.09*** (-16.5)	-0.09*** (-16.4)	-0.09*** (-16.4)	-0.09*** (-16.6)	-0.09*** (-16.4)
E[T]	-0.01*** (-9.3)	-0.01*** (-8.9)	-0.01*** (-8.9)	-0.01*** (-8.9)	-0.01*** (-8.2)
E[T]*arriving later than work restr.		0.0009 (0.7)			0.001 (1.1)
E[T]*departing earlier than home restr.			-0.005*** (-2.7)		-0.003 (-1.3)
E[T]*departing later than home restr.				-0.006*** (-3.1)	-0.007*** (-3.8)
E[SDE]	-0.0186*** (-8.5)	-0.017*** (-6.4)	-0.02*** (-7.6)	-0.02*** (-8.5)	-0.01*** (-5.8)
E[SDE]*arriving later than work restr.		-0.004 (-1.6)			-0.004* (-1.7)
E[SDE]*departing earlier than home restr.			-0.01*** (-3.7)		-0.01*** (-3.3)
E[SDE]*departing later than home restr.				0.003 (0.7)	0.003 (0.8)
E[SDL]	-0.02*** (-8.6)	-0.018*** (-6.1)	-0.02*** (-9.3)	-0.02*** (-8.9)	-0.018*** (-5.9)
E[SDL]*arriving later than work restr.		-0.01*** (-3.3)			-0.006** (-1.9)
E[SDL]*departing earlier than home restr.			0.003 (0.7)		0.0001 (0.01)
E[SDL]*departing later than home restr.				-0.0037 (-0.778)	0.001 (0.2)
Probability of late arrival (later than PAT)	-0.094* (-1.9)	-0.08* (-1.8)	-0.09* (-1.9)	-0.09* (-1.9)	-0.09* (-1.9)
Uncertainty	0.002 (1.2)	0.002 (1.2)	0.002 (1.3)	0.002 (1.3)	0.002 (1.1)
Dummy for arriving later than work restr.	-0.63*** (-6.2)				-0.6*** (-5.7)
Dummy for departing earlier than home restr.	-0.32*** (-4.4)				-0.14 (-1.5)
Dummy for departing later than home restr.	-0.18* (-1.2)				-0.27** (-2.3)
Dummy for departing 30-59 min earlier than PDT	0.29*** (8.9)	0.29** (8.9)	0.30*** (9.1)	0.29*** (8.9)	0.29*** (8.8)
Dummy for departing 60-89 min earlier than PDT	-0.13*** (-3.6)	-0.14*** (-3.7)	-0.14*** (-3.7)	-0.14*** (-3.7)	-0.13*** (-3.6)
Dummy for departing more than 90 min PDT	-0.52*** (-6.0)	-0.52*** (-5.9)	-0.5*** (-6.1)	-0.52*** (-5.9)	-0.52*** (-5.9)
Log likelihood	-15387.63	-15414.93	-15399.98	-15413.79	-15367.50
R-sqrd Adjusted	0.09	0.09	0.09	0.09	0.09

Note: t-statistics are shown in parenthesis. Significance is indicated by ***, **, and *, referring to significance at the 99%, 95%, and 90% levels, respectively.

Appendix 4E

Estimation results of trip length, income, gender, education, and cost compensation effects

Explanatory variables	Model 11 Est. b	Model 11 t-stats.	Model 12 Est. b	Model 12 t-stats.	Model 13 Est. b	Model 13 t-stats.	Model 14 Est. b	Model 14 t-stats.	Model 15 Est. b	Model 15 t-stats.
ASC of public transport alternative	-0.84***	(-15.4)	-0.77***	(-14.8)	-0.77***	(-14.7)	-0.77***	(-14.8)	-0.82***	(-15.5)
Travel cost C	-0.11***	(-16.5)	-0.1***	(-17.0)	-0.092***	(-16.1)	-0.09***	(-16.5)	-0.11***	(-18.6)
E[T]	-0.012***	(-5.9)	-0.009***	(-4.7)	-0.01***	(-8.7)	-0.01***	(-9.1)	0.004	(1.6)
E[T]*Trip length L2 (30-60 km)	0.0002	(0.08)								
E[T]*Trip length L3 (>60 km)	-0.0078***	(-3.8)								
E[T]*Income2 (household inc. €28,500-45,000)			-0.002	(-1.08)						
E[T]*Income3 (household inc. €45,000-68,000)			-0.01***	(-6.6)						
E[T]*Income4 (household inc. >€68,000)			-0.008***	(-4.9)						
E[T]*Female					-0.003**	(-2.0)				
E[T]*Higher education (HBO and above)							-0.0001	(-0.050)		
E[T]*Fully compensation of travel cost									-0.02***	(-7.6)
E[T]*Partial compensation of travel cost									-0.02***	(-9.9)
E[SDE]	-0.02***	(-9.3)	-0.02***	(-7.9)	-0.016***	(-6.9)	-0.018***	(-7.2)	-0.02***	(-5.2)
E[SDE]*Trip length L2 (30-60 km)	0.009***	(3.2)								
E[SDE]*Trip length L3 (>60 km)	0.006*	(1.8)								
E[SDE]*Income2 (household inc. €28,500-45,000)			0.005	(1.5)						
E[SDE]*Income3 (household inc. €45,000-68,000)			0.007**	(2.2)						
E[SDE]*Income4 (household inc. >€68,000)			0.003	(1.2)						
E[SDE]*Female					-0.011***	(-3.5)				
E[SDE]*Higher education (HBO and above)							-0.0032	(-1.2)		
E[SDE]*Fully compensation of travel cost									0.0045	(1.1)
E[SDE]*Partial compensation of travel cost									-0.0037	(-0.9)
E[SDL]	-0.03***	(-9.5)	0.0299***	(-8.022)	-0.02***	(-8.981)	-0.03***	(-9.295)	-0.029***	(-5.8)
E[SDL]*Trip length L2 (30-60 km)	0.01***	(3.8)								
E[SDL]*Trip length L3 (>60 km)	0.02***	(4.4)								
E[SDL]*Income2 (household inc. €28,500-45,000)			0.0032	(0.733)						
E[SDL]*Income3 (household inc. €45,000-68,000)			0.0133***	(2.948)						
E[SDL]*Income4 (household inc. >€68,000)			0.0109***	(2.718)						
E[SDL]*Female					0.001	(0.262)				
E[SDL]*Higher education (HBO and above)							0.008**	(2.440)		
E[SDL]*Fully compensation of travel cost									0.009*	(1.7)
E[SDL]*Partial compensation of travel cost									0.005	(0.9)
Probability of late arrival (later than PAT)	-0.08*	(-1.7)	-0.0932*	(-1.9)	-0.09*	(-1.8)	-0.09*	(-1.864)	-0.1**	(-2.0)
Uncertainty	0.001	(0.7)	0.0014	(1.5)	0.002	(1.2)	0.002	(1.405)	0.0015	(1.0)
Dummy for departing 30-59 min earlier than PDT	0.2***	(6.5)	0.29***	(8.8)	0.31***	(9.4)	0.29**	(8.8)	0.26***	(7.9)
Dummy for departing 60-89 min earlier than PDT	-0.14***	(-3.6)	-0.14***	(-3.8)	-0.14***	(-3.8)	-0.14***	(-3.7)	-0.15***	(-4.0)
Dummy for departing more than 90 min PDT	-0.39***	(-4.3)	-0.51***	(-5.8)	-0.55***	(-6.25)	-0.52	(-5.9)	-0.46***	(-5.3)
Log likelihood	-15390.69		-15384.71		-15405.94		-15413.49		-15355.98	
R-sqrd Adjusted	0.09		0.09		0.09		0.09		0.09	

Note: t-statistics are shown in parenthesis. Significance is indicated by ***, **, and *, referring to significance at the 99%, 95%, and 90% levels, respectively.

Appendix 4F

Explanation and population share of explanatory (dummy) variables of data set (N=1115)

Categories	Definitions and population share
Gender	Male = 1 if male (76.23%) Female = 1 if female (23.77%)
Education	Lower education = 1 if senior general secondary (HAVO/VWO) or lower (55.25%) Higher education = 1 if Bachelor (HBO/WO) or higher (44.75)
Income	Income 1 = 1 if household gross yearly income is less than 28,500 euros (20.72%) Income 2 = 1 if household gross yearly income is 28,500 – 45,000 euros (26.73%) Income 3 = 1 if household gross yearly income is 45,000 – 68,000 euros (26.10%) Income 4 = 1 if household gross yearly income is more than 68,000 euros (26.46%)
Trip length	Trip length L1 = 1 if the usual commuting distance is less than 30 km (35.16%) Trip length L2 = 1 if the usual commuting distance is 30 - 60 km (36.95%) Trip length L3 = 1 if the usual commuting distance is more than 60 km (27.89%)
Late arrival time restriction	Late arrival time restriction =1 if commuters cannot arrive at work later than certain time (54.71%)
Early departure time restriction	Early departure time restriction =1 if commuters cannot depart from home earlier than certain time (15.07%)
Late departure time restriction	Late departure time restriction = 1 if commuters cannot depart from home later than certain time (14.44%)

Chapter 5

The effects of road pricing: short-term responses and car ownership from a survey among car owners

5.1 Introduction

People's responses to transport pricing are not straightforward. Price increases may not necessarily lead to trip suppression, they may also induce travellers to change their modal use or change their departure time, depending on the type of measure. Chapter 3 provided a literature overview of the effects of road pricing, which revealed that pricing may affect many behavioural dimensions, many of which have been studied, both theoretically and empirically. Empirical studies are often limited to conventional pricing measures, such as fuel taxes and parking pricing, and the practical experiences of road tolls. This is relevant in many situations. But the Dutch situation may call for a more applied approach, given the interest in a kilometre charge combined with hypothecation of the revenues. The present study does this by systematically analysing the behavioural responses to different forms of road pricing, including a specification of revenue use. While previous studies have looked at the effects on car use, less attention has been given to what people will do when they decide not to use their car anymore. There is even less knowledge on how to explain the different types of responses; this will also be included here.

This chapter presents the results from an empirical survey among car owners in the Netherlands (of whom half have participated in the questionnaire described in Chapter 4: car commuters who experience congestion). We study effect sizes and type of responses to different types of road pricing measures. Given the policy relevance (in particular for the Dutch situation), we have evaluated three different variants of a kilometre charge. We will analyse the short-term behavioural responses in terms of sensitivity and type of change for three different trip purposes. Furthermore, the aim is to find important explanatory variables for the level of effectiveness (expressed as the share of trips that will be changed). A more long-term response, car ownership, will be analysed separately.

This chapter is organised as follows. Section 5.2 explains the structure of the questionnaire and the type of pricing measures that were evaluated by the respondents. Then Section 5.3 presents the effectiveness outcomes in terms of car trips that will be replaced by the respondents (including how these trips will be changed). A statistical analysis is conducted in Section 5.4, which identifies important explanatory variables (positive or negative) for the level of effectiveness of each type of measure. Section 5.5 focuses on car ownership. It analyses the probability that respondents will sell their car if different price measures are implemented. Section 5.6 concludes.

5.2 Data collection and survey description

5.2.1 Data collection

The data have been obtained through an (interactive) internet survey among Dutch car owners. The total sample consists of 562 respondents, of whom half are car commuters who experience congestion on a regular basis, as investigated in an earlier questionnaire.[8] These respondents were confronted with three different road pricing measures, and we asked them if and how they would expect to change their behaviour in response to these measures. The

[8] These respondents have been selected from the sample presented in Chapter 4. Note that this survey was 'over-sampled' in the lower income groups so as to obtain a sufficient number of observations.

focus is first on the short-term responses; the long-term decision with respect to car ownership and car change will be analysed in Section 5.5. 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.

5.2.2 Survey

Three different pricing measures will be considered, each in multiple variants. Table 5.1 shows the various measures that have been developed: 6 different variants for measure 1, 2 variants for measure 2, and again 6 variants of the third measure (a more detailed description of these measures can be found in Appendix 5a). The variants were divided randomly over the respondents, and each respondent evaluated one variant of each measure (so three in total). As a result, we obtained at least 88 observations for each variant of measure 1 (see also Table 5.3), 282 for measure 2A, and 280 for measure 2B, and about 95 for each variant of measure 3 (see also Table 5.7).

Table 5.1: Short description of the road pricing measures presented to the respondents

Measure	Variant
1: Flat kilometre charge with different charge levels and different revenue use	A: 3 €cents, abolition of car ownership taxes B: 6 €cents, abolition of existing car taxation (purchase and ownership) C: 12 €cents, abolition of existing car taxation and investment in new roads D: 3 €cents, revenues used to lower income taxes E: 6 €cents, revenues used to lower income taxes F: 12 €cents, revenues used to lower income taxes
2: Differentiated kilometre charge with different charge levels and different revenue use	A: 2 €cents with multi-step (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 €cents outside peak times and 6 €cents in peak, abolition of car ownership taxes B: 4 €cents outside peak times and 12 €cents in peak, abolition of existing car taxation C: 8 €cents outside peak times and 24 €cents in peak, abolition of existing car taxation and new roads D: 2 €cents outside peak times and 6 €cents in peak, revenues used to lower income taxes E: 4 €cents outside peak times and 12 €cents in peak, revenues used to lower income taxes F: 8 €cents outside peak times and 24 €cents in peak, revenues used to lower income taxes

All descriptions of the measures, as shown to respondents, consisted of two major components: we explained both the structure and level of the charge, and the allocation of the revenues. Furthermore, we provided each respondent individually with an estimation 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). We assume that each respondent will make a cost calculation based on their present situation. 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 estimate of the financial benefits resulting from recycling of revenues via lower income taxation, we only presented the savings for those measures where existing car taxes are abolished to help the respondents with their cost-benefit assessment[9]. We also explained some practical issues that were meant to prevent various practical considerations from affecting the

[9] 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 average savings 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).

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.).
The survey began with some general questions asking the respondent for important background variables. These variables may help explain the differences in reported effectiveness levels. The variables included in our statistical analyses are explained in more detail in Appendix 5b, which shows the profile of our sample.
All respondents own a car, which is used for different trip purposes. These are not necessarily commuting because not all respondents have a job (17.6% are not employed: see Appendix 5b). The educational level of our sample seems relatively high. About 29% of the Dutch car owners have a bachelor's or master's degree (based on CBS data for 2003), but in our survey this share is considerably higher (40%). CBS statistical data also suggests that car ownership increases with income. About 20% of the car owners in this sample have 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 are older than 55, while this share is only 16% in this survey. Most of the respondents are located in the Randstad area (the category rest west and three large cities in our sample), the northern part of the Netherlands is only modestly represented with 6.4%.
Whether respondents have the possibility to work at home or not may have an impact on the effectiveness of a road pricing measure. Since we have information on this, it has been included into the analysis. About 62% of the employed respondents who use their car for their commuting trip do not have the possibility to work at home. Respondents who do not make car commuting kilometres or do not have a job have not answered this question (they form the 'unknown' group: about 32% of the sample). We also asked whether the respondents received compensation for their commuting costs from their employer. Most car owners are at least partly compensated. A small group incurs no commuting costs: these may be people who do their work at home but it may also be respondents who have misinterpreted the question and, in fact, are completely compensated by their employer (because they indicated that they do drive commuting kilometres).
After a brief description of each measure, the respondents were asked whether they would change the number of car trips for the following three different trip purposes (only in those cases where the respondent indicates that he/she actually makes this type of trip):

- Commuting trips (made at least sometimes by 70.8% of the respondents);
- Trips to visit people (made at least sometimes by 80.1% of the respondents);
- Other type of trips (e.g. shopping, sports activities, etc., made at least sometimes by 92.9% of the respondents).

Commuting trips are only made by 71% of the respondents, but the intensity of these trips during the week is relatively higher compared with the other types of trips.
If respondents indicated that they did expect to adjust their travel behaviour[10], 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 respondents will change their departure time when a flat kilometre charge is presented), various possibilities were presented:

- Public transport;
- Non-motorised transport (walking, bicycle);
- Motorised private transport (motorbike, motor);
- Carpool (only asked for commuting trips);
- Work at home (only asked for commuting trips);

[10] It is possible that people indicate that they intended to make more car trips, and in that case we only asked how many extra trips this person would make.

– Travel at other times (only when measure is time dependent);
– 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 made in a normal week. Because some (types of) trips are only made once a week, we asked the respondents to indicate how many trips they would change in a period of 4 weeks (by 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 would be changed. Respondents had to make sure that the number of trips changed was equal to the number of trips allocated over the different alternatives.

This approach, as with most research on future, hypothetical situations, may involve some drawbacks. Respondents may answer strategically ('I want this measure not to be implemented, so I will not change behaviour') or give socially desirable answers. It may also be the case that the questions are too difficult to understand for the respondents (e.g. as a consequence of many uncertainties), which may give problems with interpretation of the answers. We have tried to obviate this by giving detailed information about the policy measure and the future costs for each individual. These issues should be taken into account when explaining the results.

5.3 Effectiveness of different pricing regimes

The aim of this survey is to analyse the behavioural responses to realistic and policy-relevant road pricing measures[11]. 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 travel (visits), and other (e.g. shopping)). The overview at the end of this section gives a short comparison with findings in the previous literature (discussed in Chapter 3) on this subject whenever possible and relevant.

We have information on the behavioural responses in terms of number of trips that an individual would adjust, and how these would be adjusted. Since we also have an individual estimation of the yearly number of kilometres driven for each trip purpose, it is also possible to express changes in terms of kilometres. Information on both outcomes will be presented below.

5.3.1 Measure 1: flat kilometre charge (3, 6 and 12 €cents) and different revenue use

The number of respondents who indicated they would adjust their car trips if measure 1 became a reality was 45 for commuting (11% of commuters change trips), 119 (26%) for visits and 125 (24%) 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 the number of trips and kilometres. Table 5.2 shows the aggregated outcomes for all variants together; Appendix 5c 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 is in line with the findings for price elasticities that were presented in Chapter 3. It may be explained by the fact that a trip suppression is not a serious alternative for commuting trips (only 0.5% of trips to be adjusted will not be made anymore), whereas for other reasons people can 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

[11] At this moment, policy makers in the Netherlands are seriously considering the implementation of a kilometre charge that replaces current car taxation.

in particular an alternative for visits and other trips, as 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 5.2: Aggregated outcomes and variation of behavioural responses to measure 1: a flat kilometre charge

		Commuting	**Visits**	**Other**
Total number of trips (driven in 4 weeks)		6800	3620	7780
Number of trips adjusted		400 (5.9%)	513 (14.2%)	846 (10.9%)
Of which:				
Public transport		31.8%	17.8%	13.3%
Non-motorised transport		32.2%	44.6%	64.9%
Motorised		9.5%	8.9%	1.8%
Carpool		19.5%	not relevant	not relevant
Working at home		6.5%	not relevant	not relevant
Not making trip		0.5%	28.6%	19.9%
Kilometres adjusted (as a % of total)		3.9%	11.6%	9.2%
Trip purpose population	Variance	0.042 (N=398)	0.056 (N=450)	0.041 (N=522)
	Skewness (st. error)	3.50 (.122)	1.90 (.115)	2.07 (.107)
Population adjusting trips	Variance	0.099 (N=45)	0.051 (N=119)	0.039 (N=125)
	Skewness (st. error)	0.15 (.354)	0.66 (.222)	0.82 (.217)

While it is useful to present aggregated results, these mask the variations among individual responses. In fact, they may be skewed as a result of extreme responses by some individuals and sampling biases. It is therefore important to report variation measures of individual responses. We report the skewness and the variance for two different samples: 1) those respondents who indicate that they made a particular type of trip (including the large group who indicated they would not change); and 2) those respondents who indicate to change behaviour. The large sample has a positive (to the right) skewness with considerably smaller standard errors, which can be explained by the large number of zeros in this sample. The variances for both populations are not very different from each other. Similar patterns have been found for the other two measures, but these will only be reported and not discussed.

It is also interesting to consider the relative effectiveness of the various variants of measure 1. As expected and confirmed by previous studies, a kilometre charge of 12 €cents has more effect than a similar measure with lower charges. Table 5.3 shows the impact of each variant 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 €cents) seems slightly more effective than measure 1E (6 €cents) for particular trip purposes. Measure 1F induces the strongest trip changes. Variants A, B, and C are measures where car taxation is abolished, which seem to be less effective than those measures where revenues are used to lower income taxes. The perceived higher costs for each individual involved with the latter measures, stemming from our inability to predict the reduction in income tax, may provide an explanation for this. None of the 96 respondents who evaluated measure 1A (with the low toll) indicated that they would change their commuting trips.

Table 5.3: Effectiveness related to the variants of measure 1: a flat kilometre charge

Measure	Number of respondents	% of total trips adjusted		
		Commuting	Visits	Other
1A (3 €cents/MRB)	96	0	9.5	13.6
1B (6 €cents/MRB+BPM)	94	5.0	9.4	9.5
1C (12 €cents/MRB+BPM+new roads)	88	11.3	20.3	17.6
1D (3 €cents/income taxes)	101	25.0	15.0	21.2
1E (6 €cents/income taxes)	91	19.7	20.5	16.7
1F (12 €cents/income taxes)	92	39.0	25.3	21.5

5.3.2 Measure 2: kilometre charge with multi-step bottleneck toll (2A), and kilometre charge differentiated according to weight of the vehicle (2B)

Table 5.4 shows the behavioural responses for both variants of the second measure separately, because these are very different. The first variant is a peak-period charge combined with a flat kilometre fee, while measure 2B is differentiated according to weight of the vehicle. Compared with the previous measure, 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 variant. Changing travel time is very attractive for all trip purposes: people prefer car use at other times over public transport and non motorised travel, 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 (relative to measure 2B). Note that this variant 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 5.5 confirms this. It shows that measure 2A is responsible for almost three-quarters of the adjusted commuting trips. Finally, it appears that slower travel modes are an attractive alternative especially for social purposes. These trips probably often have nearby destinations.

Table 5.4: Behavioural responses to measure 2A (multi-step toll), and 2B (km charge/weight vehicle)

Measure	Measure 2A			Measure 2B		
Trip purpose	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**
Total number of trips (driven in 4 weeks)	3188	1824	3892	3612	1796	3888
Trips adjusted (% total)	358 (11.2%)	166 (9.1%)	359 (9.2%)	145 (4.0%)	150 (8.4%)	308 (7.9%)
Of which:						
Public transport	22.3%	16.9%	13.1%	13.8%	14.0%	9.7%
Non-motorised travel	8.9%	29.5%	38.7%	26.2%	46.7%	66.6%
Motorised	2.5%	1.4%	1.7%	38.6%	8.7%	1.0%
Car pooling	10.6%	NR	NR	12.4%	NR	NR
Travel at other times	51.1%	42.2%	38.2%	NR	NR	NR
Working at home	4.2%	NR	NR	6.9%	NR	NR
Not making the trip	0.3%	10.2%	8.3%	2.1%	30.7%	22.7%
kilometres adjusted (as a % of total)	11.3%	10.3	8.2	2.5	6.7	7.4

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

Table 5.5: Effectiveness related to both variants of measure 2, and variation in responses

		Number of respondents	**% of total trips adjusted**		
			Commuting	Visits	Other
2A: multi-step bottleneck toll		282	71.2	52.5	53.8
2B: km charge/weight vehicle		280	28.8	47.5	46.2
			Variation for aggregated outcomes		
Trip purpose population	Variance		0.048 (N=398)	0.034 (N=450)	0.060 (N=522)
	Skewness (st. error)		3.01 (.122)	3.81 (.115)	2.07 (.107)
Population adjusting trips	Variance		0.094 (N=56)	0.067 (N=81)	0.060 (N=97)
	Skewness (st. error)		0.20 (.319)	0.72 (.267)	0.81 (.245)

5.3.3 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 with 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 commuting trips 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 would be adjusted would be replaced by trips made off-peak (see Table 5.6, and Appendix 5c for the disaggregated results). Non-motorised travel 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, and the same holds for carpooling. The findings for variation in responses are similar to those of measure 1: the distribution for the large sample is skew to the right as may be expected.

The pattern shown in Table 5.7 is somewhat different from what could be expected. This measure combines different charge levels with different types of revenue use. Variants C and F have the highest charges, considerably higher than A and D. The estimated benefits of revenue use for variants A to C were presented to the respondents, but this was not done for the variants where revenues are used to lower income taxes (D to F). Since higher charges tend to have more effect, variants C and F may be expected to have more effect than the other alternatives, and B and E again more than A and D. However, this is not found here. Measure 3B, for instance, is considerably less effective than measure 3A for all purposes. The effect of revenue use (not only MRB, but also BPM) may be responsible for this. A similar pattern is found for measure 3E (compared with 3D), but in this case the allocation of revenues was unchanged. Most remarkable is that the variants with the lowest charge levels (A and D) are even more effective than variants C and F for certain purposes. But the answers remain responses to hypothetical situations. 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 measures 3C (visits) and 3A (other purposes) are different in this context, revenues hypothecated to reduce car taxation dominates income tax compensation in terms of effectiveness. We will analyse the impact of the type of measure (distinction between revenue use and charge level) in a more detailed way by conducting a statistical analysis in Section 5.4.

Table 5.6: Aggregated outcomes of behavioural responses to measure 3 including variation: peak and off-peak kilometre charge

		Commuting	Visits	Other
Total number of trips (driven in 4 weeks)		6800	3620	7780
Number of trips adjusted		1004 (14.8%)	529 (14.6%)	1028 (13.2%)
Of which:				
Public transport		17.6%	13.6%	14.1%
Non-motorised transport		12.7%	28%	28.9%
Motorised		8.8%	1.7%	1.5%
Carpool		4.5%	not relevant	not relevant
Travel at other times		47.7%	47.8%	47.3%
Working at home		7.9%	not relevant	not relevant
Not making trip		0.6%	8.9%	8.3%
Kilometres adjusted (in % of total)		14.6%	13.2%	11.2%
Trip purpose population	Variance	0.099 (N=398)	0.091 (N=450)	0.069 (N=522)
	Skewness (st. error)	1.93 (.122)	1.88 (.115)	2.20 (.107)
Population adjusting trips	Variance	0.125 (N=102)	0.090 (N=114)	0.081 (N=116)
	Skewness (st. error)	-0.15 (.239)	0.10 (.226)	0.33 (.225)

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 does not seem much difference over trip purposes for the other measures.

Table 5.7: Effectiveness related to the variants of measure 3: peak and off-peak kilometre charge

Measure	Number of respondents	% of total trips adjusted		
		Commuting	Visits	Other
3A: 2/6 €cents (off-peak/peak), MRB	96	16.0	14.2	21.6
3B: 4/12 €cents, MRB+BPM	91	13.8	10.0	12.1
3C: 8/24 €cents, car taxation and new roads	97	15.8	25.9	13.1
3D: 2/6 €cents, income taxes	96	19.0	18.9	14.4
3E: 4/12 €cents, income taxes	94	13.9	14.4	15.7
3F: 8/24 €cents, income taxes	88	21.3	16.6	23.2

5.3.4 Overview

In terms of trips, the effectiveness of the measures is in the range of 6% to 15% for all trip purposes. The effect in terms of kilometres is somewhat smaller. It is often difficult to compare these results with the 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 also included respondents not owning a car. The outcomes in terms of kilometres for measure 1A and 1B may be compared with 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.

In Chapter 3 we discussed the properties of elasticities and showed literature estimates. The structure of the previously described experiment allows us to derive elasticities (although not for every measure), since both changes in demand and prices are available. Table 5.8 shows elasticity values for measure 1 and 3 (the percentage change in quantity divided by the percentage change in price). We assume that the present level of variable cost of driving equals the fuel cost (€1.50/litre which is about €0.11/kilometre for an average petrol car, we neglect differences between fuel types and maintenance costs). The difference in the price measure ('delta p') is straightforward for measure 1: the level of the kilometre charge. The percentage change in demand is equal to the number of trips adjusted for each variant as a fraction of the total number of trips made (which differs for each trip purpose, see appendix 5c). Measure 3 is a time differentiated measure, which makes things slightly more complicated. We decided to focus on the trip timing effect of the additional peak period charge, and exclude other behavioural responses. Therefore Table 5.8 presents peak period demand elasticities for measure 3. We assume that all 'travel at other times' trips will be outside the defined peak period with the additional charge (so there is no 'return to the peak' effect). In addition, we assume that 46% of the commuting trips, 18% of the visit type of trips, and 14% of the 'other' trips is presently driven within those peak periods (based on CBS data available for the Netherlands).

Table 5.8: Elasticities for measures 1 and 3

	Commuting	**Visits**	**Other**
1A: 3 €cents	0	-0.32	-0.28
1B: 6 €cents	-0.03	-0.13	-0.12
1C: 12 €cents	-0.04	-0.15	-0.12
1D: 3 €cents	-0.30	-0.48	-0.47
1E: 6 €cents	-0.12	-0.32	-0.19
1F: 12 €cents	-0.14	-0.20	-0.13
3A: peak charge of 6 €cents	-0.36	-0.54	-1.00
3B: peak charge of 12 €cents	-0.11	-0.33	-0.32
3C: peak charge of 24 €cents	-0.02	-0.21	-0.17
3D: peak charge of 6 €cents	-0.38	-0.83	-0.72
3E: peak charge of 12 €cents	-0.14	-0.40	-0.43
3F: peak charge of 24 €cents	-0.08	-0.14	-0.21

The range of estimates (between 0 and -1.0) is comparable to the literature estimates presented in Table 3.2. However, direct comparison is not possible since our car use elasticities are in number of trips, while those of Chapter 3 are in car kilometres. The variety between measures is considerable. The elasticity estimates decrease when price changes become larger. This is explained by the considerable changes in prices, and the relatively small differences in demand changes. It indicates that a kilometre charge with low charge levels is, in a relative sense, more effective. We should note that an additional charge of €0.03 (as in measure 1A and 1D) is already a price increase of 28%, which is substantial. Additional increases are not very effective anymore. This is not in line with research by MuConsult (1997), which suggests that fuel price elasticities (of the demand for car kilometres) increase with price increases (up till 60% of price changes).
For measure 3 we find, again, elasticities decreasing with (peak) charges. The considerable elasticities for 'visit' and 'other' type of trips is explained by the relative small number of trips made in the peak. The estimates may implicitly include an underestimation as well as an overestimation of the effectiveness of peak period pricing. Overestimation, because we do not include extra trips made in the peak period (due to improved road conditions). Underestimation, because we only consider one type of response, car owners may also decide to use public transport instead.

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

Non-motorised 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 easily be replaced by walking or cycling. Driving at different times than before 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 not serious options for most of the respondents), but there does seem to be some flexibility to allow the rescheduling of trips. This is confirmed by the empirical results from Singapore (see Olszewski and Xie, 2005) and time-dependent modelling studies (see Chapter 3).

The impact of the type of measure is not straightforward. Previous research and common sense suggest that higher kilometre charges have more impact. Our own results are, however, somewhat mixed on this issue and are difficult to explain. However, the statistical analysis of Section 5.4 does not confirm statistically that measures with lower charge levels may be more effective. There are of course two opposing effects: a price increase caused by the kilometre tax and the indirect subsidy of revenue spending. The abolition of present taxation may be considered as an income effect that gives purchasing power to the consumer (countervailing force). Given the nature of the measures – revenue neutral to the government – the level of compensation of both types of revenue use is similar. But we do find a difference in effectiveness: those measures with revenues allocated to lower income taxes generally have more effect on car use. Although difficult to explain, it may be caused by the difference in perception of both types of income compensation. The financial consequences of the abolition of car taxation have been estimated and presented to the individuals. This has not been the case for those variants where income taxation was lowered. In addition, respondents may reserve a certain budget for travel related expenses. It may then be justified to spent transport related bonuses on transport matters, and keeping the number of kilometres travelled constant. Compensation by means of income taxation may earlier be used for purposes outside the transport area reducing the travel budget relatively more.

5.4 Statistical analysis on effectiveness of pricing measures

The previous section discussed the behavioural responses of the respondents to three different road pricing measures. It appeared that there are differences between purposes and between measures. But it is unknown whether these aspects have a significantly different impact on the effectiveness levels of the different measures. Moreover, responses may differ by such factors as income, age, etc. The aim of this section is to find and interpret factors that have an impact on the level of effectiveness. We will link socio-economic characteristics of the respondents, type of measure evaluated and other information available (answers to other questions) to the trip changes reported by the respondents. We first explain the methodology in Section 5.4.1. This is followed by the results of our analysis.

5.4.1 Methodology

The methodology to be applied is motivated by the structure of the data. The aim is to explain the level of self-reported effectiveness for the various measures. The dependent variable is the fraction of the total trips made during 4 weeks that will be adjusted as indicated by the respondents, i.e. a number between 0 (no change) and 1 (all car trips will be adjusted). Hence, the effectiveness of the measures is defined as the fraction of current trips adjusted as a result of pricing. We have chosen to use the fraction of trips for reliability reasons. It was very difficult for respondents to give an approximation of kilometres driven for the various purposes, let alone the amount that would be changed. The information on reported behaviour is only available for a trip when the respondent indicated that they made that type of trip. We have, therefore, information on behavioural changes for 398 respondents who made commuting trips, 450 who made social (visits) trips, and 522 respondents who use the car to go shopping or participate in sports.

The dependent variable is not of an ordinary type. Because most of the people indicate no change in behaviour, the effectiveness variable is often a '0'. This has consequences for the appropriate methodology for this type of analysis. In order to increase the number of observations, we pool the three (for each trip purpose) observations. We keep the data for each measure (1, 2 and 3) separated. These pooled data sets contain 1370 observations. This increases the sample size for each measure, while we still have the possibility to correct for different trip purposes.

The structure of the dependent variable is such that a standard type of regression analysis (assuming a normal distribution of the dependent variable) is not applicable because of the large number of zero value observations. Instead, censored regression models, in which the dependent variable is observed in only some of the ranges, are more appropriate. Tobin (1958) analysed this problem, and formulated a regression model that was later called the Tobit model. This model is defined as follows when censoring takes places at zero, as in our case (Maddala, p 151, 1983):

$$y_i = \beta' x_i + u_i \text{ if } RHS > 0$$
$$y_i = 0 \text{ otherwise,}$$

where in our case y_i is the effect of the measure (fraction of trips changed) as reported by individual *i*; x_i is a set of explanatory variables; β' is a vector of coefficients to be estimated; and u_i are residuals that are independently and normally distributed, with mean zero and a common variance. This implies that we consider y_i as the observed realisation of an underlying latent variable that describes the intention of a respondent to change behaviour. When this intention is positive, we equate the observed variable to the latent variable. When the latent variable is zero or smaller than zero, our measurement variable equals zero, thus $y_i = 0$. We imposed an upper limit of 1 to the dependent variable, since all values of the dependent variable are between 0 and 1. We used the computer program Limdep to obtain the maximum-likelihood estimates of the parameter values for the explanatory variables.

Various specifications of the model for all measures (by including variables that may be expected to have some explanatory power) have been estimated. The following tables present our preferred specifications of the Tobit analyses. The results presented are the marginal effects on the observed effectiveness (the standard errors also refer to these marginal effects). These coefficients can more easily be interpreted than the standard output of the maximum-likelihood estimates which relate to the latent variable (we refer to Greene (1993) for the differences in computations). The estimations for each type of measure have been made with the same explanatory variables (except for the 'type of measure' variable), in order to maximise comparability between the models.

5.4.2 Results for measure 1: a kilometre charge (3, 6 and 12 €cents,) and different types of revenue use

Table 5.9 presents the estimation results for measure 1. The data set contains 1081 zero observations, leaving 289 observations of changed behaviour. The first column of Table 5.8 presents all explanatory variables that have been included in the estimation. It appears that the type of measure (split into charge level and type of revenue use) has a significant impact on the individual effectiveness scores. As expected, the measures with lower charge levels (3 €cents and 6 €cents compared with 12 €cents) are in general less effective. Abolition of car taxation seems less effective than when revenues are used to lower income taxes. This can be explained by the fact that with the latter types of measures only the extra costs of the charge were presented to the respondent (it was not possible to present a realistic estimation of the benefits of lower income taxes). The purpose of the trips has an impact on the level of effectiveness. The findings presented in Section 5.3.1 are here confirmed in terms of marginal effects. Commuting trips appear significantly less sensitive to pricing than 'other' and 'visiting' trips.

Table 5.9: Estimation results (marginal effects on the observed effectiveness) of Tobit analysis with the effectiveness of measure 1 as the dependent variable

Variable	Tobit y measure 1	Sign.
Constant	-.048 (.315)	*
Number of kilometres driven yearly	-.374E-06 (.31E-06)	
Age	-.472E-03 (.45E-03)	
Weekly number of times in congestion	-.760E-03 (.45E-03)	
Income (dummy inc1 (<€28,500) = base)		
Incunk (do not know or won't say)	-.119 (.048)	**
Inc2 (€28,500-45,000)	.016 (.013)	
Inc3 (€45,000-68,000)	.003 (.014)	
Inc4 (> €68,000)	-.047 (.019)	**
Type of measure (dummy charge 12 = base)		
Dummy charge 3 €cents	-.052 (.012)	***
Dummy charge 6 €cents	-.033 (.012)	***
Type of measure (dummy road taxes = base)		
Dummy income taxes	.040 (.010)	***
Trip purpose (dummy other = base)		
Dummy commuting	-.062 (.014)	***
Dummy visiting	.017 (.012)	
Employed		
Dummy yes	-.023 (.012)	
Possibility to work at home (dummy not possible (home2) and unknown (home3) = base)		
Working home1 (possible)	.027 (.013)	**
Compensation for commuting costs (dummy no commuting costs or unknown = base)		
Comp1 (no costs paid by employer)	.026 (.019)	
Comp2 (costs partly compensated)	.035 (.015)	**
Comp3 (full compensation)	-.024 (.018)	
Children in household (Yes = base)		
No children	-.021 (.010)	**
N	1370	
Log-likelihood	-713.946	

Notes: The standard errors are shown in brackets. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively, (two-sided *t*-test).

We have included a dummy for working respondents; but in fact they do not seem to respond differently from non-working respondents. Within the group of employed people driving from home to work, it does make a difference whether they have the opportunity to work at home on certain days. This group is more flexible and hence tends to change behaviour sooner than others who do not have this possibility. Respondents driving to work (at least once a week)

who obtain partial compensation for their costs tend to change behaviour sooner than drivers who have no commuting costs at all (this group may work at home for instance). This result may have been anticipated for the first group who receive no compensation at all. One explanation might be that compensation is in many cases rather modest.
Respondents in the highest income category tend to be less price sensitive, and this is also what we find here. People without children are also less inclined to change behaviour. Other variables, such as age, car usage (yearly number of kilometres), frequency of experiencing congestion, gender (not included) or education (not included and correlated with income) do not seem to have an important impact on the level of self-reported effectiveness.

5.4.3 Results for measure 2: a kilometre charge with multi-step bottleneck toll (2A), and a kilometre charge differentiated according to weight of the vehicle (2B)

Table 5.10 shows the estimation results for the second measure. Because both variants are very different in nature, we have estimated a model for each variant separately. The differences between trip purposes are not significant for measure 2A (which is in line with the findings of Section 5.3.2). Measure 2B tends to have less effect on commuting trips. The possibility to work at home is only important for variant 2A, and has, again, an important and positive impact on the level of effectiveness. People may stay at home, or may decide to work part of the day at home and travel at another time to work.

Table 5.10: Estimation results (marginal effects on the observed effectiveness) of Tobit analysis with the effectiveness of measure 2A and measure 2B as dependent variables

Variable	Tobit y measure 2A	Sign.	Tobit y measure 2B	Sign.
Constant	-.059 (.048)		.025 (.034)	
Number of kilometres driven yearly	-.112E-05 (.81E-06)		-.103E-06 (.26E-06)	
Age	-.134E-02 (.75E-03)	*	-.115E-02 (.49E-03)	**
Weekly number of times in congestion	.520E-02 (.30E-02)	*	.263E-04 (.20E-02)	
Income (dummy inc1(<€28,500) = base)				
Incunk (income unknown)	-.103 (.057)	*	^	
Inc2 (€28,500-45,000)	.309E-02 (.024)		.024 (.016)	
Inc3 (€45,000-68,000)	.017 (.024)		.026 (.016)	
Inc4 (> €68,000)	-.075 (.033)	**	-.149E-03 (.020)	
Trip purpose (dummy other = base)				
Dummy commuting	-.70E-02 (.021)		-.029 (.014)	**
Dummy visiting	.332E-02 (.019)		.291E-02 (.012)	
Employed				
Dummy yes	-.039 (.033)		-.097 (.024)	***
Possibility to work at home (dummy not possible (home2) and unknown (home3) = base)				
Working home1 (possible)	.052 (.021)	**	.440E-02 (.013)	
Compensation for commuting costs (dummy no commuting costs or unknown = base)				
Comp1 (no costs paid by employer)	.037 (.032)		.065 (.022)	***
Comp2 (costs partly compensated)	.046 (.026)	*	.037 (.020)	*
Comp3 (full compensation)	-.018 (.027)		.030 (.023)	
Children in household (Yes = base)				
No children	.30E-02 (.017)		-.563E-02 (.011)	
Vehicle weight (dummy weight3 =base)				
Weight1			-.041 (.018)	**
Weight2			-.032 (.034)	**
N	686		684	
Log-likelihood	-379.446		-271.310	

Notes: The standard errors are shown in brackets. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively, (two-sided *t*-test). ^ This variable has been left out, because the coefficient could not be estimated.

Measure 2A is a bottleneck charge affecting car drivers during peak hours on congested roads. It is therefore explainable that the measure tends to change the behaviour of people who

regularly experience congestion more than others. Measure 2B is differentiated according to the weight of the vehicle; therefore vehicle weight has only been included in this estimation. We see that the measure has relatively more impact on respondents owning a heavy car which is rather plausible given the higher charge applying to these car types. Other explanatory variables of the effectiveness of measure 2B include the age of the respondents (with older people being less inclined to change), employment (working people tend to change less) and the compensation of commuting costs by the employer. The measure has more effect for those who have to pay these costs themselves, which seems rather plausible.
Section 5.3.2 suggested that measure 2A has more effect on the number of trips that people change than measure 2B (especially for commuting trips). We have tested this by estimating one model on the total data set and including a dummy variable for the variant. The statistical results confirm that measure 2A is more effective: the estimated coefficient of the dummy variable for measure 2B is negative and significant. This can to a large extent be explained by the effect on commuting trips. Commuters tend to be more sensitive to a bottleneck charge than to a flat kilometre charge.

5.4.4 Results for measure 3: a peak and off-peak kilometre charge, with different revenue use

The third measure that we have analysed consists of a kilometre charge with an additional coarse peak charge during peak hours. The variants differ in charge levels and type of revenue use. In Section 5.3.3, we concluded that the impact of the type of measure on the level of effectiveness was not entirely clear. The outcomes in Table 5.11 confirm this result. The level of the charge is less significant, and the type of revenue use is not significant at all. The individual costs and the benefits, however, were presented differently to the respondents than for measure 1. The difference is that here the level of the charge depends on the time of driving. And, since we did not have information on the number of kilometres driven during these peak periods, we decided to present both extremes to each respondent (costs when all or no kilometres are driven during peak hours). While the off-peak charges are lower than with measure 1, the peak charges are considerably higher. The benefits from lower car taxation may be perceived by the respondents as being rather low, which may explain the stronger effectiveness levels for measure 3 relative to measure 1 for the first three variants. This may then also be an explanation for the low level of significance of revenue use here (Section 5.3.3 suggests that income taxation is more effective, but apparently the differences were only very marginal). The lower coefficient of the dummy for charge level 6 €cents than for that of 12 €cents (suggesting a less negative effect) confirms the findings in Table 5.7 which says that the 6 €cent charge is more effective than the higher 12 €cent charge. But both coefficients are not statistically different from each other (based on a comparison of the 90% confidence intervals for both coefficients).
In contrast with the previous measures, we find that employment does make a difference. Employed respondents (not necessarily making a commuting trip by car) seem to be less tempted to change behaviour in general (for all type of trips). Also new is the importance of the number of times during a week that people usually experience congestion. This measure leads to more trip adjustments among car drivers who drive regularly in congestion. The structure of the measure, mainly affecting peak-hour drivers (when congestion is usually most severe), is the most likely reason for this. Similar to the previous measures, we find a significant impact (with the expected sign) of the possibility to work at home. This measure has no differentiated effect on trips made for a certain purpose. This finding corresponds with the results presented in Table 5.6, where effect sizes are similar for the different purposes. Respondents with a higher income are also less price sensitive here, which is rather plausible. Finally, it appears that the compensation of commuting costs by employers is important for

the self-reported effectiveness of this measure. Those who receive only partial compensation seem to be willing to change behaviour relatively more than others. Strangely (and similar to the findings for measure 1), there is no such effect among people who are not compensated (and nor is there an opposite effect for fully-compensated respondents).

Table 5.11: Estimation results (marginal effects on the observed effectiveness) of Tobit analysis with the effectiveness of measure 3 as the dependent variable

Variable	Tobit y measure 3	Sign.
Constant	-.035 (.045)	
Number of kilometres driven yearly	-.634E-06 (.47E-06)	
Age	-.884E-03 (.67E-03)	
Weekly number of times in congestion	.652E-02 (.26E-02)	**
Income (dummy inc1(<€28,500) = base)		
Incunk (income unknown)	-.200 (.069)	***
Inc2 (€28,500-45,000)	-.061 (.021)	***
Inc3 (€45,000-68,000)	-.017 (.021)	
Inc4 (> €68,000)	-.056 (.026)	**
Type of measure (dummy charge 24 = base)		
Dummy charge 6 €cents	-.024 (.018)	
Dummy charge 12 €cents	-.039 (.018)	**
Type of measure (dummy road taxes = base)		
Dummy income taxes	.019 (.015)	
Trip purpose (dummy other = base)		
Dummy commuting	.021 (.019)	
Dummy visiting	.027 (.018)	
Employed		
Dummy yes	-.108 (.032)	***
Possibility to work at home (dummy not possible (home2) and unknown (home3) = base)		
Working home1 (possible)	.058 (.018)	***
Compensation for commuting costs (dummy no commuting costs or unknown = base)		
Comp1 (no costs paid by employer)	.040 (.030)	
Comp2 (costs partly compensated)	.058 (.024)	**
Comp3 (full compensation)	.021 (.027)	
Children in household (Yes = base)		
No children	.163E-02 (.015)	
N	1370	
Log-likelihood	-907.408	

Notes: The standard errors are shown in brackets. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively, (two-sided *t*-test).

5.5 Car ownership

It is generally acknowledged that the level of car ownership depends, *inter alia*, on the available income, household structure, and the costs of car use and car ownership. However, the relationship between pricing and car ownership has less often been studied as discussed in Chapter 3. Research has been done on the effects of fuel prices on car stock (see, e.g., Goodwin, 1992). The effects are likely to be modest (with elasticities of around -0.2), and lower than the effects on fuel consumption. But the increased policy interest for variabilisation in the Netherlands also entailed increasing attention for the impact of this measure on vehicle ownership. The impact on car ownership is ambiguous due to the change in costs (lower fixed costs and higher variable costs). People without a car may decide to purchase one after variabilisation, as cars become cheaper to own. Theoretically one may expect that this will lead to an increase in car ownership. However, modelling studies have shown some mixed results on this. A stated preference survey by MuConsult in 2002 does indeed report an increase of car ownership when variabilisation is implemented (by an average of 3%). The effect of car owners deciding to sell their car was present (ranging from

1.3% (MRB only) to 4.6% (MRB and BPM)), but the effect on people buying an extra car or a new car (by respondents presently not owning a car) was higher.
This suggests that it is not completely clear what can be expected; much depends on the price structure and the type of revenue allocation. Variabilisation tends to increase car ownership, while road pricing alone seems to have a (mild) limiting effect on the car stock. But, given the few studies done, and the uncertainties in effect sizes, there is scope for further research on this issue. Below, we present the findings on a few car ownership questions that we included in our survey.

5.5.1 Survey

After questions about each measure, we asked whether the respondents would consider selling their car. With measure 2 (including a variant that is differentiated according to the weight of the car), we added the possibility of replacing their existing car with a heavier vehicle or with a lighter one. Buying a heavier car may seem implausible (due to the higher charge for measure 2B), but this may happen due to the abolition of fixed taxes on car ownership and car purchase (in that event owners of a heavy car have relatively more financial benefits, given the higher existing taxes).
In addition to these questions, we have added a fourth measure to analyse the "opposite" of variabilisation on car ownership, where fixed taxes are increased and variable taxes decreased. The reason for adding this measure is that, unfortunately, the survey did not allow us to include respondents who at present do not own a car. However, the expected impact of variabilisation on car ownership levels depends to a large extent on the reaction of these people. Still, to get an impression of the behavioural response (in terms of car ownership) to variabilisation of the group that is close to indifference about owning a car (but owns a car now and is therefore included in our sample), we considered a measure that was the opposite of variabilisation. An increase of the fixed costs and a decrease of variable costs may stimulate people to sell (one of) their car(s). The measure (we call this measure 4) was presented as an increase of car ownership taxes by €150 per year (independent of car type) and a decrease of the fuel price by 10 €cents per litre (as an average for all fuel types). Since we know the yearly number of kilometres driven and the fuel type of the car for each respondent, it was possible to estimate the financial consequences on a yearly basis. Hopefully, the reactions of car owners who are close to selling their car are a good indicator for the reactions of people currently not having a car, but consider buying one. Note that there may be some asymmetry between car owners and non-car owners. The group that have only just decided to buy a car (who can be part of the sample) may be less inclined to give up car ownership because of perceived benefits of car usage and the probability of losing money when selling the car again.
This all means that we analyse four questions in total. In addition, we asked the respondents how probable it is that they would sell one of their cars, or in case of measure 2 also how likely it is that they will buy another type of car. People could indicate this probability on a 7-point scale, ranging from 'very unlikely' to 'very likely'.

5.5.2 Results for measures 1, 2 and 3

Table 5.12 shows the mean results and the percentages answering 'very likely' and 'likely'. The differences between the measures are rather small, with an average score on the question whether people will sell their car of about 1.6 (with 2 being 'unlikely' and 1 'very unlikely'). This score is confirmed by the percentages of respondents answering 'likely' or 'very likely': about 2% of the respondents chose one of these two categories. These effects seem very marginal, but are in the range of results of variabilisation among car owners found by

MuConsult (2002) (finding that 1.4% to 4.6% of the respondents indicated that they would sell their car).

The differences in the probability scores (although modest) could be explained by the different structures of the measures. This may be difficult because the variabilisation measures (1A to 1C and 3A to 3C) contain two opposing effects, for which the overall consequences for car ownership (and the decision to sell a car or not) are hard to predict. On the one hand, the fixed tax decreases (providing an incentive to keep a car), while on the other, a price per kilometre replaces these (discouraging car use and indirectly ownership). The presence of opposing effects becomes clear when looking at the results. A higher charge does not lead to higher probabilities of selling a car, both for measure 1 and measure 3. Variants D to F for measures 1 and 3 do not include compensation by means of lower fixed car taxes, so one may expect higher probabilities of selling when comparing alternatives with equal charge levels. Comparing D with A, E with B and C with F, this is indeed the case for measure 1 but not for measure 3, which is strange. But differences are very small and not significantly different from each other. These ambiguous findings for car ownership for measure 3 are similar to the results on effectiveness in Sections 5.3.3 and 5.4.4 for the same measure.

Table 5.12: Mean of probability scores on each type of measure (level 1 = very unlikely; level 7 = very likely)

Measures	How probable is it that you would sell your car?		How probable is it that you would replace it by a heavier car?		How probable is it that you would replace it by a car with less weight?	
	Mean	% very likely or likely	Mean	% very likely or likely	Mean	% very likely or likely
1A (3 €cents/MRB)	1.41	2.1				
1B (6 €cents/MRB+BPM)	1.35	1.1				
1C (12 €cents/MRB+BPM+roads)	1.66	1.1				
1D (3 €cents/income taxes)	1.57	3.0				
1E (6 €cents/income taxes)	1.75	3.3				
1F (12 €cents/income taxes)	1.68	4.3				
2A: multi-step bottleneck toll	1.54	2.5	1.91	2.2	2.08	3.5
2B: km charge weight vehicle	1.53	1.4	1.75	0.7	2.79	9.7
3A: 2/6 €cents (off-peak/peak), MRB	1.64	2.1				
3B: 4/12 €cents, MRB+BPM	1.73	5.5				
3C: 8/24 €cents, MRB+BPM+ roads	1.68	1.0				
3D: 2/6 €cents, income taxes	1.53	0				
3E: 4/12 €cents, income taxes	1.67	3.2				
3F: 8/24 €cents, income taxes	1.75	1.1				

Measure 2 seems to generate a slightly lower probability of selling the car. Both variants do indeed include an abolition of fixed taxation and modest charge levels compared with the other measures. However, measure 2A may have considerable financial consequences for those driving in peak hours. But most of these drivers are commuters who are relatively more car-dependent and less inclined to sell their car.

After the questions on measure 2, we also asked about the respondents' intention to replace their car by another type (lighter or heavier), because measure 2B was differentiated according to the weight of the vehicle. The intention to sell a car may be low, but the intention to replace a car appears to be somewhat higher. Respondents tend to consider the purchase of a car with less weight more seriously, especially if a weight-differentiated measure is implemented with the replacement of both MRB and BPM (a score of 2.79, 3 is 'a bit unlikely'). The differences with measure 2A are explainable: this is a peak-hour measure not differentiated according to weight. People are less inclined to buy a heavier car if the charge for this type of cars is higher.

5.5.3 Results for measure 4: an increase of car ownership taxes and decrease of fuel costs

Table 5.13 shows that most respondents, as expected, will not sell their car (or one of their cars). A few respondents (1.6%) do seriously consider giving up car ownership. This may suggest that the effect of non-car owners buying a car may also be limited. However, we should not forget that both groups are not necessarily equal and comparable. For instance, respondents who have recently purchased a car may not be very much inclined to give up their car soon afterwards. This makes comparison with other findings difficult, but nevertheless interesting. MuConsult (2002) find that 9% of the households without a car will buy a car after variabilisation of the MRB only (with an average charge of 2.5 €cents). We decrease the variable costs by 10 €cents/litre, which is about 0.85 €cent/kilometre for petrol cars (one third of the charge in MuConsult (2002)). Assuming that all respondents answering 'very likely' will sell their car, 75% of category 6 ('likely'), and 50% of the people who indicated 'a bit likely', we find that 2.8% will give up using their car - nearly one-third of the percentage of MuConsult. Correcting for the differences in charge levels, the results then seem surprisingly close (given the differences in methods). Of course, the percentages assigned to the different categories are a bit arbitrary, but they do not seem wildly unrealistic.

Table 5.13: Probability of selling the car if measure 4 would be implemented

Score	Number of respondents (% of total)
1: very unlikely	340 (60.5)
2: unlikely	153 (27.2)
3: a bit unlikely	23 (4.1)
4: not likely, not unlikely	21 (3.7)
5: a bit likely	16 (2.8)
6: likely	5 (0.9)
7: very likely	4 (0.7)

Finally, it is interesting to analyse these probability scores. For instance, one may wonder whether the people doubting about car ownership have a relatively lower income. Various econometric techniques are of course available that can be used to investigate the relation between various variables. The methodology to be applied depends to a large extent on the structure of the data. Here, the aim is first to explain the probability level of selling a car, where the dependent variable consists of a choice out of an ordered set of probability variants. Given this framework, the ordered probit (OP) technique seems to be most appropriate (see for discussion of OP Maddala (1983)). Ordinary Least Squares (OLS), which assumes an unbounded continuous dependent variable, is less appropriate, although it would have had the advantage of more easily interpretable coefficients.

The underlying response model for an OP estimation is of the following form (see Davidson and MacKinnon, 1993):

$$PROB^* = \beta' X_i + \varepsilon.$$

The underlying continuous response variable PROB* is unobserved, X is the vector of explanatory variables, β gives the vector of coefficients, and ε is the residual. The observed discrete response variable PROB is related to PROB* as follows:

$$PROB = 1 \quad \text{if } PROB^* \le \mu_1,$$
$$PROB = 2 \quad \text{if } \mu_1 \le PROB^* < \mu_2,$$
$$PROB = 3 \quad \text{if } \mu_2 \le PROB^* < \mu_3,$$

$$\vdots$$
$$PROB = 7 \quad \text{if } \mu_6 \leq PROB^* .$$

The μ's (threshold values in the model output) are unknown parameters to be estimated jointly with β, and the model assumes that ε is normally distributed across observations. The constants μ therefore divide the domain of PROB* into 7 segments, which corresponds with observations of the discrete response variable. The model estimates probability intervals for the seven possible answers:

$$\text{Prob}\,(Z_{ij} = J) = \Phi(\mu_j - \beta' X_i) - \Phi(\mu_{j-1} - \beta' X_i)$$

where Φ is the cumulative standard normal, and $Z_{ij}=J$ represents each probability score. The interpretation of the estimated coefficients is not straightforward. The estimated coefficients for the included explanatory variables can be interpreted as indications of shifting the distribution to the left or the right depending on the sign of the β's. Assuming that β is positive, this means that that the probability of the leftmost category (in this case PROB=1) must decline. At the same time we are shifting some probability into the rightmost cell (PROB=7). But what happens to the middle cells is ambiguous and is dependent on the local densities. Hence, we must be very careful in interpreting the coefficients in this model (see Greene, 1993). The values of the coefficients can more easily be interpreted in a relative sense: a larger value denotes a larger marginal impact.

Table 5.14 presents the coefficients and significance of the variables that have been included in the model estimation (for an explanation of the variables, see Appendix 5b). The first row presents the estimates for the thresholds values μ's explained above. The second row presents all explanatory variables. These variables have been selected on the criterion of expected relevance.

It appears that not very many variables have a significant impact on the probability to sell one of the cars available. The expected effect of income is present, but not as strong as expected. Only the lowest income group has a higher probability to sell the car (but only significant at the 10% level). We have also tested the impact of education instead of income, but the results were not different. Younger people (with lower incomes) generally have a higher probability of selling their car. These may, for instance, be students who buy very cheap second-hand cars for which the fixed taxes become a (too) high burden. Location has been included to test for responses by city people. Parking problems in city centres and good public transport accessibility may be an incentive for residents with a car to reconsider ownership sooner than people living in more rural areas. But the results do not confirm this assumption.

Respondents driving many kilometres may be less tempted to sell their cars than others because of the lower variable costs, and a presumably greater dependence on the car, but again this is not confirmed by the results. The number of cars available in households, in contrast, is important. People with (only) one car available seem to be less tempted to give up their car than households who own more cars. Apparently, the presence of at least one car is important; it will be easier to consider having more than one car if fixed and variable costs are changed.

These results reveal some of the characteristics of the group that reconsiders car ownership when fixed and variable costs change. Our results suggest that variabilisation tends to increase car ownership especially among younger people with lower incomes. In most cases vehicles will be bought, with increasing levels of households having a second or third car as a consequence. However, it is still recommended to conduct more in-depth research on car ownership behaviour among non-car owners in order to obtain better insight into the effects of variabilisation on car ownership levels.

Table 5.14: Results of ordered probit analysis with the probability to sell the car as the dependent variable

Variable	Probit ACC measure 4	Sign.
Threshold (μ's)		
μ_1	-.638 (.410)	
μ_2	.321 (.409)	
μ_3	.574 (.410)	
μ_4	.921 (.413)	**
μ_5	1.426 (.423)	***
μ_6	1.755 (.441)	***
Gender (female)	-.123 (.114)	
Income (dummy inc4 (>€68,000) = base)		
Inc1 (< €28,500)	.354 (.182)	*
Inc2 (€28,500-45,000)	.016 (.166)	
Inc3 (€45.000-68.000)	-.009 (.160)	
Incunk (income unknown)	.146 (.321)	
Residence location (dummy loc 5 (south) =base)		
Loc1 (3 large cities)	-.096 (.173)	
Loc2 (rest west)	.064 (.140)	
Loc3 (north)	.289 (.218)	
Loc4 (east)	.122 (.151)	
Fuel type (dummy fuel3 (gas) = base)		
Fuel1 (petrol)	-.090 (.268)	
Fuel2 (diesel)	-.207 (.276)	
Age (other dummies = base)		
Age1 (18-25)	.322 (.189)	*
Car ownership (dummy car3 (3 or more cars) = base)		
Car1 (1 car)	-1.238 (.274)	***
Car2 (2 cars)	-.663 (.273)	**
Number of kilometres driven yearly	-2.77E-07 (.000)	
Vehicle weight (dummy weight3 (heavy) = base)		
Weight1 (low weight)	.198 (.161)	
Weight2 (middle weight)	.043 (.135)	
N	562	
Log-likelihood	-568.083	***
Pseudo R-square	Cox and Snell	.094
	Nagelkerke	.106
	McFadden	.045

Notes: The standard errors are shown in brackets. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively, (two-sided *t*-test).

5.6 Conclusions

The major contribution of this chapter lies in the attractiveness of the various alternatives for current road use and the impact of individual characteristics on the intention to change behaviour. Previous research has suggested that road use will most likely decline after variabilisation, but less is known about choosing alternatives.

The results presented in this chapter confirm that road pricing may have considerable effects, but 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, comparable with results found in a similar study (which included non-car owners) by MuConsult (2002). There are considerable differences between trip purposes, with commuting generally being least sensitive (well-known from the literature) when the charge is time-independent. Trips made to visit people or for shopping reasons will be modified first with non motorised transport (walking, cycling) being the most chosen alternative for the car. This suggests that car use for short-distance trips will be reconsidered, even if a flat kilometre charge is implemented. Note, however, that our sample includes relatively few elderly for whom walking or cycling may not always be an option.

When policy makers want to affect peak-time (commuting) road traffic, a time-differentiated measure seems most appropriate. The kilometre charge with additional peak charge is the most effective overall, especially for commuting trips. Governments should be aware that the implementation of these (time-dependent) charges most probably leads to driving at other times, especially for commuting trips. Commuting trips are necessary (working at home or not making the trip are not serious options for most of the respondents), but there seems to be some level of flexibility which allows scheduling of trips.

The impact of the type of measure is not straightforward. Previous research and common sense suggest that higher kilometre charges should have more impact. Our results are somewhat mixed on this issue and are difficult to explain. The statistical analysis confirms that a time-differentiated measure has more effect on drivers who experience congestion (most of them being commuters). This does not hold for a flat kilometre charge. Charge levels seem to matter when a flat fee is considered (higher charges have more effect), but this seems of less importance if considerable peak and off-peak fees are implemented. The effect of revenue use seems clear when considering the aggregated outcomes: revenues allocated to lower income taxes generally have more effect (but not significantly different for the peak/off-peak measure). This may partly be explained by the 'perceived' income effect, as it is caused by the design of the questionnaire. An estimate of the benefit from revenue recycling could be calculated and shown to the respondent for car tax reductions, but not for income tax reductions.

We have also tested the effect of several individual characteristics on effectiveness, whereas previous studies mostly focused only on income. Despite the fact that working at home is not always a feasible option, it appears that the possibility to do this is an important explanatory variable. People having this possibility tend to be more flexible and change behaviour more than others. Road users driving many kilometres are not particularly more sensitive to any form of road pricing. One of the previous studies found that people with a higher income tend to reduce kilometres driven less strongly than those with a lower income. We also find this effect, but in most cases only for the very highest income category.

Road pricing can have considerable consequences for road usage, but policy makers should not forget that it may also affect car ownership (and indirectly also road use). The effects of road pricing and revenue recycling on the car stock are an as yet unsettled issue, given the mixed results in the literature. Our results indicate that about 2% of the respondents most probably will sell their car, or one of their cars, if a variable charge is implemented. Variation between measures is low, indicating that revenue use and type of charge have a minor impact on car ownership. It seems strange that there is no, or only a very small, difference between the case where revenues are used to abolish existing car taxes and where income taxes are lowered. Our results show that the measure that is often proposed to realise a more fuel-efficient car stock, a weight differentiated charge, may actually have such an effect. It does not only have more effect among heavy vehicle owners, but the results also indicate that respondents seriously consider buying a smaller (more fuel-efficient) type of vehicle.

We have also considered the opposite of variabilisation, with the aim to analyse behaviour of (car-owning) respondents if car ownership becomes more expensive. This may give an approximation of the intentions of non-car owners to buy a car after a variabilisation of taxes, because these respondents in some sense belong to the same group of people who are currently near indifference in terms of car ownership. The case where road pricing is implemented and revenues are recycled by an abolition of ownership taxes may lead to a reduction of car use, or at least a change in mobility patterns. However, policy makers should not forget that car usage may increase if non-car owners decide to buy a car. Our findings suggest that only a few respondents (1.6%) would seriously consider giving up car ownership. Given the assumed asymmetry between both groups (car owners and non-car owners), the similarity of this finding with the result of another study among non-car owners to buy a car after variabilisation (MuConsult 2002) is remarkable. A statistical analysis revealed that younger people and households owning two or more cars are more likely to sell their (one of their) car(s), which suggests that the total number of kilometres driven will only slightly be reduced (or increase in the case of variabilisation).

Finally, it is hard to determine whether or not these results can be generalised to other countries. For example, the availability (e.g. of public transport) and inherent popularity of alternatives (e.g. cycling) may differ between countries; the spatial structure may be different, and many other factors may cause further deviations. Although it is tempting to present, for example, the conclusion on the importance of time-differentiation of charges for effectiveness in commuting as a more general result, we cannot draw such conclusions from our study and therefore leave it as material for further (local) study.

Appendix 5A

Description of measures

Measure	Variants
1: Flat kilometre charge, with different revenue allocations	**A**: 3 €cents, revenues used to abolish car ownership taxes (MRB) **B**: 6 €cents, revenues used to abolish existing car taxation (purchase (BPM) and ownership (MRB)) **C**: 12 €cents, revenues used to abolish existing car taxation and construct new roads **D**: 3 €cents, revenues used to lower income taxes **E**: 6 €cents, revenues used to lower income taxes **F**: 12 €cents, 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 €cents, additional multi-step 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 €cents per kilometre; middle weight cars pay 6 €cents per kilometre; heavy cars pay 8 €cents 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 €cents outside peak times and 6 €cents in peak on working days (7.00-9.00 and 17.00-19.00), abolition of car ownership taxes **B**: 4 €cents outside peak times and 12 €cents in peak on working days (7.00-9.00 and 17.00-19.00), abolition of existing car taxation **C**: 8 €cents outside peak times and 24 €cents in peak on working days (7.00-9.00 and 17.00-19.00), abolition of existing car taxation and new roads **D**: 2 €cents outside peak times and 6 €cents in peak on working days (7.00-9.00 and 17.00-19.00), revenues used to lower income taxes **E**: 4 €cents outside peak times and 12 €cents in peak on working days (7.00-9.00 and 17.00-19.00), revenues to lower income taxes **F**: 8 €cents outside peak times and 24 €cents in peak on working days (7.00-9.00 and 17.00-19.00), revenues used to lower income taxes
4: Opposite of variabilisation	An increase of car ownership taxes by €150, together with a decrease of fuel costs by 10 €cents/litre.

Appendix 5B

Explanation and population share of explanatory (dummy) variables in the original data set (N=562)

Variable	**Type**	**Levels**
Gender	Dummy	Male (61.2%); Female (38.8%)
Age	Continuous and dummies (Section 5.6)	Age1: 18-25 (7.3 %); Age2: 26-35 (31.0%); Age3: 36-45 (26.6%); Age4: 46-55 (18.9%); Age5: 56-65 (9.1%); Age6: 65+ (7.1%)
Income (gross yearly)	Dummies	Inc1: less than € 28,500 (21.4%); Inc2: € 28,500-45,000 (31.5%); Inc3: € 45,000-68,000 (28.5%); Inc4: more than € 68,000 (15.7%); Inc5: do not know or won't say (3.0%)
Weekly number of times in congestion	Continuous	
Employed	Dummy	Employed (82.7%); Not employed (17.3%)
Trip purpose (effect of measure on type of car trip) (for N = 1370)	Dummies	Dummy commuting (29%), Dummy visiting (33%), Dummy other (38%)
Type of measure (charge)	Dummies	Dummy charge 3 €cents (measure 1) Dummy charge 6 €cents (measure 1) Dummy charge 12 €cents (measure 1) Dummy charge 6 €cents (measure 3) Dummy charge 12 €cents (measure 3) Dummy charge 24 €cents (measure 3)
Type of measure (revenue use)	Dummy	Dummy road taxes (revenues are used to lower existing road taxes (1A, 1B, 3A,3B) and construct new roads (1C and 3C)) Dummy income taxes (revenues are used to lower income taxes, measures 1D to 1F and 3D to 3F)
Possibility to work at home (available for employed people making a commuting trip by car at least once a week)	Dummies	Working home1: possible to work at home (26%); Working home2: not possible (42.2%); Working home3: unknown or not working (31.8%)
Number of kilometres driven yearly	Continuous	
Compensation of costs by employer (available for employed people making a commuting trip by car at least once a week)	Dummies	Comp1: none (11.4%); comp2: partial (32.2%); comp3: completely (19.9%); comp4: have no commuting costs (4.8%); comp5: unknown or not working (31.8%)
Residential location	Dummies	Loc1: 3 large cities* (16.0%); loc2: rest west (31.9),; loc3: north (6.6%); loc4: east (23.1); loc5: south (22.4%)
Vehicle weight	Dummies	Weight1: low weight (28.3%); weight2: middle class (47.2%); weight3: heavy (24.6%)
Fuel type	Dummies	Fuel1: petrol (71.2%); Fuel2: diesel (24.9%); Fuel3: gas (3.9%)
Car ownership (number of cars in household)	Dummies	Car1: 1 (58.5%); Car2: 2 (38.4%); Car3: 3 or more (3.0%)
Children in household	Dummy	Yes (one or more) (45.7%); No (54.3%)

* Amsterdam, Rotterdam and The Hague.

Appendix 5C

Behavioural responses to each variant of measures 1 and 3

Measure	Measure 1A			Measure 1B			Measure 1C		
Trip purpose	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**
Total number of trips (driven in 4 weeks)	1104	556	1468	1176	652	1176	1084	628	1160
Trips adjusted (% total)	0 (0%)	49 (8.8%)	115 (7.8%)	20 (1.7%)	48 (7.4%)	80 (6.8%)	45 (4.1%)	104 (16.6%)	149 (12.8%)
Of which (%):									
Public transport		30.6%	15.6%	20%	10.4%	6.3%	51.1%	10.6%	14.1%
Non-motorised		38.8%	64.3%	10%	56.3%	77.5%	22.2%	44.2%	60.4%
Motorised		0%	0%	0%	8.3%	2.5%	6.7%	18.3%	6.0%
Car pooling		NR	NR	60%	NR	NR	0%	NR	NR
Working at home		NR	NR	10%	NR	NR	20%	NR	NR
Not making the trip		30.6%	20%	0%	25.0%	17.8%	0%	26.9%	19.5%

Measure	Measure 1D			Measure 1E			Measure 1F		
Trip purpose	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**
Total number of trips (driven in 4 weeks)	1212	592	1408	1176	592	1332	1048	600	1236
Trips adjusted (% total)	100 (8.3%)	77 (13.0%)	179 (12.7%)	79 (6.7%)	105 (17.7%)	141 (10.6%)	156 (14.9%)	130 (21.7%)	182 (14.7%)
Of which (%):									
Public transport	12.0%	27.3%	14.0%	39.2%	12.4%	9.2%	36.5%	20.9%	17.0%
Non-motorised	55.0%	53.2%	63.7%	30.4%	39.0%	68.8%	24.4%	41.1%	61.5%
Motorised	14.0%	0%	0%	1.3%	11.4%	0.7%	12.8%	8.8%	1.6%
Car pooling	11.0%	NR	NR	24%	NR	NR	23.1%	NR	NR
Working at home	7.0%	NR	NR	5.1%	NR	NR	2.6%	NR	NR
Not making the trip	1.0%	19.5%	22.3%	0%	37.1%	21.3%	0.6%	29.0%	19.8%

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

Measure	Measure 3A			Measure 3B			Measure 3C		
Trip purpose	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**
Total number of trips (driven in 4 weeks)	1256	636	1572	1096	500	1160	1168	708	1200
Trips adjusted (% total)	161 (12.8%)	75 (11.8%)	222 (14.1%)	139 (12.7%)	53 (10.6%)	124 (10.7%)	159 (13.6%)	137 (19.3%)	135 (11.3%)
Of which:									
Public transport	2.5%	34.7%	16.2%	21.6%	13.2%	25.8%	28.9%	8.7%	3.7%
Non-motorised	0%	10.7%	23.4%	20.1%	20.8%	23.4%	30.2%	30.6%	29.6%
Motorised	13%	0%	0%	6.5%	0%	0.8%	8.8%	2.9%	1.5%
Car pooling	0%	NR	NR	0%	NR	NR	3.8%	NR	NR
Travel at other times	71.4%	45.3%	56.3%	43.9%	60.4%	46%	20.1%	43.8%	46.7%
Working at home	13.0%	NR	NR	7.9%	NR	NR	8.2%	NR	NR
Not making the trip	0%	9.3%	4.0%	0%	5.7%	4.0%	0%	13.9%	18.5%

NR = not relevant, measure may not be differentiated according to time or variant is not related to trip purpose.

Measure	Measure 3D			Measure 3E			Measure 3F		
Trip purpose	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**
Total number of trips (driven in 4 weeks)	1136	640	1256	1112	524	1224	1032	612	1388
Trips adjusted (% total)	191 (16.8%)	100 (15.6%)	148 (11.9%)	140 (12.6%)	76 (13.9%)	161 (13.2%)	214 (20.7%)	88 (14.4%)	238 (17.2%)
Of which:									
Public transport	23.0%	4%	3.4%	10%	3.9%	8.7%	18.2%	22.7%	22.2%
Non-motorised	7.8%	38%	43.9%	15.7%	25%	32.9%	7.%	34.1%	24.4%
Motorised	0%	2%	2.6%	0%	3.9%	0%	21%	0%	3.8%
Car pooling	8.4%	NR	NR	12.8%	NR	NR	2.3%	NR	NR
Travel at other times	57.1%	52%	46.6%	55%	53.9%	50.3%	39.7%	38.6%	38.2%
Working at home	3.1%	NR	NR	5.7%	NR	NR	9.8%	NR	NR
Not making the trip	0.5%	4%	4%	0.7%	13.1%	8%	1.9%	4.5%	11.3%

NR = not relevant, measure may not be differentiated according to time or variant is not related to trip purpose.

Part II: Institutional aspects of transport pricing

Chapter 6

Auctioning concessions for private roads

6.1 Introduction

Government involvement in transportation is very common throughout the globe, the reasons for intervention have been outlined in Chapter 2 and may take several forms, ranging from small regulatory rules to full ownership and operation of particular services. Transportation infrastructure, such as highways, ports and airports, absorbs a large share of public sector capital investments in most countries (Gomez-Ibanez and Meyer, 1993). Some changes can, however, be observed, and nowadays private involvement in the provision and pricing of infrastructure is increasing, following deregulation and privatisation in the US and in the UK during recent decades. In fact, the private supply of infrastructure is not a new idea, as the early development of railways, canals, ports and inter-urban highways in many parts of the world was market-led by private sector entrepreneurs. The return of interest in private involvement can mainly be explained by the growing concern over public budgetary deficits, and the perceived inability of public bodies to manage complex infrastructure efficiently.

This chapter deals with the specific, but realistic, case where private firms are involved in the provision and tolling of road infrastructure. We are in particular concerned with the dilemma caused by the fact that private operators – potentially bringing efficiency improvements – will be primarily (or exclusively) concerned with profit maximisation. Specifically, we will consider the question of whether the associated welfare losses can be mitigated by optimising the design of auctions for the right to privately build and operate a certain road, in terms of the criterion or indicator that is used to identify the winning bid. We present a small two-link simulation model to analyse the effects of various types of private bids for the right to build and operate a new road parallel to an existing road.

This chapter thus studies one important aspect surrounding the franchising of highways. Any auction – or, indeed, any other selection mechanism – to choose between competing potential private road operators will affect the eventual properties of the road to be built and the tolling scheme to be applied. While studying how this fact can be employed for the benefit of society at large, our analysis also demonstrates that these properties (capacity, tolls) and the resulting welfare impacts may differ rather strongly over different auctions, even when restricting attention to plausible auctions alone. This is, of course, important information for the design of auctions. At the same time, there are many other urgent policy issues surrounding the franchising of highways that this chapter does not address. Those include demand uncertainty, information asymmetry, strategic behaviour by the concessionaire, renegotiation of contracts, etc. However, the advantage of ignoring these issues is that we obtain a more transparent picture of the impacts of different auction designs on road capacity and toll. The consequence is that there are still many important issues left for future research, as we will acknowledge and discuss in more detail at the end of Section 6.3.

This chapter starts in Section 6.2 with some basic (pricing) issues related to the involvement of private parties in road infrastructure provision. Section 6.3 introduces the model, and presents some simulation results when private firms may bid for the construction and operation of a road in an auction. Section 6.4 concludes.

6.2 Investment and pricing of infrastructure

Investments in transport infrastructure are usually made by the public sector, and private involvement has so far been limited in most countries. The private sector usually seeks commercial profit that can be gained either as income from investment interest, or as value capture through an improvement in the transport system. Despite the higher cost of capital raised from commercial sources and the need to cover the risks and gain commercial profit, it may be that the overall cost for the community will be lower with private financing than when tax funds are used. One potential source of efficiency improvements involves cost-effectiveness induced by private enterprise's profit objectives. Next, government funds are often raised using distortive taxes, which may further increase the social costs of public investments (note that this argument becomes irrelevant when comparing priced public and private roads that require no funding other than toll revenues). Private management may lead to increased innovative ideas in the project, or to more rapid decision making. Private financing may also minimise the debt burden or financial guarantees on the finances of the government and increase the financial resources that might be available for the projects.

Despite these potential benefits, it may be difficult to interest private investors in financing roads. Considerable risks and uncertainties may make infrastructure not a very attractive investment, and high fixed costs and long construction and planning periods often require large sums of capital in the beginning, while the pay-back period is long (see Rienstra and Nijkamp, 1997, on the various risks and uncertainties for private investors).

An important potential social disadvantage of private road provision stems from the pricing strategies of the private firm. It may be expected that, when allowed to build and operate infrastructure, firms will not price efficiently, and will set charges above optimal levels, both when operating a road in isolation and when an unpriced substitute exists (e.g. Edelson, 1971; Mills, 1981; Verhoef et al., 1996). Unless demand is perfectly elastic – an implausible circumstance for road traffic – the profit-maximising toll exceeds the welfare-maximising toll. Whether the use of such profit-maximising charges is considered acceptable is likely to depend on the question of whether socially-optimal charges on their own would lead to reasonable profits, or – at least – avoid losses for the private operator.

The relationship between the total costs of the infrastructure manager, and the revenues collected by tolls, if the charges are set equal to marginal social costs, will depend upon the underlying cost conditions in the supply of infrastructure conditions. If the long-run average costs (when all inputs are variable) are falling over the relevant range of output (increasing returns to scale), marginal cost based charges will tend, on average, to yield less than the full ongoing costs of the infrastructure manager. The reverse will hold in the case of decreasing returns to scale; then profits can be made. Constant long-run average costs will enable full cost recovery (Small, 1999; Mohring and Harwitz, 1962). Studies of cost conditions, and the evidence of the revenues produced when marginal cost-reflecting charges have been applied in practice, suggest that the extent of scale economies varies between the different types of transport infrastructure (e.g. NERA et al., 1998). Road infrastructure tends to show returns to scale that are approximately constant (e.g. Small et al., 1989). This pattern of project returns will encourage a highly conservative approach by the private sector to provide infrastructure against marginal cost-based prices, since the resulting profits would be small or negative. It is, therefore, not surprising that most projects of interest to private investors have been those which are discrete, clearly bounded and largely self-contained with no close-competitor. Indeed, the most common privately financed schemes have been bridges and tunnels (Vickerman, 2002).

Because of the likely discrepancy between socially-optimal and profit-maximising prices, governments may wish to consider exercising some control over the process. The natural monopoly argument has been, and still is, the underlying rationale for public involvement in infrastructure provision since the nineteenth century (see Vickerman, 2002). Most toll bridges do face price controls for instance. Pure private financing, in which the private party carries all costs, runs all risks, and receives all revenues from user charges, is therefore only seldom the case.

Financial regulation can take several forms, including a maximum toll rate indexed to inflation (as in France: Fisher and Babbar, 1996), a return on investment ceiling, and traffic or revenue guarantees (e.g. shadow tolling, where the government guarantees a certain toll depending on the traffic, which takes away a great deal of commercial risk). An indexed maximum toll rate is the most common form of regulation, mainly due to its practical advantages (Fisher and Babbar, 1996). Return on investment regulation with no toll rate ceiling is more flexible in allowing toll rate adjustments to optimise revenues. California, for instance, selected an innovative one-time contractual approach, setting the ceiling for the rates of return allowed over the life of the project in each franchise agreement.

The specification of the design of the road may range from virtually no public involvement to public sector responsibility for preliminary design (including capacity, location and number of interchanges and crossings, materials used, etc.). Although little information is available about current practice, it is often the public sector that selects project proposals, which meet their pre-defined conditions. At the same time, a lower level of public responsibility for design allows the private sector to bring in innovative solutions and better match market demands. Bidders for the SR 91 road in California, for instance, had full responsibility for all project design subject to governmental approval. The contract was fully negotiated only after a concessionaire was selected. The basis for comparing bids and selecting the concessionaire was therefore somewhat subjective, since the government had to compare different designs of the project. However, this process allowed the private sector to propose innovative projects and designs and negotiate risk-sharing terms (Fisher and Babbar, 1996).

In conclusion, governments normally want to keep some form of control when private firms are involved in road construction and operation. Governments have various options to control private firms. They could focus only on toll regulation, after the road has already been constructed. Governments may also want to leave both construction and operation to the private sector, but still keep control over design of the road and toll levels. This was the case in California (SR 91) when a private firm was allowed to build a new lane parallel to an existing road. Instead of applying more direct types of regulation, governments may also decide to use an auction to achieve specific objectives. Private firms are then invited to make a bid and obtain the right to construct and operate a road. This bid would include a specification of the design of the road and the toll level that will be levied during operation. In a setting of open bidding, certain evaluation criteria for ranking proposals may be set by the government. Specifically, it may choose criteria that are likely to produce bids which meet the public objectives as closely as possible. In the following section, we analyse these effects of an auction, and in particular the consequences of setting different rules to evaluate the bids of private firms.

6.3 A modelling framework for evaluating auctions for private roads

From the viewpoint of society, it is important to assess the welfare implications of the construction and operation of a new road. Certain toll levels and capacities may lead to profits but need not maximise welfare; or vice-versa, a socially-optimally designed road may generate substantial welfare gains but without being profitable – and would hence be unattractive to private firm.

We develop a model that allows us to study the effects of highway tolls and capacities on welfare and profits in a relatively simple setting. We are particularly interested in the question of how auctions for concessions to build and operate a private road can be used to optimise two decision variables of interest: the road's capacity, and the toll that will be charged.

We will use a simulation model to investigate the consequences of various types of roads (differing in capacity and toll) in terms of welfare and profit, and to find suitable "indicators" for selecting the winning bid that governments could use in auctions. For instance, an auction with the rule that the bid with the maximum capacity (which is possibly a relevant objective for an authority) will get the right to build and operate may not necessarily lead to the optimum in terms of welfare (and hence be an inferior indicator). The consequences of various auction rules will be investigated by using a simple two-road network. We are aware that auction design affects outcomes, and is very important for the success of it. The most important features of an auction are its robustness against collusion and its attractiveness to potential bidders (Klemperer, 2002). Besides, local circumstances matter in the practical design of auctions. We will discuss some crucial assumptions on auction design below, indicating that we focus on the analysis of the auction rule set by the government, and not so much on the explicit design of the auction itself. The model will be explained in greater detail after we have discussed previous studies that use a similar setting.

6.3.1 Previous studies

Analytical studies have paid attention to the welfare consequences of different ownership (and pricing) regimes. Several analytical studies of private toll roads can be found in the literature. Most of them consider a simple road network with one origin and one destination connected by one or more parallel routes (Edelson, 1971; and Mills, 1981). Many employ static models, in which drivers' choice is limited to route and travel demand, possibly with flat tolls (time independent). Recognising that institutional constraints may prevent the implementation of optimal tolls, more recent research has focused on the properties of second-best tolls, which are computed subject to given constraints. A common constraint encountered in practical situations is that tolls are only implemented on single lanes or roads, with travel on alternative routes being unpriced. An example is the SR 91 road in California (Liu and McDonald, 1998). Imposition of 'quasi first-best pricing' on the toll road (simply ignoring spill-overs to the unpriced parallel road) is then not welfare-maximising (Lévy-Lambert, 1968; Marchand, 1968). One analysis of different ownership regimes is in Verhoef et al. (1996), who considered a network with one origin and one destination connected by two parallel routes. The authors consider two private ownership regimes: one in which one of the routes is private and the other is free access, and a second situation in which a private monopoly controls both routes. It is shown that revenue-maximising tolling on two routes may actually lead to a more efficient usage of road space than does optimal one-route tolling. Hence, it may be more efficient to have a monopolist controlling the entire network, rather than just a part of it. Verhoef and Small (2004) obtained a similar result in a comparable set up, which, however, allows for heterogeneity with respect to value of time.

De Palma and Lindsey (2000) focused on the allocative efficiency of private toll roads vis à vis free access and public toll road pricing on a similar network, but allowing for dynamics of peak congestion. This study suggests that two competing private roads can yield most of the potential efficiency gains from first-best pricing if neither road has a dominant fraction of total capacity. They look at two parallel routes between one origin and destination that can differ in capacity and free-flow travel time. A single private road competing with a free-access road tends to be most efficient if the two roads have approximately equal capacities and if the private road does not suffer a significant travel time disadvantage.

Yang and Meng (2000) look at the selection of the capacity and toll charge of a new road (in a build-operate-transfer (BOT) framework) and the evaluation of the relevant benefits to the private investor, the road users, and the society as a whole. A profit-maximising private firm will consider the trade-off among traffic demand, toll charge, and road capacity. Toll setting and capacity choice by private organisations will have important consequences in terms of efficiency, which may call for government intervention. The Yang and Meng study investigated private sector profit and total social welfare gain generated from a proposed BOT project under a wide range of capacity-toll combinations and employing a general road network. They show how, and under what circumstances, a highway project is profitable, and how it may benefit the road users.

Tsai and Chu (2003) studied regulation alternatives for governments on private highway investment under a BOT scheme set up to protect both consumers and firms. The impact of various circumstances (such as a minimum flow constraint) on traffic demand, as well as users' cost, profit levels, and welfare are explored. They found that a BOT project with regulation performs between the cases of maximizing welfare and that of maximum profit.

Our analysis is possibly closest to that by Tsai and Chu (2003). However, they focused on two types of regulation for one private firm that will construct the road. Here, we focus on the auctioning of concessions to privately operate the road, and consider various criteria ("indicators") that a government may use to realize more satisfying bids from interested firms.

6.3.2 Model formulation

In our model, we study the relative efficiency of a new route, parallel to an existing untolled alternative that is to be operated and constructed by a private firm. The case of a new road without an existing substitute is a special case of our model, with the existing road's capacity set equal to zero. We assume that the existing (public) road will remain untolled. An unrestricted monopolist would prefer to set tolls and capacity at profit-maximising rather than welfare-maximising values. We consider the question of how such behaviour can be affected by using particular types of auctions for the right to operate the private road.

Clearly, if the government had perfect knowledge of prevailing demand and cost conditions, it would be simple to design such an auction: the firm that promises to set toll and capacities equal to the socially-optimal (second-best) levels would win the concession. Auctions become relevant only if the government is uncertain about what is optimal, while potential suppliers have more information. We assume that this is the case. Specifically, we assume that suppliers have perfect knowledge of the market conditions, and that the government only knows the (single) value of time of the road's potential users[12]. Otherwise, we make assumptions that will prevent any other distortions from affecting the (relative) efficiency of the auctions we consider. First, we will assume that there is competitive bidding: there is no tacit collusion between bidders, they do not have market power in the bidding process, and bids will be such that the winning firm will make zero profits. Secondly, we assume that the potential bidders are identical. Under these unrealistic, idealised conditions we can focus on the performance of different indicators that the government could use in setting up auctions for roads. And thirdly, we assume that the firms make truthful bids, that is: bids to which they will indeed adhere once given the concession. This means that we implicitly assume that there is a credible and effective penalty on deviating from the bid made. The complications arising when these assumptions are not fulfilled are certainly interesting, but considered as material for future work. These include the existence of differences between potential firms, the existence of collusion during the auction, other imperfections in the auction if the number of bidders becomes smaller, the existence of uncertainty also for the potential bidders, etc.

Finally, we assume that the government has the objective of maximising social surplus, defined as total (Marshallian) benefits minus total user costs (including time costs), minus the capacity costs. The objective of the private road operators would normally be to maximise profits, defined as total toll revenues minus capacity costs. However, when an auction is in place, the firm's objective will become to maximise (or minimise) the indicator specified by the regulator, under the constraint that the profits from the operation be non-negative. For all the auctions that we consider, this constraint will be binding. The idea is thus that a firm that would not maximise (or minimise) the indicator would be certain not to win the auction.

The challenge faced by the government is then as follows: can an auction be designed such that the bidding private firms propose a capacity and toll that are close to the second-best optimal

[12] This assumption is made to ensure that both the government and all bidders can communicate in terms of average user cost, without having to worry about different parties having a different view on the relation between equilibrium travel times and implied average user costs. This is relevant for some of the auctions we consider below, in which the indicator includes the generalised price (average travel costs plus toll) on route T.

value? Specifically, which "indicator" (the target variable that bidders should maximise or minimise and that thus will be used to select the winning bid) will achieve this objective as closely as possible?

Our network model builds on the one used by Verhoef et al. (1996). Our analysis, however, includes capacity and capacity costs, which enables us to compare different combinations of toll and capacity proposed by the bidders, leading to various profit and welfare levels. But the general setting is the same: a simple network with two competing (possibly) congested roads. One route (the existing one) remains free of toll (route U) and another route will be built and tolled by the concession-winning private firm (route T).

Car drivers regard the two alternatives as perfect substitutes We therefore consider one single demand function $D(N)$, where N denotes the total number of road users on both routes (naturally $N = N_T + N_U$), and there are two average user cost (including time costs) functions $C_T\ (N_T, cap_T)$ and $C_U\ (N_U, cap_U)$. In line with Wardrop's first principle (Wardrop, 1952), at any equilibrium with both routes used, the average cost on route U should then be equal to the average cost on route T plus the one-route fee t_T: otherwise, people would shift from one route to the other. Furthermore, both average costs should be equal to marginal benefits ($D(N)= D(N_T + N_U)$). We assume that the demand is linear:

$$D = d - a *(N_T + N_U). \qquad (1)$$

Next, for both routes i, the average social cost (c_i) consists of a free-flow cost component k_i and a congestion cost component, which is assumed to be proportional to total road usage (N_i) with a factor b_i, being a constant term divided by the capacity of the road:

$$c_i = k_i + b_i *N_i; \qquad i = T,U. \qquad (2)$$

$$b_i = \beta/cap_i; \qquad i = T,U. \qquad (3)$$

The generalised price, for both roads, can then be defined as the sum of c_i and the toll (if any);

$$p_i = c_i + t_i; \qquad i = T,U. \qquad (4)$$

Profits (π_T) for the private operator are defined as the difference between revenues from the tolls and the net costs for road provision (capacity costs, plus or minus a lump-sum payment or subsidy (if any)). Hence, we neglect other costs for the provider such as maintenance and costs involved with toll collection. A road project is interesting to private firms when a stream of revenues is sufficient to meet their costs and allows them a minimum profit. The costs depend on the size of the project (the capacity of the road), while the revenue depends on the combination of the toll charge and traffic demand for the new road. In our analysis of various auctions, we include at some stage the possibility for private firms to ask for a certain amount of subsidy (*sub* in the model) from the government that may be necessary to offer a profitable bid. The capacity costs are assumed to be proportional to the capacity of the road (cap_i) with a fixed price per capacity unit (p_{cap}, equal for both routes)[13];

$$\pi_T = t_T*N_T - cap_T* p_{cap} + sub; \qquad (5)$$

[13] Note that the average cost function implied by (2) and (3) and the constancy of the unit price for capacity implies that our road network qualifies for the application of the Mohring-Harwitz (1962) result on exact self-financing of optimally designed and priced roads (see also below).

Total welfare (W) is now equal to the 'variable' social surplus (the benefits B as given by the relevant area under the demand curve, minus total user costs) minus the total capacity costs:

$$W = B - N_U{*}c_U - N_T{*}c_T - (cap_U + cap_T){*}\,p_{cap} \qquad (6)$$

All parameters are non-negative, and we will only consider regular networks, where both routes are at least marginally used.
The equilibrium conditions are:

$$D = p_U \text{ and } D = p_T$$

and (for all auctions that we will consider):

$$\pi_T = 0.$$

6.3.3 Numerical Example

For the 'base case' of our numerical model, it is assumed that the private road is not yet available, and the following parameter values were chosen: a = 0.1; d = 140; $k_U = k_T$ = 20; β = 20; p_{cap} = 2; cap_U = 1000; and cap_T = 0. The base-case equilibrium leads to a reasonable demand elasticity of –0.4, at an equilibrium use of 1000 and equilibrium travel costs that are twice the 'free-flow' level (a table with detailed results is provided in Appendix 6b). These parameter values were otherwise not motivated by any desire to represent a realistic situation. Before turning to the auctions, we will first discuss a few benchmark situations. The table in Appendix 6b gives detailed numerical results, whereas Appendix 6c describes the Lagrangian objective functions that have been solved to find these results.

First-best

The first-best social optimum (maximum welfare) in this network involves an optimisation of both the capacity of route T and both tolls (first-best pricing requires pricing of the whole network). The optimal road price is then equal to 6.32, with marginal private costs of 26.32 and marginal social costs amounting to 32.64 (see Appendix 6b). The total capacity of both roads together is 3.4 times as high as the initial capacity. This is rather extreme. It is a direct consequence of the level of p_{cap} that we have chosen, relative to the other parameters, and could therefore easily have been avoided. We have however, chosen this parametrisation so as to create sufficient disparity between the initial equilibrium and the optimum, so that relative differences between various policy options can easily be observed[14]. Moreover, Figure 6.4 below shows the results of a sensitivity analysis with respect to p_{cap}. The zero profit result for the provision of road T confirms the Mohring and Harwitz (1962) result of optimal investment. The revenues from an optimal toll will just cover the costs of the facility provider as long as there are no economies or diseconomies of scale in facility capacity and the facility provider is investing optimally.

Second-best

For the evaluation of the various auctions to be considered, it is useful to know the (welfare) properties of the second-best solution, with only one route tolled and its capacity optimised. Optimal welfare under these conditions (second-best optimum) appears to be only a fraction lower

[14] Note also that the sensitivity analysis with respect to the initial capacity, displayed in Figure 6.2 below, shows that with initial capacities exceeding 1700, auctions that do not allow for a lump-sum subsidy to the bidders would become irrelevant from the perspective of social welfare, as these would no longer be capable of generating any social benefits.

than the first-best optimum (ω = 0.98)[15]. The toll, however, is equal to 0.57, significantly lower than the first-best toll. But, it is unlikely that private firms will voluntarily provide a road with these specifications, because profits are negative. This means that, if the government succeeds in designing an auction that duplicates the second-best outcome, it will have to allow for a subsidy to be given to the private operator.

Second-best under zero profit constraint
The second-best solution under the zero profit constraint leads to a considerable lower welfare level (ω = 0.79). It is, in fact, no surprise that the toll level in this situation equals the first-best tolls. In the long run, marginal and average capacity costs per user for route T are constant. Because we are looking for the second-best optimal situation for this new road, given that no profit or losses should be generated, the ratio of N_T divided by the capacity costs of road T is independent of the use of this road, and hence the optimal variable costs will be constant. This means that the average total costs for route T will be minimised. The optimal charge is now again equal to the average capacity costs per road user, which is 6.32. Total revenues from the toll charge equal the total capacity costs, as demanded by the zero profit constraint.

Profit maximisation
Without governmental intervention, private ownership of the road will lead to profit maximisation. Note that we only consider non-discriminatory fees, the operator is only allowed to set just one toll for all users. The results show that the capacity of the road provided by the private firm will be rather small (compared with the previous optima) and the toll will be equal to 10. The index of relative welfare improvement ω is equal to 0.47[16].

6.3.4 Auction rules for governments
We will now consider possible rules that a government may use in an attempt to organize the auction such that a desired outcome is achieved. The scenarios presented in the previous subsection are interesting benchmarks to identify relative efficiency effects, and to determine the performance of the auction rules. Four different auctions are considered, each with a different objective rule (“indicator”). A fifth possible rule will be dismissed shortly. These rules are based on plausible aims that the government might have in such a setting. Note that the assumptions we have described in Section 6.3.2 apply here. Hence, we assume that there is competitive bidding, and that there will be zero profits for the winning firm.

[15] This indicator ω is defined as the difference between welfare in the situation under study and base-case welfare divided by the difference between first best welfare and base-case welfare.

[16] A remarkable aspect of our model is that the profit-maximising fee turns out to be independent (and equal to 10 in this numerical example) of the road capacity chosen. This is most likely a peculiarity of our linear set-up (although we have not explored this issue any further).

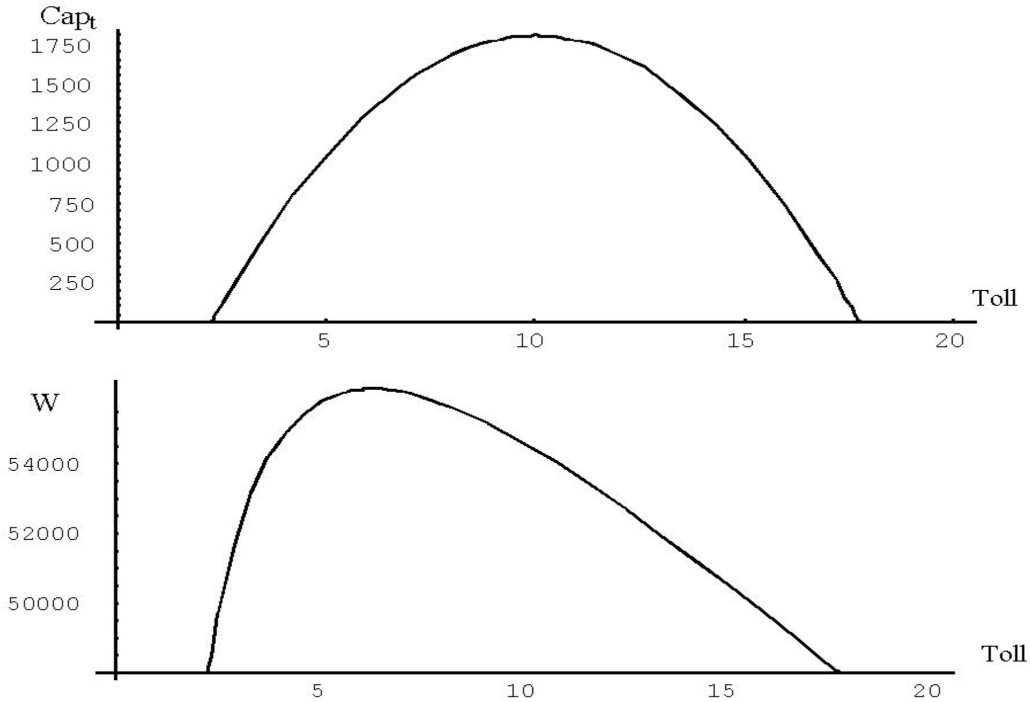


Figure 6.1: Combination of toll and capacity under zero profit condition (upper panel), and combination of toll and welfare levels under zero profit condition (lower panel)

We first identify combinations of toll and capacity that lead to zero profit for the bidder, when no subsidisation is allowed for. The upper panel in Figure 6.1 shows those combinations between toll and capacity of the new route that lead to zero profit. The figure thus maps out the potential outcomes of an auction in which no lump-sum subsidy or payment is foreseen as part of the auction. The lower panel in Figure 6.1 shows the resulting combinations of welfare and toll (with capacity chosen according to the upper panel). The optimal toll among these is 6.32 (which is the second-best zero profit result).

This figure immediately shows that a fifth possible auction, with the rule to minimise the toll to be charged, is not of interest. The lowest possible toll under a zero-profit condition occurs at a zero capacity. Therefore, no practically meaningful bids with positive capacity can be expected from this auction.

Auction 1: Minimise generalised price, including toll, on route T

A first indicator that the government might use would be to ask bidding firms to minimise generalised travel costs including the toll on the new lane (minimise $c_T + t_T$). Because the value of time is common knowledge, in practice this would, for instance, mean that the bidders mention the toll they will charge, and the average speed they promise to offer – which is easily converted into travel costs. When bids are evaluated on this criterion, firms have the incentive to reduce the toll as well as the travel costs. They also face an incentive to minimise capital costs (per user), as this allows charging a relatively low toll – while preventing losses from operation. The simulation results suggest that the lowest generalised travel cost (including toll) is reached at the same toll where welfare is maximised in a second-best situation under zero profit (see Appendix 6c for all objective functions that have been used to obtain the results). This occurs, because the firm will minimise its (capacity) costs and, due to the indicator, also the generalised price. Consequently, the average total costs for route T are minimised, and therefore the same result as with 'second-best zero profit' will prevail. This means that the relative welfare improvement indicator is equal for both situations ($\omega = 0.79$), but still substantially below the second-best situation ($\omega = 0.98$); see also Figure 6.2. This result suggests that a minimum travel costs indicator may lead to considerable welfare improvement compared with the current situation, but also to an unrestricted monopoly ($\omega = 0.47$).

Auction 2: Maximise capacity of route T
A second possibility is that the government selects the bid with the largest capacity (e.g. motivated by the hope to minimise congestion). This indicator leads to an upward pressure on the capacity costs of the bidding firm, but does not directly affect the generalised travel costs (only indirectly by increased capacity). The private firm will search for a bid with the largest capacity of route T, but still without making losses. Figure 6.1 shows the winning zero profit level: a toll of 10 with a capacity of 1800. The higher toll and larger capacity lead to a smaller welfare gain. The index of relative welfare improvement is about 0.64, which is, as expected, lower than that of the previous auction (see also Figure 6.2). Hence, this criterion is not recommended when regulators aim for maximum welfare. The results show that the larger capacity is not accompanied by larger usage, because of the higher toll. This auction would therefore not necessarily become relatively less attractive when environmental costs from road use were also considered, as one might have anticipated for an auction that maximises road capacity.

Auction 3: Minimise subsidy
For the next two auctions, we introduce the possibility of lump-sum payments from, or subsidies to the private operator. Recall that the second-best outcome would require a subsidy. As a first variant, we consider what might be called a 'traditional' auction: namely, one in which the winning bid is the one that requires the lowest subsidy, or, equivalently, promises the largest payment for the right to build and operate the road (when sub is negative). The amount of subsidy (which has been set at zero in the previous auctions) is included in the profit function (4). It appears that the minimum level of the subsidy (negative, indicating that firms are willing to pay) is reached at a capacity of 697, and a toll of 10. The result is equal to the outcome of unconstrained profit maximisation, as could have been expected. It indicates that firms will set the price and capacity in such a way that they can pay the government the highest price (all profits) without making losses. The auction forces the firms to choose a (pre-subsidy) profit that maximises toll and capacity, which are known to lead to potentially considerable welfare losses. This is therefore not a very attractive option from the efficiency perspective ($\omega = 0.47$).

Auction 4: Minimise travel costs and subsidy divided by total traffic demand
The fourth rule that we consider combines the subsidy requested and the generalised travel costs (including a toll) on the new road. The aim reflects the desires for low travel costs and a small subsidy. The indicator is defined as $c_T + t_T + sub/(N_T + N_U)$. The resulting welfare level is very near the second-best outcome, and the index of relative welfare improvement is nearly equal to the second-best solution. However, a subsidy is required to approach the second-best optimum, since this second-best optimum cannot be realised without losses. This auction rule outperforms all other indicators in terms of welfare gains. This can be explained by the fact that it forces firms to minimise total costs (travel and capacity costs, as in auction 1), while requesting a small subsidy. This subsidy is, in fact, used to increase capacity of route T, while keeping toll levels low, all leading to increased welfare levels compared with no-subsidy auctions.
Note that the indicator asks the firm to consider $sub/(N_T + N_U)$ for minimisation, not the subsidy per user of the pay-lane (sub/N_T). The latter indicator was also tested, but appeared to provide perverse incentives in pushing the toll to very low, even negative, levels. The reason is that a lowering of the toll increases N_T and therefore helps in lowering sub/N_T, but does so at the expense of attracting too many users from route U. By including N_U in the denominator of the third term in the indicator, this perverse incentive is removed. Figure 6.2 below will show that, as the capacity of route U and hence its equilibrium use approaches zero, the present indicator

remains performing well. The declining impact of N_U in the indicator is matched by the fact that a low capacity of road U means that the described perverse incentive in terms of inefficient route split also vanishes.
Appendix 6d presents the analytical solution for this auction, and demonstrates that the bidders first-order condition for optimising capacity coincides with the second-best first-order condition, while the optimal toll in both regimes shows a discrepancy which apparently is of minor importance under the base-case parameters.

6.3.5 Sensitivity analysis

The previous results for ω are of course likely to change with the parameter values chosen. In order to consider the robustness of our results, we have analysed three types of effects. First, we will look at the effect of changing the capacity of the untolled route on *ω*. Next, the impact of demand elasticity on ω for the various auctions is investigated. And, thirdly, we consider changes in p_{cap}. Finally, we briefly discuss the possible effects of changing some of our basic underlying assumptions.

Varying the capacity of the untolled lane

Figure 6.2 shows the results of relative welfare improvements for the various auctions when changing the capacity of the untolled lane (recall that all previous results concern a capacity of the untolled lane of 1000). An *ω* of 1 is the first-best result, and both second-best situations approach the first-best optimum when the capacity of the existing road decreases and the amount of unpriced capacity decreases.
It appears that the well-performing criterion of the minimisation of travel costs (auction 1: A1) maintains a high *ω*, equal to the second-best situation under a zero profit constraint, for changing capacities of the untolled lane. When this capacity approaches zero, auction 1 approaches maximum efficiency, since – due to the Mohring-Harwitz result – no subsidies are required when initial capacity is zero and the new road is designed and priced optimally. Auction rule 4 (A4 in Figure 6.2, minimising travel costs and subsidy divided by total traffic demand) also remains nearly equal to the second-best situation without zero profit constraint for all capacities shown.
It appears that results depend heavily on the capacity of the untolled lane. The figure shows that when congestion is more likely to occur (when decreasing the capacity of the untolled lane), the performance of most indicators improves. An exception is auction rule 2. This reflects that the discrepancy between optimal capacity and the maximum capacity that can be supplied against zero profits increases as the capacity of the untolled road decreases. This is accompanied by an increasing difference between the toll from the auction and the second-best optimal toll, thus inducing further distortions from this auction 2. On the other hand, when the capacity of the initial lane is sufficiently large, it becomes more difficult to achieve any welfare gains at all from adding a pay-lane, because the second-best constraint of unpriced capacity becomes relatively more important.

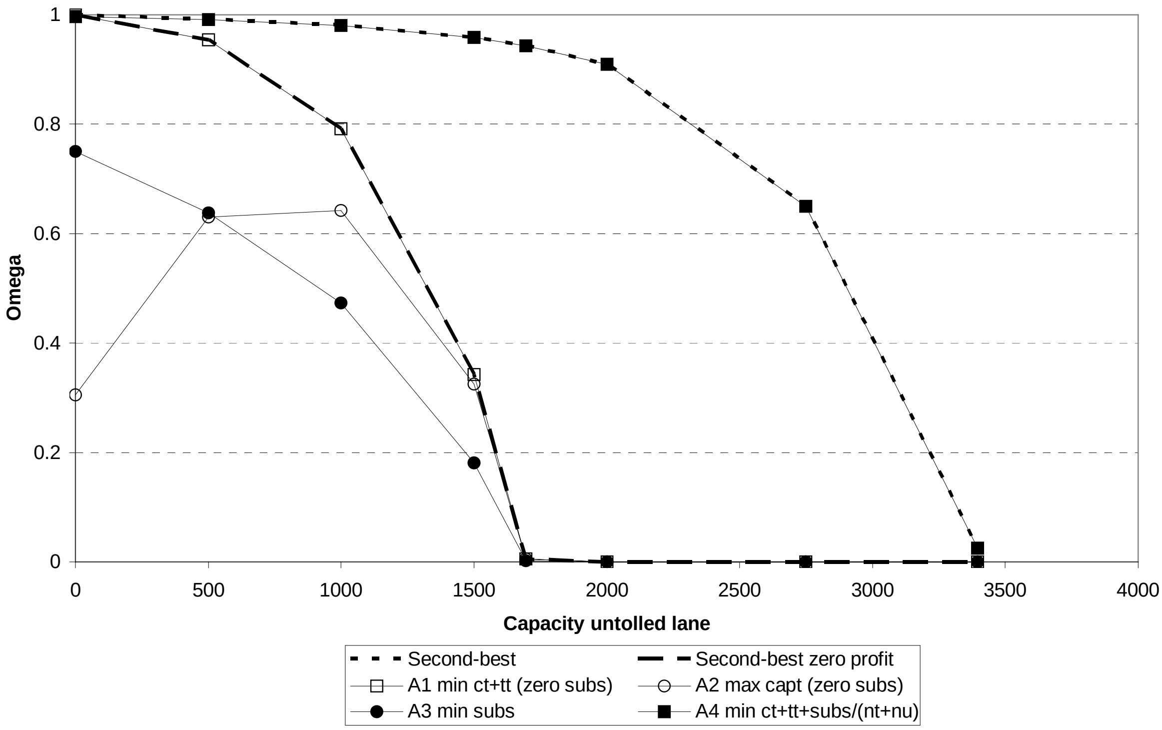


Figure 6.2: The index of relative welfare improvement for the auctions with various capacities of the untolled route

Varying demand elasticity

Figure 6.3 shows the results in terms of ω when changing the equilibrium demand elasticity (by simultaneously changing the parameter values of a and d such that the same base equilibrium is obtained for every elasticity). It indicates that the results are rather robust for different demand elasticities; the prevailing demand structure is apparently not a crucial factor. This may appear surprising at first sight, especially because prior studies of profit-maximising tolling on a pay-lane have emphasised the importance of demand elasticity upon its relative efficiency (e.g. Verhoef et al. 1996; Verhoef and Small, 2004). The reason why this is not the case in the present set-up is that not only the toll but also the capacity of the priced road is adjusted in response to changes in demand elasticity. As a result, N_U and c_U remain constant for nearly each scenario along the demand elasticities shown in Figure 6.3, with the exception of second-best and auction 4 (where small changes are observed). The same holds for c_T (constant for all scenarios) and t_T (relatively large changes in a relatively small absolute toll value occur only in – again – second-best and auction 4). The demand elasticity therefore only determines the 'size' of the new market (on road T), expressed in cap_T and N_T, but leaves the relative efficiency effects of the various scenarios largely unaffected.

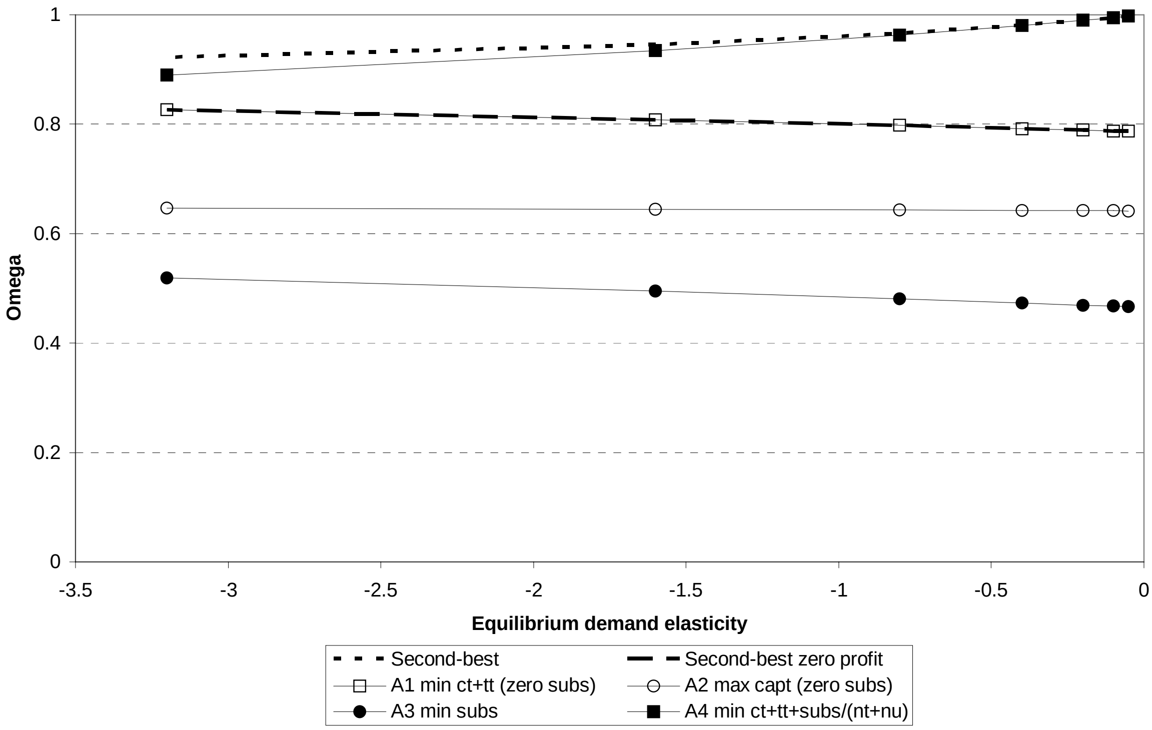
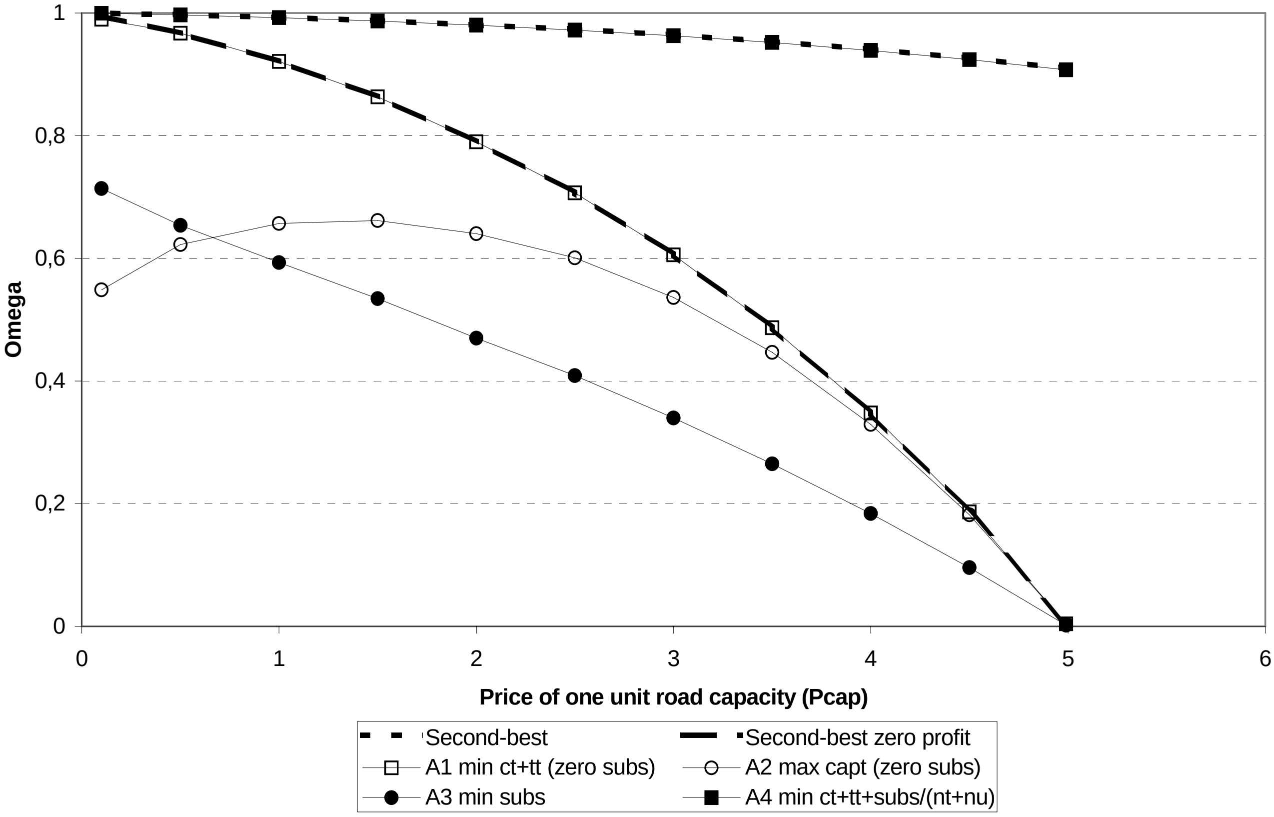


Figure 6.3: The index of relative welfare improvement for the auctions with various demand elasticities

Varying the price of road capacity

Figure 6.4 shows what happens with ω for the various auctions when changing the unit price of road capacity (p_{cap}). Note that the patterns are similar to those of Figure 6.2. Increasing the price of capacity leads to considerable lower welfare gains for most auctions, except for auction 4 (over the range shown). Note that the performance of auctions 1 and 4 again remains (nearly) equal to their second-best counterparts. When it becomes cheaper to construct a road, it is more likely that capacities will increase (attracting more road users), and hence tolling becomes more efficient for all cases. The results suggest that auction 4 may be particularly useful to policy makers when considering the construction of a new road in (congested) urban areas by a private consortium. Higher land prices may make it more expensive to build a new road. The relevant part of Figure 6.4 to consider is the right-hand side, where the relative advantage of auction 4 over the other auctions increases rapidly.



Note: high levels of capacity prices (more than 5) imply no meaningful results for auctions 1,2 and 3, as they lead to zero capacities.

Figure 6.4: The index of relative welfare improvement for the auctions with various prices of road capacity

Limitations of the analysis

The above analysis has demonstrated that the relative performance of different indicators in auctions may deviate rather strongly, and that the relative efficiency of all indicators may in addition depend strongly on local circumstances such as the relative size of existing unpriced capacity and the unit price of capacity. These conclusions are not very likely to change when including other complications that may be relevant for the franchising of highways; nor is there any a priori reason to believe that such other complications would systematically change the ranking of the different auctions considered in this chapter. Nevertheless, this is an issue that deserves further analysis. It is now worthwhile to briefly consider the most pressing simplifications in the above analysis, and to reflect on how these could be addressed in future work and what the potential impacts of doing so might be.

A first simplification in the model is caused by its static nature. Demand uncertainty, however, and the question of how to deal with it in setting up auctions, raises important questions in practical highway franchising (e.g. Engel et al. 1996). It could be addressed in our set-up by making the parameters of the demand function random, and by possibly also introducing a risk premium for private parties' profits. The resulting model could shed light on a number of pressing questions. Under which conditions does demand uncertainty lead to a stronger risk-averse behaviour of private road operators than is socially desirable? And, does some form of public insurance (directly or implicitly via the rules of the game in auctions) become desirable? In auctions such as auction 1 and auction 4, is it feasible and socially desirable to decentralise the risks involved in demand uncertainty to the private operator through a system of taxes and subsidies, which would punish or reward the operator on a per-user basis for exceeding or staying below the pre-agreed generalised cost level? Are there then other ways to reduce the risk for private operators, without removing incentives to operate efficiently?

Demand uncertainty is closely related to the problem of contract renegotiation. Without demand uncertainty, there would be little reason to accept such renegotiation. But especially when demand is uncertain because of future public policies such as investment in parallel highway or rail capacity, things would change. Illustrative of this is the experience with the Californian SR-91, which reverted from private to public ownership in 2003 because of a "non-compete clause" in the original contract that became binding after demand had grown more rapidly than foreseen and created the desire for additional capacity. The same modelling set-up as described for demand uncertainty could be used to analyse uncertainty-induced renegotiation, and especially the question of whether it can be avoided by adjusting auctions to reflect contingencies. For example, the government could announce a maximum generalised cost level that it will allow on alternative connections, above which it will (have the right to) invest in additional capacity.

Another issue concerns the assumption that competing firms are identical, and – especially – have identical capacity cost functions. A distribution of heterogeneous firms is conceptually straightforward to include in the model, although the analytics might become tedious. When maintaining the assumption of competitive bidding behaviour (no collusion or strategic interaction) and when different firms' cost functions are sufficiently close (which appears reasonable to assume in the longer run for firms that stay in operation), this would not change the results in any significant way, since firms would still maximise or minimise the specific indicator used in the auction. If the number of firms becomes smaller, and competitive bidding becomes less likely, the model would change rather drastically, since strategic behaviour and interactions in the bidding process would have to be taken into account. This will certainly change the outcome of the auctions. Whether it would also affect the ranking of indicators obtained here is less certain, and is left for further research.

Another issue is that private firms might be tempted not to obey what was promised in the bids. Obviously, a contract between a firm and the government should clearly specify the details of the winning bid (toll and capacity), and penalties should guarantee that companies do make serious offers. But especially in the context of uncertainty, renegotiation and strategic behaviour of bidders, the system of penalties itself might provide unexpected incentives that are worthy of further investigation.

Despite the simplifying assumptions underlying our model and the rather broad menu of future research issues that we can identify, the results may still be relevant to governments organising an auction. If anything, the results show that the choice of the "indicator" is – as expected – an important determinant for the results of the auctions. Our results suggest that such an indicator should include travel times guaranteed (c_T), toll levels to be charged (t_T), and preferably also the lump-sum subsidy required (*sub*). Allowing for such a subsidy improves social welfare when this subsidy is relevant, but does not seem to diminish the auction's efficiency when the second-best optimal level of the subsidy becomes small (e.g. when initial capacity becomes small in Figure 6.2).

6.4 Conclusions

Regulation of private firms operating road infrastructure can take several forms. In this chapter we have considered regulation by means of an auction organised by the government. We studied private involvement in road provision in a competitive bidding setting and analysed the effects of imposing various auction rules ("indicators") by the government. We considered a simple network with one origin and one destination connected by two parallel routes, one of which is to be constructed and operated by a private firm. This is relevant in practice since the expansion of existing road capacity is often the type of road building that is considered nowadays. Using a simulation model, we investigated the effects of various indicators on the outcomes of the auction. Different criteria may lead to rather different road capacities and tolls bid by private companies. The previous literature considered the welfare effects of different ownership regimes with varying tolls and capacities; however, to the best of our knowledge, the consequences of criteria in auctions on these effects had not yet been studied.

We have analysed the welfare consequences of four different, but plausible, rules that may be used by the government to organise the bidding process. For auctions without subsidies, it appeared that the criterion of the minimisation of generalised price on the tolled road performs just as well as the second-best situation under a zero profit constraint. However, an indicator that rewards increases in capacity does not lead to very promising results in terms of welfare. Minimising the requested subsidy or maximising the bid results in the same outcome as unconstrained profit maximisation, and is therefore not very attractive. When allowing for subsidies, the best indicator appeared to involve the minimisation of generalised travel costs including the toll on the new road, plus the subsidy divided by total traffic demand. This indicator outperforms the simpler generalised price (again including toll) criterion in terms of relative efficiency because it not only minimises travel costs but also permits a subsidy, which is important especially when the second-best optimum implies operational losses.

Finally, we have looked at the sensitivity of the results by changing the capacity of the untolled lane, the equilibrium demand elasticity, and the unit cost of capacity. It appears that results change significantly when changing the capacity of the untolled lane. The performance of most indicators generally improves when a smaller portion of total capacity remains untolled, and when congestion is more likely to occur (i.e. with a decreasing capacity of the untolled lane). On the other hand, when the capacity of the present lane is sufficiently high, it is very hard to achieve welfare gains. Similar patterns were observed for, respectively, lower versus higher costs of capacity. The results are rather robust for different demand elasticities. This was mainly because capacities are adjusted in the face of changes in demand elasticity, which affects the scale of the new road for all scenarios considered, but not their relative performance.

Appendix 6A

List of Symbols

N	Total number of road users
N_T	Number of road users on the tolled route
N_U	Number of road users on the untolled route
$D(N)$	Inverse demand function
c_T	Average social (=marginal private) costs on the tolled route
c_U	Average social (=marginal private) costs on the untolled route
cap_T	Capacity of the tolled route
cap_U	Capacity of the untolled route
W	Welfare
B	Benefits
π_t	Profit for the firm that provides road T
p_i	Price for route i (including cost and toll)
t_T	Toll
p_{cap}	Price of one unit of road capacity
k_i	Average free-flow user cost on route i
b_i	Slope of the average cost function on route i (dependent on capacity)
β	Constant
ω	Index of relative welfare improvement
a	Slope of the demand curve (negative)
d	Intersection of the demand curve with the vertical axis
sub	amount of subsidy included in the offer of the private firm

Appendix 6B

Numerical Results

Scenario	N_T	N_U	cap_T	cap_U	W	π_T	t_T	t_U	sub	ω
Base equilibrium	0	1000	0	1000	48000	0	0	0	-	-
First-best	757	316	2395	1000	57621	0	6.32	6.32	-	1
Second-best	786	345	2486	1000	57439	-4519	0.57	0	-	0.98
Second-best (zero profit)	441	632	1395	1000	55621	0	6.32	0	-	0.79
Profit maximisation	221	816	697	1000	52553	811	10	0	-	0.47
Auction 1 Minimise generalised price (including toll) on route T	441	632	1395	1000	55621	0	6.32	0	0	0.79
Auction 2 Maximise capacity of route T	360	700	1800	1000	54180	0	10	0	0	0.64
Auction 3 Minimise subsidy	221	816	697	1000	52553	0	10	0	-811	0.47
Auction 4 Minimise generalised price (including toll) on route T including subsidy divided by total travel demand	810	325	2561	1000	57430	0	0.18	0	4980	0.98

Appendix 6C

Description of the Lagrangian objective functions

The relevant optima (the numerical results can be found in Appendix 6b) have been found by solving the following Lagrangian functions for the benchmark situations and the auctions under study. These functions were differentiated with respect to the relevant choice variables to find the first-order conditions. It would take too far to present all these necessary first-order conditions, so we have limited ourselves to presenting the Lagrangians of our problems. The Lagrange multipliers λ_T and λ_U refer to the equilibrium constraints that marginal benefits equal prices on both roads. The Langrange multiplier on the zero profit constraint is λ_π.

First-best optimum

$$L = \int_0^N D(n)dn - N_T * c_T - N_U * c_U - (cap_U + cap_T) * p_{cap} + \lambda_T (D(N) - p_T) + \lambda_U (D(N) - p_U)$$

This equation was solved for $N_T, N_U, cap_T, t_T, t_U, \lambda_T$ and λ_U.

Second-best optimum

$$L = \int_0^N D(n)dn - N_T * c_T - N_U * c_U - (cap_U + cap_T) * p_{cap} + \lambda_T (D(N) - p_T) + \lambda_U (D(N) - p_U)$$

This equation was solved for $N_T, N_U, cap_T, t_T, \lambda_T$ and λ_U, with $t_U = 0$.

Second-best optimum with zero profit condition

$$L = \int_0^N D(n)dn - N_T * c_T - N_U * c_U - (cap_U + cap_T) * p_{cap} + \lambda_T (D(N) - p_T) + \lambda_U (D(N) - p_U)$$
$$+ \lambda_\pi (t_T * N_T - cap_T * p_{cap} + sub)$$

This equation was solved for $N_T, N_U, cap_T, t_T, \lambda_T, \lambda_\pi$ and λ_U, with $t_U = 0$.

Profit maximisation

$$L = t_T * N_T - cap_T * p_{cap} + sub + \lambda_T (D(N) - p_T) + \lambda_U (D(N) - p_U)$$

This equation was solved for $N_T, N_U, cap_T, t_T, \lambda_T$ and λ_U, with $t_U = 0$.

Auction 1: Minimise p_T (zero profits and no subsidy)

$$L = p_T + \lambda_T (D(N) - p_T) + \lambda_U (D(N) - p_U) + \lambda_\pi (t_T * N_T - cap_T * p_{cap} + sub)$$

This equation was solved for $N_T, N_U, cap_T, t_T, \lambda_T, \lambda_\pi$ and λ_U, with $t_U = 0$.

Auction 2: Maximise cap_T (zero profits and no subsidy)

$$L = cap_T + \lambda_T (D(N) - p_T) + \lambda_U (D(N) - p_U) + \lambda_\pi (t_T * N_T - cap_T * p_{cap} + sub)$$

This equation was solved for $N_T, N_U, cap_T, t_T, \lambda_T, \lambda_\pi$ and λ_U, with $t_U = 0$.

Auction 3: Minimise sub (zero profits with subsidy)

$$L = sub + \lambda_T (D(N) - p_T) + \lambda_U (D(N) - p_U) + \lambda_\pi (t_T * N_T - cap_T * p_{cap} + sub)$$

This equation was solved for $N_T, N_U, cap_T, t_T, \lambda_T, \lambda_U, \lambda_\pi$ and sub, with $t_U = 0$.

Auction 4: Minimise $p_T + sub/(N_T + N_U)$ (zero profits with subsidy)

$$L = p_T + sub/(N_T + N_U) + \lambda_T\left(D(N) - p_T\right) + \lambda_U\left(D(N) - p_U\right) + \lambda_\pi\left(t_T * N_T - cap_T * p_{cap} + sub\right)$$

This equation was solved for $N_T, N_U, cap_T, t_T, \lambda_T, \lambda_U, \lambda_\pi$ and sub, with $t_U = 0$.

Appendix 6D

Derivation of first-order solutions of optimal capacity and optimal toll for the second-best situation and auction 4

This appendix presents the derivation of the expressions for the first-order conditions for optimising capacity and optimising toll for both the second-best situation and auction rule 4 (minimise generalised travel costs plus subsidy divided by total traffic demand). It will be shown that the bidders first-order condition for optimising capacity coincides with the second-best first-order condition, while the optimal toll in both regimes shows a certain discrepancy. We will start with the derivation of the analytical solution for the second-best case. This is followed by the derivation of the optimal toll and the first-order expression of optimal capacity for auction rule 4.

Second-best optimal toll and expression for optimal capacity

$$L = \int_0^N D(n)dn - N_T * c_T - N_U * c_U - (cap_U + cap_T) * p_{cap} + \lambda_T (p_T - D(N)) + \lambda_U (p_U - D(N)) \quad (1)$$

$$\frac{\partial L}{\partial N_T} = D - c_T - N_T * \frac{\partial c_T}{\partial N_T} + \lambda_T \left(\frac{\partial c_T}{\partial N_T} - \frac{\partial D}{\partial N_T} \right) - \lambda_U * \frac{\partial D}{\partial N} = 0 \quad (2)$$

$$\frac{\partial L}{\partial N_U} = D - c_U - N_U * \frac{\partial c_U}{\partial N_U} - \lambda_T \frac{\partial D}{\partial N} + \lambda_U \left(\frac{\partial c_U}{\partial N_U} - \frac{\partial D}{\partial N} \right) = 0 \quad (3)$$

$$\frac{\partial L}{\partial cap_T} = -N_T * \frac{\partial c_T}{\partial cap_T} - p_{cap} + \lambda_T * \frac{\partial c_T}{\partial cap_T} = 0 \quad (4)$$

$$\frac{\partial L}{\partial t_T} = \lambda_T = 0 \quad (5)$$

$$\frac{\partial L}{\partial \lambda_T} = c_T + t_T - D = 0 \quad (6)$$

$$\frac{\partial L}{\partial \lambda_U} = c_U - D = 0 \quad (7)$$

Substituting equation (7) and (5) in (3) yields:

$$\lambda_U = \frac{N_U * \frac{\partial c_U}{\partial N_U}}{\frac{\partial c_U}{\partial N_U} - \frac{\partial D}{\partial N}} \quad (8)$$

The solution for the optimal second-best toll follows from substituting (8), (6) and (5) in (2):

$$t_T = N_T * \frac{\partial c_T}{\partial N_T} - N_U * \frac{\partial c_U}{\partial N_U} * \frac{-\frac{\partial D}{\partial N}}{\frac{\partial c_U}{\partial N_U} - \frac{\partial D}{\partial N}} \tag{9}$$

This is the standard second-best optimal toll consisting of the first-best toll minus a term that corrects for congestion on the untolled parallel road (see also Verhoef, Nijkamp and Rietveld, 1996).

The second-best first-order condition for optimal capacity is obtained when (5) is substituted in (4):

$$p_{cap} = N_T * -\frac{\partial c_T}{\partial cap_T} \tag{10}$$

As for first-best capacity choice, capacity should be expanded up to the point where the marginal costs of doing so (p_{cap} on the left-hand side of (10)) are equal to the marginal benefits (the right-hand side).

Auction rule 4: optimal toll and first-order condition for optimal capacity

$$L = p_T + \frac{sub}{N_T + N_U} + \lambda_T\left(p_T - D(N)\right) + \lambda_U\left(p_U - D(N)\right) + \lambda_\pi\left(t_T * N_T - cap_T * p_{cap} + sub\right) \tag{11}$$

First we derive:

$$\frac{\partial L}{\partial sub} = \lambda_\pi + \frac{1}{N_T + N_U} = 0 \Rightarrow \lambda_\pi = \frac{-1}{N_T + N_U} \tag{12}$$

$$\frac{\partial L}{\partial t_T} = 1 + \lambda_T + \lambda_\pi * N_T = 0 \Rightarrow \lambda_T = -1 + \frac{N_T}{N_T + N_U} = \frac{-N_U}{N_T + N_U} \tag{13}$$

and use these expressions directly in what follows.

The first-order conditions for N_U and N_T are:

$$\frac{\partial L}{\partial N_U} = -\frac{sub}{\left(N_T + N_U\right)^2} - \frac{N_U}{N_T + N_U} * -\frac{\partial D}{\partial N_U} + \lambda_U\left(\frac{\partial c_U}{\partial N_U} - \frac{\partial D}{\partial N_U}\right) = 0 \tag{14}$$

$$\frac{\partial L}{\partial N_T} = \frac{\partial c_T}{\partial N_T} - \frac{sub}{\left(N_T + N_U\right)^2} - \frac{N_U}{N_T + N_U} * \left(\frac{\partial c_T}{\partial N_T} - \frac{\partial D}{\partial N}\right) - \lambda_U\left(\frac{\partial D}{\partial N}\right) - \frac{1}{N_T + N_U} * t_T = 0 \tag{15}$$

Substituting (15) in (14) leaves the following expression for the optimal toll:

$$t_T = N_T * \frac{\partial c_T}{\partial N_T} - \lambda_U * \frac{\partial c_U}{\partial N_U} * (N_T + N_U) \tag{16}$$

Rewriting (14) we find an expression for λ_U. Using this expression in (16) gives the following solution for the optimal toll for auction rule 4:

$$t_T = N_T * \frac{\partial c_T}{\partial N_T} - N_U * \frac{\partial c_U}{\partial N_U} * \frac{-\frac{\partial D}{\partial N}}{\frac{\partial c_U}{\partial N_U} - \frac{\partial D}{\partial N}} - \frac{\frac{\partial c_U}{\partial N_U}}{\frac{\partial c_U}{\partial N_U} - \frac{\partial D}{\partial N}} * \frac{sub}{N_T + N_U} \tag{17}$$

Note that (17) is an implicit solution for t_T, since *sub* still appears on the right-hand side. Nevertheless, the expression in (17) is insightful as it shows that the toll expression is almost equal to the second-best toll as shown in (9), but differs in an extra term that should be subtracted. For a positive subsidy, the optimal toll for this auction rule will be below the optimal second-best toll, as is also shown in the numerical results. Admittedly simplistic intuition suggests that this last term need not be large (and hence does not lead to large deviations from the optimal second-best toll), because the auction rule asks bidders to also minimise $\frac{sub}{N_T + N_u}$.

Finally, the expressions for λ_T and λ_π in equations (12) and (13) imply:

$$\frac{\partial L}{\partial cap_T} = \frac{\partial c_T}{\partial cap_T} - \frac{N_U}{N_U + N_T} * \frac{\partial c_T}{\partial cap_T} + \frac{p_{cap}}{N_T + N_U} = \frac{N_T}{N_T + N_U} * \frac{\partial c_T}{\partial cap_T} + \frac{p_{cap}}{N_T + N_U} = 0 \Rightarrow$$

$$p_{cap} = -N_T * \frac{\partial c_T}{\partial cap_T} \tag{18}$$

Indeed, this term equals the first-order condition for optimal capacity in the second-best situation (as shown in (10)).

Chapter 7

Governmental competition in road charging and capacity choice

7.1 Introduction

Chapter 2 has shown that prices should be set equal to marginal costs to reach an efficient allocation of resources. However, this policy prescription holds exactly only under first-best conditions, and even then only when distributional considerations are ignored, or lump-sum redistribution is possible. One of the conclusions in that chapter also indicated that, in reality, these conditions are never completely met, i.e. there are always additional constraints, apart from the inevitable technological ones. The regulator has then to resort to 'second-best' pricing: setting prices that are available optimally under the constraints applying. It is interesting to study welfare consequences of these, more realistic, prices.

This chapter focuses on one particular reason for the presence of second-best constraints: the fact that authorities of different jurisdictions pursue their own objectives and use their own policy instruments. Such interactions between different governments (e.g. federal level versus regions or cities) introduce the potential for vertical or horizontal tax competition[17]. The chosen instrument values may be optimal for the population represented by the decision maker (for instance, the inhabitants of a region), but may at the same time be suboptimal when also considering the interest of people elsewhere (in different regions). In such cases, the values of the policy variables determined by the one authority are beyond direct control of other authorities, implying a second-best constraint.

It is obvious that different types of institutional relationships may be relevant in the field of transport policy competition. This chapter addresses competition in road capacity and road tolling between a city and a region. Many transport problems have a strong local or urban dimension. This may explain the increasing interest in giving sufficient possibilities for regional/local authorities to deal with these issues: at least they know local circumstances best. So far, regions or cities usually have had some form of regulation within their control (e.g. parking), but their possibilities to implement other forms of transport (pricing) policy are generally limited. Nevertheless, it seems that initiatives with greater policy responsibilities at a lower level may be gaining ground, and can be very successful in addressing local transport problems. Good examples are value pricing projects in the US (see also Chapter 3), and the London congestion charging scheme. One difficulty that often arises with such schemes is the involvement of multiple levels of government, which typically can differ in their objectives and powers. For example, local authorities may assign lower weights to the welfare of non-residents than do national or regional governments. The cost of funds may differ, because of differences in the types and levels of taxes that governments rely on for revenue. And control of various pricing and non-pricing policies may be divided up between levels of governments. All these differences create the potential for conflict, as well as strategic behaviour in the form of tax exporting, tax competition, etc.

In this chapter we study the welfare consequences of strategic interaction between an urban government and a region, both having two different policy instruments: tolls, and investment in road capacity. We will use a small two-link network that enables us to study these choices in the simplest possible network configuration. The chapter begins with a discussion of the previous literature relevant in the context of our analysis. Section 7.3 introduces the model,

[17] Vertical tax competition refers to a situation in which governments at different hierarchical levels compete, while horizontal tax competition results when governments at the same level compete.

and presents the simulation results for different situations (ranging from the first-best optimum as a useful benchmark to various non-cooperative game situations). This section also presents some sensitivity analyses. Section 7.4 concludes.

7.2 Previous literature on governmental competition in a small network setting: a review

Chapter 6 already discussed specific studies dealing with second-best pricing of road use. There, we focused on the inclusion of private firms in the provision and tolling of road infrastructure. The analysis considered the auctioning of concessions to privately operate the road, and various criteria ("indicators") that a government may use to realise more satisfying bids (in terms of tolls and road capacity) from interested firms.

Here, we focus on the competition between different governments choosing tolls and capacities. An interesting study in this context is by De Borger and Van Dender (2005) who analysed the duopolistic interaction between facilities subject to congestion (such as airports or roads) that supply perfect substitutes and make sequential decisions on capacities and prices. The situation of competition (Nash equilibria) is compared with the results of a monopoly and first-best outcomes. They show that price competition between duopolists is beneficial for consumers, but introducing capacity competition is harmful. The duopolist situation offers lower service quality (defined as the inverse of time costs) than the monopolist, who does provide the socially-optimal quality level.

Tax competition between different levels of government may occur (for a review, see De Borger and Proost (2004)). Optimal transport pricing with multiple governments can become complicated, because many vertical and horizontal fiscal externalities occur simultaneously, with spillovers of congestion and environmental externalities (see Markusen et al., 1995; Wilson, 1999). First, the importance of international transport, including pure transit flows, in some countries implies that a substantial share of locally-generated externalities is due to foreigners. To the extent that these flows can be taxed, this may induce tax-exporting behaviour. Second, international transport implies that the tax base of transport services is to a large extent mobile between countries. This may be the basis for inefficient tax competition. Third, vertical externalities arise because different levels of government (e.g. city and national governments) may be interested in taxing the same base, for example, in an effort to tackle pollution or congestion. Alternatively, they may actually use different instruments to deal with the same problem. Fourth, some transport externalities generate international spillovers (e.g. global warming, acid rain, etc.), which should be appropriately accounted for. Finally, apart from tax externalities, transport generates various expenditure externalities: investment in infrastructure has benefit spillovers to foreigners, local road investments affect federal fuel tax revenues, etc. It appears that literature on these kinds of tax competition issues in transport (we restrict ourselves to transport and do not include the public finance literature) is fairly limited (De Borger and Proost, 2004). But some studies addressing tax (in terms of road pricing) competition in transport have been found and will be discussed in the following subsections.

7.2.1 Horizontal linkages

Horizontal tax competition refers to a situation where governments at the same hierarchical level compete; for instance, Austria and Switzerland compete for toll revenues from traffic between Germany and Italy. This example, in which road users have a choice of routes and where both routes are priced by a different government, is called parallel tax competition. Only a few models look explicitly at parallel tax competition between two governments.

De Borger et al. (2005) analyse tax competition between countries that each maximise the surplus of local users plus tax revenues in controlling local traffic and through-traffic (similar to the situation of Austria and Switzerland). Three different pricing systems were considered: one with toll discrimination between local traffic and transit traffic; with only uniform tolls; and one system with tolls on local drivers only. The results suggest that the welfare effects of introducing transit tolls are large, but that differentiation of tolls between the different types of traffic as compared with uniform tolling does not yield large welfare differences. Countries may decide to cooperate on toll setting, but this leads only to small welfare gains in comparison with non-cooperative transit tolling (Nash equilibrium with uniform tolls).

Another study compares the outcomes of tax policies of Belgium and the rest of Europe in a model with both domestic and international freight transport flows and domestic passenger transport (De Borger et al. (2004)). They used a numerical optimisation model to determine optimal pricing policies (consistent with EU legislation: no discrimination between domestic and international freight transport) for four situations: a reference situation reflecting unchanged policies; a federal optimum; a local optimum for one individual country; and the Nash equilibrium solution. The local optimum for Belgium and the Nash equilibrium demonstrated the inefficiency of tax exporting behaviour: taxes on freight flows were found to be substantially higher than in the federal optimum, depending on the share of international flows in countries. The local optimum for Belgium (maximise welfare of Belgian residents) involved higher welfare than both the federal optimum and the Nash equilibrium outcome. The former was due to tax exporting (taxes on freight transport largely exceed marginal external costs), the latter to the absence of reactions by the rest of Europe.

A second type of horizontal tax competition can be referred to as serial tax competition. Traffic using a route that sequentially runs through the territory of different governments can be taxed by each of the governments. These countries may apply individual tolling instruments on their part of the network, with potentially substantial welfare losses as a result. Despite its importance, serial tax competition in transport has not been given much attention in the literature (De Borger and Proost, 2004). One exception is the empirical work of Levinson (2001). He examines the question why some US States impose tolls while others rely more heavily on fuel and other taxes. The share of highway revenues from tolls is explained by the share of non-residential workers, policies of neighbouring States, historical factors, and the population. The analysis confirms theory in the sense that jurisdictions are more likely to opt for toll financing (instead of fuel or other taxes) when the share of non-residential drivers is large. Obviously, tolls become more attractive because they allow price discrimination and tax exporting. It is also suggested that decentralising financial responsibilities and creating smaller jurisdictions (the greater the share of non-local traffic) increases the likelihood of tolling.

7.2.2 Vertical linkages

Vertical tax competition refers to competition between different hierarchical levels of government. This issue too is relevant in practice, but again it has hardly been addressed in the literature. Most transport users are not only taxed or subsidised via various instruments, but typically these different taxes are set by different levels of government. Road users, for instance, may face fuel taxes determined by national governments and parking fees or cordon tolls implemented by cities or regions. The different responsibilities for transport policy instruments induces a number of complicated interactions between governments because of overlap of tax bases, differences in objectives between governments, spillovers of externalities, etc. A number of reasons can be identified to explain why the resulting tax schemes will generally be suboptimal (De Borger and Proost, 2004):

- Overlapping tax bases may create fiscal externalities: an increase in national fuel taxation reduces demand for transport, including local traffic, and therefore affects revenues from the local government (e.g. toll revenues, public transport revenues).

These side effects are often ignored by the national government in setting fuel taxes, yielding too high national taxes;

- Tax exporting by the city government: a city will take more care of its own residents than of commuters. This may lead to excessively high congestion charges for commuters from an overall welfare viewpoint;
- Externality spillovers: local authorities only care about externalities imposed on local residents; this induces them to set local taxes too low;
- The use of imperfect and different instruments by different governments: local authorities only have a few instruments available, such as cordon tolls and parking charges, to control externalities.

The welfare effects of a combination of different pricing instruments (in many cases to internalise external costs) have been studied extensively in the literature. For instance, Calthrop et al. (2000) used a numerical simulation model of an urban transport market to examine the efficiency gains from various parking policies with and without a simple cordon system. They show that the pricing of parking and road use needs to be simultaneously determined, and that second-best pricing of all parking spaces produces higher welfare gains than the use of a single-ring cordon scheme, though marginally lower than the combination of a cordon charge with resource-cost pricing of parking places.

These studies show the efficiency effects of various pricing instruments available to governments, but do not address the interaction effects when different levels of government are responsible for different pricing instruments that affect users from different jurisdictions. One study that does analyse a policy game between two different levels of governments with two different pricing policies in transport is a case study described in the EU project MC-ICAM (MC-ICAM, 2004). This analysis uses a quasi-general equilibrium model (TRENEN) with two policy instruments: a parking fee set by the city to be paid by all drivers in the city, and a cordon toll set by the region only to be paid by the commuters. Toll revenues are redistributed by the region to commuters only, while parking fee revenues are redistributed to urban citizens. The city maximises the welfare of the inhabitants only, whereas the region maximises a weighted sum of the welfare of its urban citizens and its commuters (where the weights correspond to their relative numbers in the total population). In this setting three different solutions have been analysed:

- A centralised solution, in which the region chooses both pricing instruments simultaneously and maximises the aggregate welfare of commuters and urban citizens;
- A non-cooperative Nash equilibrium, in which each government takes the other's choice as given;
- A Stackelberg equilibrium, in which the region acts as leader and chooses its policy instrument (cordon toll) first.

The results show that an efficiency loss occurs in the policy game situations because the city overcharges for parking in order to export taxes to commuters who are outside its jurisdiction (but not unlimited because city inhabitants also pay the parking fee). The region responds by setting a toll lower than the first-best level, because it does not want to discourage commuting too much. The non-cooperative Nash and Stackelberg equilibria achieve most of the welfare improvements (respectively, 89% and 92%) when compared with the (optimal) centralised solution. The reasons for these fairly high welfare levels, given by the authors, are that both governments are assumed to maximise welfare rather than revenues, and that parking fees and cordon tolls are substitutes. Further improvements can be achieved by changing the sharing rules for tax revenue in favour of the city inhabitants, although this comes at a cost of greater inequity to commuters.

7.3 A modelling framework to study government competition

Although the literature on tax competition in transport is still relatively small, a number of cases have already been considered as we discussed in the previous section. It is important to emphasise how our work differs from this earlier work. We will deal with competition between a region and a city that differ in their objectives and instruments, similar to the case study in MC-ICAM (2004). However, we bring road capacity into the analysis as a policy variable that is available to both government levels besides the road charges that they both can set. Parking fees, in contrast, are not included because they would be indistinguishable from the road tax on the city's infrastructure in our simple network.

The set-up appears to be relevant for current transport policies. Many urban areas often experience congestion problems, and it is no longer considered straightforward (in so far as it has been) that a national government should decide how to deal with these. Decentralisation has given more powers to lower levels of government, which have more knowledge of the local situation. When local authorities decide on their policy approach, a realistic set of instruments would include capacity enlargement besides road pricing. We therefore study the interaction between a region and a city that are free to choose the capacity of the roads and road tolls, and focus on the welfare consequences of their behaviour under various game-theoretic settings.

We consider a simple serial type of road network with two links, one of which is controlled by the regional authority and the other by the city. This road network is used by three different types of drivers. *Commuters* live in the region and work in the city, and therefore use both the regional road and the infrastructure of the city. *Regional drivers* live in the region and never enter the city, and therefore only use the regional road. And *city drivers* live in the city and never use the regional road. Reverse commuting (living in the city, travelling to the region) is therefore ignored. Both roads are subject to congestion.

Commuters therefore pay both tolls when levied, while regional and city drivers only pay the toll set by their own government. The two levels of government are assumed to receive the full revenues of the tax instruments they control, but they also pay for their own (road) capacity. Each government maximises the welfare of its inhabitants.

Various settings of interest can be identified. A first one involves the global optimum, where both tolls and both capacities are set so as to maximise the aggregate surplus (in the region and city together). Next, without policy coordination, two equilibrium concepts may, in principle, be relevant: a Nash equilibrium, in which both actors take the other's choices as given, and a Stackelberg equilibrium, where a leader takes the follower's responses into account, while the follower takes the leader's action as given.

Our analysis of toll and capacity decisions considers these as the results from a sequential, two-stage, game in capacities and prices. In the first stage both governments make capacity choices, and in the second stage toll competition takes place. This appears realistic because also in practice tolls can be varied in the short run, after capacities have been set. The two-stage nature of the game gives rise to various combinations of Nash and Stackelberg games in the various stages, theoretically even including reversed leadership in the two stages. We will consider a few of these; namely, those combinations that appear more realistic.

Since we are interested in the relative efficiency of these non-cooperative situations, we compare the outcomes with the first-best optimal solution in this setting, i.e., the global optimum mentioned before. To express equilibrium welfare levels in relative terms, we will, of course, also need to specify a reference equilibrium in our numerical exercises.

7.3.1 Model formulation

We consider what is probably the simplest possible set-up to study the problem just described. The network consists of two serial links, connecting the regional (suburban) area with the centre of a city. It is assumed that the pricing and capacity choice of each link is the responsibility of a different government. In the base-case equilibrium, both links have equal capacities and zero tolls. Commuters from the region (group R_1) are assumed to enter the city, and consequently use both links. Regional drivers (R_2) and city drivers (C) only use the link in their own jurisdiction. Both governments are assumed to maximise social surplus for their inhabitants, defined as total (Marshallian) benefits minus total user costs (including time costs), minus the capacity costs.

The model contains three different demand functions (one for each group), and two average-user cost functions: c_1 (N_C , N_{R1}; cap_1) for city road 1, and c_2 (N_{R1}, N_{R2}; cap_2) for regional road 2. At any interior equilibrium, average costs for the full trip, plus tolls, should be equal to marginal benefits for each type of user[18]. While Appendix 7b will derive first-order conditions for general demand and cost functions, of unspecified functional forms, we will be using linear functions in the numerical model. The inverse demand functions D_j can then be written as:

$$D_j = d_j - a_j * N_j \qquad j = C,R_1,R_2 \qquad (1)$$

where d_j and a_j are parameters, and N_j gives traffic flow for group j.

Next, for both links i, the average social cost (c_i) consists of a free-flow cost component k_i, and a congestion cost component, which is assumed to be proportional to total road usage on that link (N_i, with $N_1 = N_C + N_{R1}$ and $N_2 = N_{R1} + N_{R2}$), and inversely related to its capacity (cap_i):

$$c_i = k_i + b_i * N_i/cap_i \qquad i = 1,2 \qquad (2)$$

where k_i and b_i are parameters.

The generalised price p_i for a link adds the toll t_i to the average cost:

$$p_i = c_i + t_i \qquad i = 1,2 \qquad (3)$$

The generalised prices p_j for the three groups are then as follows:

$$\begin{aligned} p_{R1} &= p_1 + p_2 \\ p_{R2} &= p_2 \\ p_C &= p_1 \end{aligned} \qquad (4)$$

Next, operational profits (π) for the city or the region are defined as the difference between revenues from the tolls and the net costs for road provision (capacity costs). We thus neglect other costs for the government, such as maintenance and costs involved with toll collection (or assume that these are proportional to capacity). The capacity costs are proportional to capacity (cap_i) via a fixed price per capacity unit (p_{cap}, equal for both links)[19], while the revenues are the product of the toll and traffic demand. Profit thus becomes:

$$\pi_i = t_i * N_i - cap_i * p_{cap} \qquad i = 1,2 \qquad (5)$$

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[18] Corner solutions, where the demand of at least one of the groups is reduced to zero, will not be considered.

[19] Note that the average cost function implied by (2) and (3) and the constancy of the unit price for capacity implies that our road network qualifies for the application of the Mohring-Harwitz (1962) result on exact self-financing of optimally designed and priced roads (see also below).

Total social surplus (W, the sum of surpluses in the city and the region) is our measure of welfare, and is equal to the 'variable' social surplus (the benefits B as given by the relevant area under the demand curve, minus total user costs), minus the total capacity costs:

$$W = B - N_C*c_1 - N_{R2}*c_2 - N_{R1}*(c_1+c_2) - (cap_1+ cap_2)* p_{cap} \quad (6)$$

W can be decomposed into city and regional welfare as follows:

$$W_C = B_C - N_C*c_1 + N_{R1}*t_1 - cap_1* p_{cap} \quad (7a)$$
$$W_R = B_{R1} + B_{R2} - N_{R1}*(c_1+c_2) - N_{R2}*c_2 - N_{R1}*t_1 - cap_2* p_{cap} \quad (7b)$$

Note that tolls paid by commuters (residents of the region) to make use of the city link are a transfer between jurisdictions and thus increase the welfare of the city and reduce the welfare levels of the region. All other toll payments cancel out in local welfare functions, because they constitute a transfer from local residents to the local authorities. All parameters are non-negative, and we will only consider interior equilibria, where both links are at least marginally used, and all OD pairs are at least marginally active.
The (three) user equilibrium conditions are then:

$$D_j = p_j. \qquad j = C,R_1,R_2 \quad (8)$$

Appendix 7b derives analytical expressions for toll rules and investment rules for three cases: namely, the first-best case; the case where the city optimises, taking the regional toll and capacity as given; and the case where the region optimises, taking the city's toll and capacity as given. In this section, we will proceed by presenting comparative static results for the different games under consideration. These reflect the impacts of toll and investment rules upon possible equilibria, but are of course less general than our analytical results because they pertain to an assumed set of demand and cost functions. To compensate for the latter disadvantage, sensitivity analyses will be provided in Section 7.3.4.
The insights from Appendix 7b can be summarised as follows. The first-best equilibrium involves tolls that are equal to marginal external costs and a conventional investment rule that equates marginal costs of capacity expansion to the marginal benefits. When either government sets their instruments in isolation, the investment *rule* does not change: given that the level of road use capacity is set at the efficient level. Because the levels of road use will be different than in the first-best equilibrium, the capacity *level* will, of course, be different from the first-best level. Both governments would have an incentive to set the toll above the marginal external cost. For the city this extracts additional toll revenues from regional users. For the region, this is meant to (imperfectly) internalise the congestion externality that R_1 drivers impose upon one another on the city's road, link 1. We will now turn to the simulation results to see how these forces affect the eventual equilibrium.

7.3.2 Numerical example

For the 'base case' of our numerical model, the following parameter values were chosen: a = 0.6; $d_C = d_{R2} = 140$; $d_{R1} = 280$; $k_1 = k_2 = 20$; $b_1 = b_2 = 20$; $p_{cap} = 2$; $cap_1 = 500$; and $cap_2 = 500$. The base case equilibrium leads to a reasonable demand elasticity of –0.4 for each group, at an equilibrium use of 167 of both city drivers and regional drivers, twice as many commuters, and equilibrium travel costs twice the 'free-flow' levels. The equality between equilibrium demands for groups R_2 and C was motivated by the desire to have the example symmetric in as many aspects as possible. Appendix 7c shows the detailed numerical results for the various scenarios under study. These parameter values were otherwise not motivated by any desire to represent a realistic situation. Before turning to the game equilibrium situations, we will first discuss a few benchmark situations.

Global first-best optimum

The first-best social optimum (maximum welfare) in this network involves an optimisation of both the capacity of the links and all tolls (first-best pricing requires tolling on all links of the network). The optimal road price, to be set by both governments, equals 6.32 (see Appendix 7c), bridging the gap between marginal private costs of 26.32 and marginal social costs of 32.64. In Appendix 7b we derive the first-best expression for both tolls. The first-best toll equals the marginal external (congestion) cost for both roads. Most welfare gains are realised by the region, a situation which can be explained by the large number of commuters (experiencing congestion) who live in the region (the welfare gains per initial traveller are higher for the city).

The total capacity of both roads together is about 3.4 times as high as the initial capacity. This is, of course, rather extreme. It is a direct consequence of the level of p_{cap} that we have chosen, relative to the other parameters, and could therefore easily have been avoided. We have, however, chosen this parameterisation so as to create sufficient disparity between the initial equilibrium capacities and the optimum, so that relative differences between various options can easily be observed. The zero profit result for the provision of both links confirms the Mohring and Harwitz (1962) result of optimal investment. The revenues from an optimal toll will just cover the costs of the facility provider as long as there are no economies or diseconomies of scale in facility capacity and the facility provider is investing optimally (see Appendix 7b for a sketch of a proof).

Second-best optima: one government optimises

For the evaluation of the various situations to be considered, it is useful to know the (welfare) properties of the second-best solutions where only one government charges a toll for its link and optimises its capacity, with the purpose of maximising local welfare only, while the other region does not respond and sticks to the initial choices. There are two such second-best situations. Appendix 7b shows the first-order expressions for tolls and capacity in both cases.

The second-best situation in which the *city* sets the toll and capacity so as to achieve maximum welfare for its residents (N_C) leads to a considerably higher welfare level for the city compared with the first-best situation. In contrast, the welfare of the region is decreased considerably. Total welfare is decreased when compared with the base case equilibrium, leading to a negative value for the relative efficiency indicator ω [20]. The toll is equal to 78.11, more than 12 times as high as the first-best toll. The city has an incentive to set such a high toll because the toll revenues extracted from the regional commuters (N_{R1}) increase accordingly. This is of course constrained by the fact that the fees are also paid by the city residents, but note that, initially, only 1/3 of intra-city traffic concerns city residents. Moreover, toll payments by city residents, although distorting prices in the city, in themselves only constitute transfers within the city. The number of commuters decreases significantly, as well as the welfare levels in the region. The city link is also used less intensively by city drivers compared with the base-case situation, because of the excessive toll. The first-order expression of the toll set by the city under these conditions consists of the first-best toll with a positive mark-up (see Appendix 7b). Capacity chosen by the city is considerably lower compared with optimal pricing, but the ratio capacity/demand has not changed, because the first-best rule for optimising capacity still applies.

[20] This indicator ω is defined as the difference between welfare in the situation under study and base-case welfare divided by the difference between first-best welfare and base-case welfare.

The other second-best situation is when the *region* optimises under the assumption that the city does not change capacity and toll. It appears that the demand for transport is not very different from the base-case and first-best situations. Appendix 7b shows that the region will apply a capacity rule similar to the first-best rule, which means that the capacity of link 2 will also not deviate much from optimal investment. This, and a toll that internalises congestion for groups R_1 and R_2 (the former imperfectly), will increase the welfare of the region. Since the welfare of the city remains almost constant (relative to the base-case situation), overall welfare will also increase (ω = 0.48). The higher relative efficiency is to a large extent explained by the fact that the region cannot tax city residents and hence will not raise the toll with the purpose of extracting revenues from non-inhabitants. Furthermore, it internalises part of the congestion externality in the city: namely, insofar as it is imposed by regional residents on themselves.

7.3.3 Non-cooperative game equilibria

We will now consider the numerical outcomes when governments compete in order to achieve their own objectives when choosing tolls and road capacities. Different situations will be considered, corresponding with different types of game theoretic settings. Two different plausible equilibrium concepts of a non-cooperative game can be distinguished in such a setting: a Nash equilibrium and a Stackelberg equilibrium. In a Nash equilibrium, each government takes the other's choice as given. A Stackelberg game assumes that one of the two governments acts as leader and chooses its policy instruments taking the other's response into account, while the other government responds while assuming that the leader's choice will not be affected.

The present set-up is somewhat more complicated than that which we have just described, because we model the choice of capacity and tolls as a two-stage game. The choice of capacity is made first, followed by the decision to set the toll in the second stage. As a result, different types of behaviour could be assumed for each stage (Nash versus Stackelberg), with two types of leadership (i.e. the city or the region). This leaves seven different study situations when excluding reversed leadership between stages. First we analyse the Full Nash situation, in which both prices and capacities result from a non-cooperative Nash game. Then we consider three different cases with city leadership in the first, second, or both stages, followed by the same three situations with the region as the leader.

Full Nash equilibrium

In what we will call the Full Nash equilibrium, each government takes the other's choice as given in both stages. The city government chooses capacity that is the best reply to a given capacity selected by the region, while the regional government will select capacity as its best reply to the city government's selected capacity. Given these capacity choices, tolls are set in a similar way resulting in a stable Nash equilibrium in prices and capacities. Figure 7.1 shows this graphically. The thinner lines give iso-surplus contours in the capacity-capacity space, and connect capacity combinations yielding equal local surpluses, given that a Nash price game will be played once the capacities are set. The solid contours refer to the city and represent a higher surplus when moving to the right. The dashed contours refer to the region and represent a higher surplus when moving up. Next, the thicker lines give the reaction function: the best response (in terms of capacity) given the capacity set by the other government, and given (again) that a Nash price game will be played once the capacities are set. The solid city's reaction function is therefore found as the connection between absolutely vertically-sloped points of the city's various iso-surplus functions. The region's reaction function, in a similar fashion, connects absolutely horizontally-sloped points of the region's various iso-surplus functions. Finally, the intersection of the two reaction functions then defines the Full Nash equilibrium.

Appendix 7c shows that the Nash situation results in a small (overall) welfare gain ($\omega = 0.07$) compared with the base-case equilibrium. The city again has the incentive to extract toll revenues from the non-residents (commuters), leading to excessively high tolls. Regional tolls are somewhat lower than the second-best "region" situation because congestion in the city has reduced. The capacities in both jurisdictions are adjusted more or less proportionally to equilibrium link flows compared to the first-best situation, but not exactly because capacity choice has become a strategic instrument in the game's first stage.

City leadership

When introducing strategic leadership in our game-theoretic framework, we can in fact then distinguish three different situations depending on the stage(s) in which leadership is exercised. The first is the Nash (pricing)/Stackelberg (capacity) situation; then, second, its mirror image is the Stackelberg (price)/Nash capacity situation, and the third possibility is the "Full" (both stages) Stackelberg equilibrium. Assuming that the city is the leader, prices in the first situation are set according to the properties of a Nash game (without any leadership), while the city takes account of the capacity chosen by the follower (region) when planning its own capacity level. The second situation is the opposite of the first: city leadership in setting tolls, while a first-stage Nash game characterises decisions on capacities. The last situation is a full Stackelberg solution in which both prices and capacities are set by the city, while anticipating correctly the reaction of the region for both instruments. Because there is no compelling reason why the one situation is more relevant than the other, we will consider them all, and determine in particular also whether there are large differences between them. We will coin the different games such that Nash/Stack means Nash behaviour in the short run (the second, price stage) and Stackelberg in the long run (the first, capacity stage).

For the two Nash/Stack games, the same iso-surplus contours and reaction functions are relevant as for the Full Nash game discussed earlier. When the city is the leader, it takes the reaction of the region into account (the region's reaction function is known to the city) when setting its own capacity. In fact, the city searches the highest surplus level for each point on the region's reaction function. This must be the point where the reaction function of the region and the iso-surplus curve of the city have equal slopes. This is the Nash/Stack equilibrium point (city leader) indicated in Figure 7.1. The increase in capacity of the region is very small compared with the full Nash equilibrium. The change in capacity chosen by the leader is somewhat larger. This explains the higher surplus level obtained by the leader caused by the information advantage for capacity setting only. But it is not only the leader that gains in terms of welfare; the follower also benefits from the higher level of capacity: both jurisdictions end up on a higher iso-surplus contour. However, the welfare changes are very small: given that the pricing game entails Nash competition, the nature of the capacity game appears less important for the final outcome.

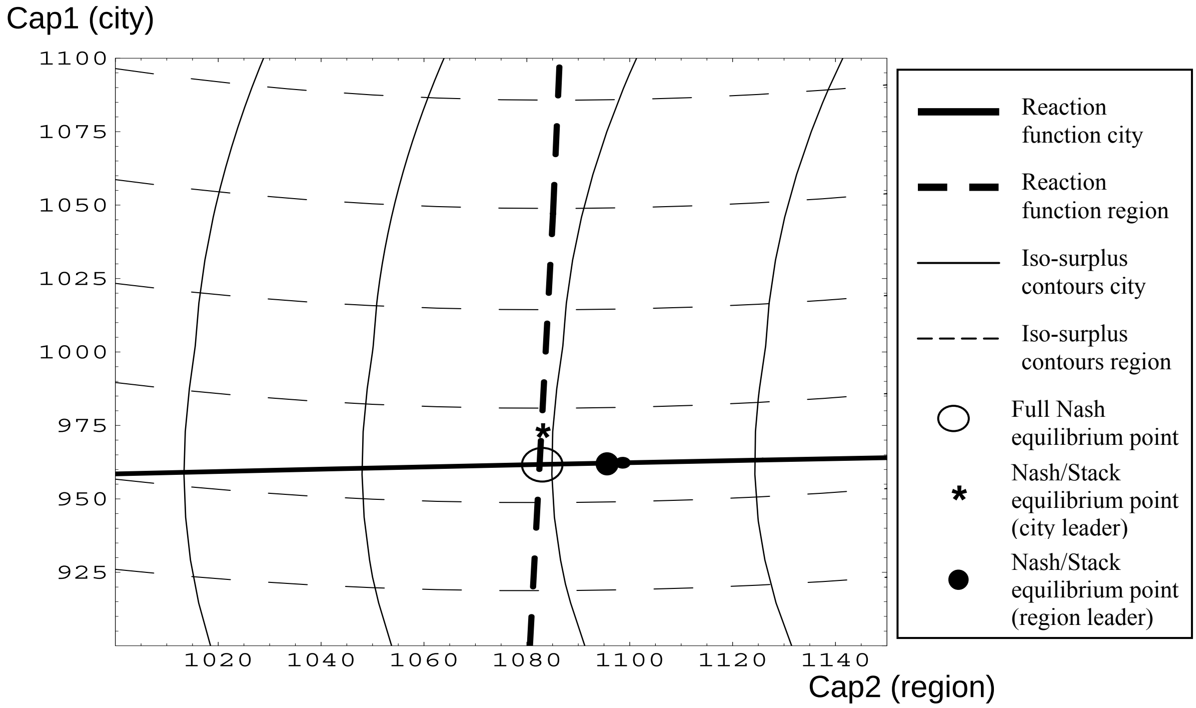


Figure 7.1: Reaction functions and iso-surplus contours for Nash pricing games

When the price stage is characterised by Stackelberg competition, another set of iso-surplus contours and (hence) reaction functions of course applies. Figure 7.2 illustrates the sets applying under city leadership in the price stage. Two equilibria are of interest: the Stack/Nash where capacities are chosen in a Nash way (where the reaction functions cross), and the Stack/Stack where both instruments are chosen in a Stackelberg way. It is now possible for the city to anticipate the toll response of the region. This leads to slightly higher city tolls than under Nash pricing, as well as slightly higher capacities, and a slightly higher welfare level for the city compared with the Nash pricing games. The welfare of the region decreases slightly in this situation compared with the various Nash-pricing equilibria. What causes the differences between Stackelberg pricing under city-leadership and Nash pricing to be so small, relatively speaking? It reflects that the region's toll response to the city's toll decision is relatively unimportant to the city. This unimportance stems from two facts. First, the region's toll is relatively small compared with the city's toll, so that changes in the region's toll (even when significant in a relative sense) are relatively unimportant to the city. Secondly, the region's toll aims to internalise the region's commuter congestion, both on the region's and the city's road. Because a change in the city's toll only affects congestion for some of the region's travellers, and only for a part of their trip, also relative changes of the region's toll in response to city toll changes will be limited.

Similar to the previous Stackelberg capacity game (with Nash prices), the city seeks a point on the reaction line of the region with slopes equal to its own iso-surplus curve. This is the Stack/Stack equilibrium point in Figure 7.2. The Stack/Nash equilibrium is again located at the intersection of the reaction functions.

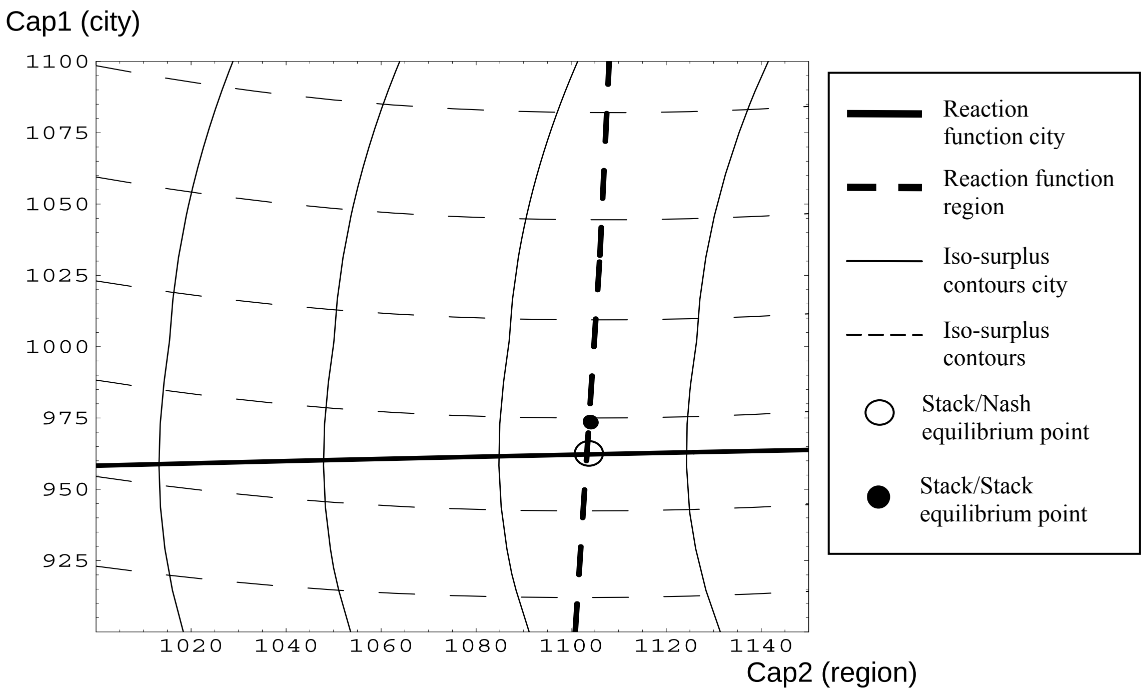


Figure 7.2: Reaction functions and iso-surplus contours for Stackelberg pricing games (city leadership)

Region leadership

Region leadership can also assume three forms. The earlier Figure 7.1 already illustrated the equilibrium situations with Nash pricing behaviour. The equilibrium outcome with the region as leader in the capacity game is therefore shown in this same figure (Nash/Stack point, region leader). It can be verified in Figure 7.1, that both jurisdictions would prefer the other to lead in a Stackelberg capacity game, when followed by a Nash price game. Such seemingly counterintuitive results are not that rare in game theory (see Dowrick, 1986). Note that both jurisdictions prefer to lead in a Stack/Nash game when compared with Nash/Nash.

While the differences between equilibria with Stackelberg leadership in the capacity stage and Nash in the pricing stage terms of capacity are very small, price leadership for the region does change outcomes. When setting its own toll, the region takes into account the incentive of the city to adapt its own toll. This leads to a regional toll that is around three times the toll under other games. The city toll is somewhat lower. As a consequence, commuters are less inclined to travel, leading to less pressure on road space in the city. Capacity chosen by the city is therefore lower than in the other non-cooperative game situations, and that of the region is slightly higher. The main reason why the region, when leading the price stage, increases its toll is that, by doing so, it can discourage its commuters from travelling in the city and, hence, 'losing' toll revenues to the other government. Again, the nature of the game in the capacity stage is less important for the eventual outcome as soon as we know that the region leads the price game. The Stack/Stack and Stack/Nash equilibrium points are relatively close in Figure 7.3.

Therefore, whereas price leadership of the city leads to only small changes compared with Nash price behaviour, the differences are bigger when leadership of the region is at stake. The explanation mirrors the one given earlier. The relatively high toll levels in the city, and the direct losses for the region stemming from this, make it worthwhile for the region to adapt their own toll with the purpose of affecting the city's toll.

These situations are shown in Figure 7.3. The reaction functions and surplus contours are again different from Figures 7.1 and 7.2. Surplus levels are higher for the region and lower for the city than in Figure 7.2. Price leadership may be attractive to the region, but it is not beneficial for overall welfare, given the negative value for ω mentioned in Appendix 7c. The combination of high toll levels with relatively small levels of capacity does not contribute to high welfare levels.

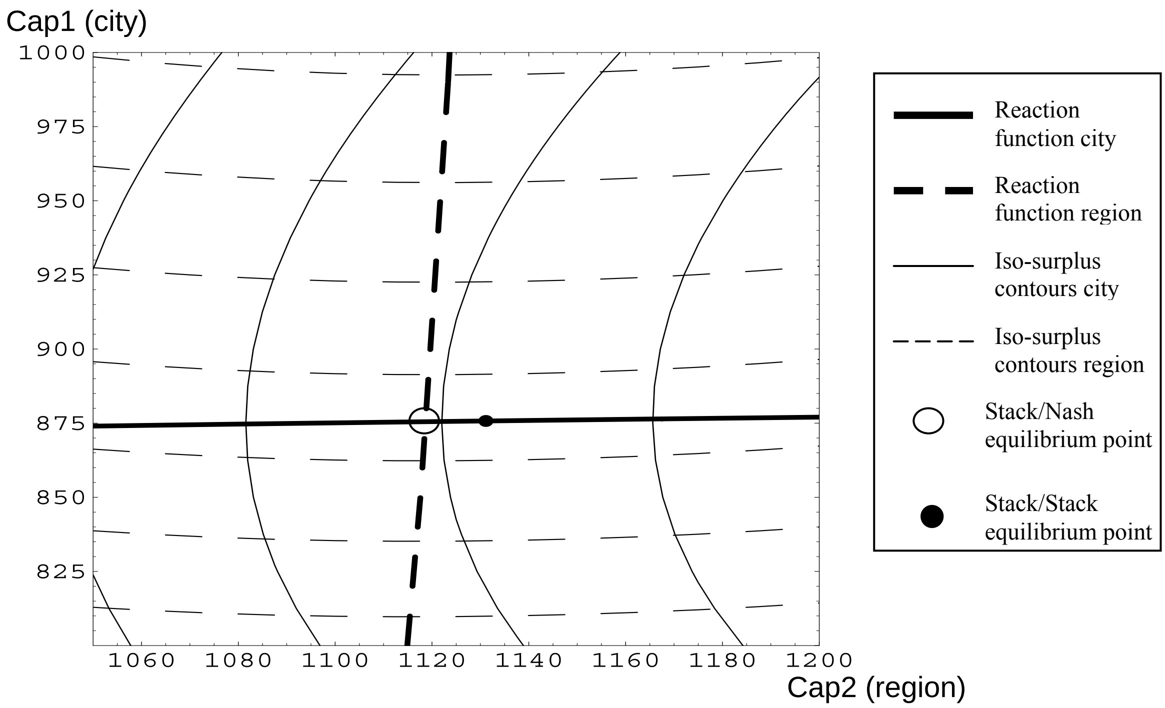


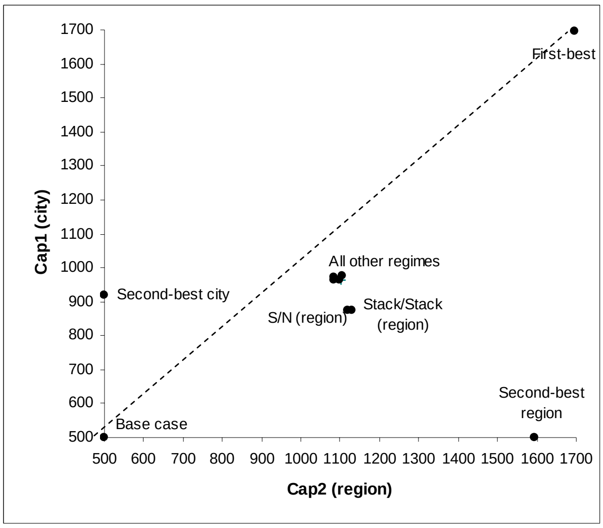
Figure 7.3: Reaction functions and iso-surplus contours for Stackelberg pricing games (region leadership)

Summary of the previous findings

Figure 7.4 illustrates the differences in capacities (left panel) and tolls for the different scenarios in our numerical example. While the assumed symmetry in the numerical example leads to identical toll levels and capacity in the first-best equilibrium, as well as in the base-case, the figure shows that all other regimes produce asymmetric outcomes. Independent of the type of game, we find that in the game equilibria, capacities are below first-best levels and tolls are above first-best levels, while the region has a higher capacity and a lower toll than the city. The interpretation is as given before. Next, the differences between the game theoretic equilibria are relatively small. More precisely, there are two clusters of equilibria: one cluster in which the region leads in the price stage, and one cluster that encompasses all other regimes. The differences within the clusters are so small that the dots in Figure 7.4 cannot even be distinguished graphically. But also the two clusters are relatively close, compared to the first-best choices of tolls and capacities. This suggests that the main issue is not which exact type of game is played between the two actors, but much more whether there is cooperation (leading to first-best) or competition between governments, where of secondary importance is the question who is leading in the price stage (if there is a leader). Leadership in the capacity stage is nearly without consequences in our numerical model.

The previous results show that competition between two different governments, in this setting, may not necessarily improve the welfare of society compared with a reasonably realistic initial situation, and, even if it does, the gains may be relatively small. The results depend heavily on the asymmetry that commuters should pay a toll levied by the city; while the opposite situation does not occur, this gives the city a tax-exporting instrument. The

difference between both second-best situations illustrates this. In the non-cooperative game situations too, we find that the city has an incentive to set excessive tolls.
We find that Stackelberg leadership in one or both instruments improves the welfare of the leader when compared with a game with Nash properties. Being the leader in the toll stage is more important than in the capacity game. Under Nash prices, a jurisdiction may in fact actually prefer the other government to lead in the capacity game, rather than leading themselves. But leading in the price stage may also be more important to one party than to the other. Factors that are of influence here are the Nash tolls set by the other government (the higher this toll, the more relevant it is to affect it), and the sensitivity of the other government's toll to one's own toll (the stronger this sensitivity, the more relevant it is to affect it).



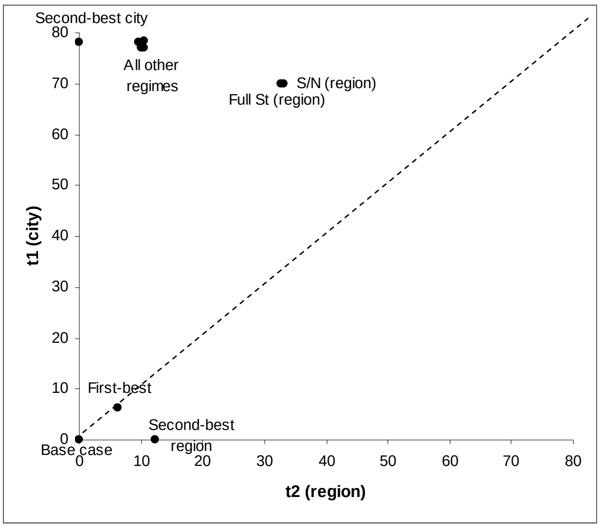


Figure 7.4: Overview of equilibria capacity levels (left panel) and tolls (right panel) for the different regimes

7.3.4 Sensitivity analysis

The results shown above are, of course, likely to change with the parameter values chosen. In order to consider the robustness of our results, we have analysed two types of effects. First, we will look at the effect of changing the demand elasticity. While undoubtedly affecting the absolute impacts of different schemes, it is also of interest to see whether it affects their relative performance. Next, the impact of changes in p_{cap} will be considered. This is a means of controlling for the relative importance of congestion management, as opposed to strategic considerations, in the setting of tolls. We will summarise our findings by reporting the impacts on our efficiency indicator ω for changing the demand elasticity, and on a slightly different welfare indicator (the share of the optimal welfare) when changing the price of capacity.

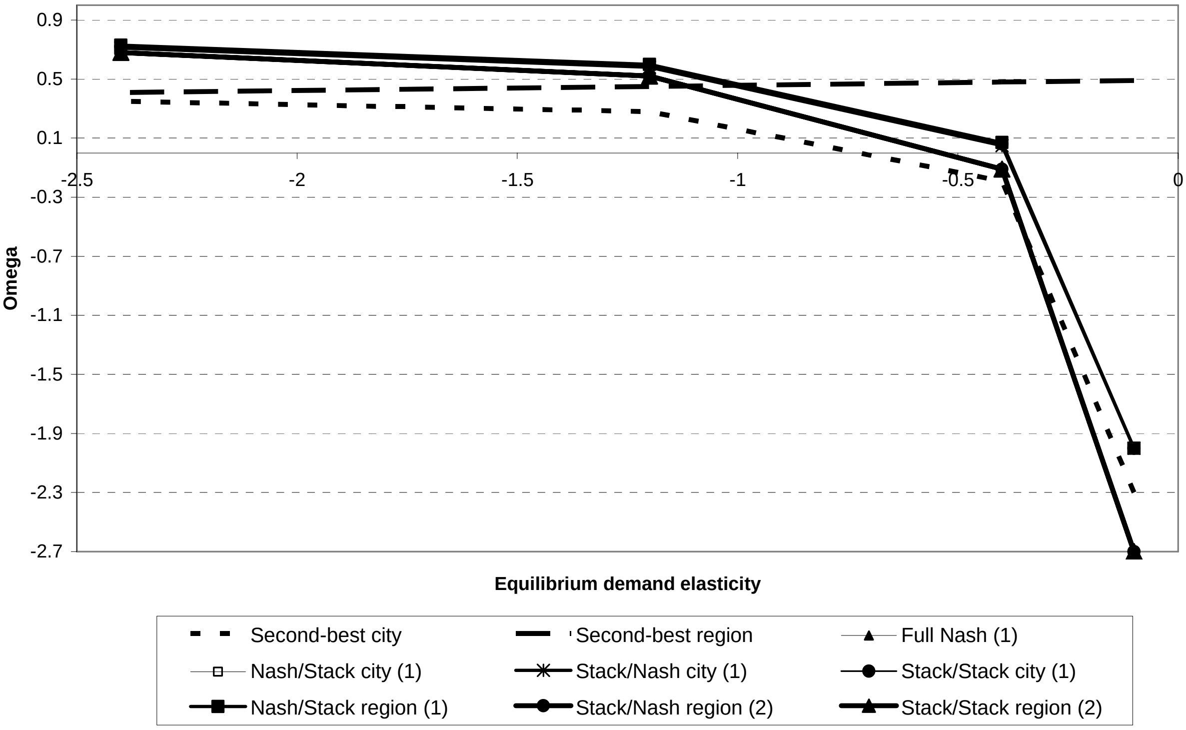


Figure 7.5: Indexes of relative welfare improvement with varying demand elasticities

Varying demand elasticity

Figure 7.5 shows the results in terms of ω when changing both the equilibrium demand elasticities from relatively elastic (left-hand side) to relatively inelastic (right-hand side) (by simultaneously changing the parameter values of a and d, for all demand functions, such that the same base equilibrium is obtained for every elasticity). While showing 9 indicators ω, only four clusters can be distinguished visually. This reflects that the relative closeness of the Full Nash, Nash/Stack city, Stack/Stack city, Stack/Nash city and Nash/Stack region remains. These cases all come under the heading "Group 1". The same holds for closeness within "Group 2", comprising the Stack/Stack region and Stack/Nash region. These similarities, already identified for our base parametrisation, are therefore robust and do not depend on the assumed demand elasticity. However, all schemes become less efficient when demand becomes less elastic. The "Second-best city" shows why: the city has a greater incentive to exploit its market power when demand becomes less elastic. The relative importance of the socially inefficient motive for tolling (revenue extraction from regional drivers by the city) rises compared with the socially-efficient motive (congestion internalisation). Only the "second-best region", where the city's toll is fixed at zero, does not suffer from this inefficiency, as shown by the course of the associated curve.

Varying the price of road capacity

Changing prices of road capacity (p_{cap}), our welfare indicator ω unfortunately becomes less insightful. The reason is that, when the price of capacity increases (when moving to the right), the difference between welfare in the optimal situation and the base case becomes rapidly smaller, because welfare levels in the base case remain relatively constant. It is then not so much the welfare level of the situation under study that determines the score of the welfare indicator, but rather the small number of the denominator. All ω's, consequently, reflect the changing difference between first-best and equilibrium rather the welfare in the region under consideration. Therefore, we simply decided to use the welfare of the situation under study as a fraction of the first-best welfare level.

Figure 7.6 shows that, when the price of road capacity changes, the performance of all scenarios remains rather constant. About 80% of the first-best welfare level is achieved in the various scenarios, with the second-best region situation performing relatively best for all prices of road capacity. With lower prices of capacity, congestion becomes more easily solved through capacity adjustments. The region reacts accordingly by setting a lower toll. The distortive impact of tolling by the city (caused by the city's extraction of toll revenues from regional drivers) remains important, but the city's toll levels will not change much. As a result, welfare fractions remain fairly unchanged. Note that the same two clusters of regimes emerge as in Figure 7.4.

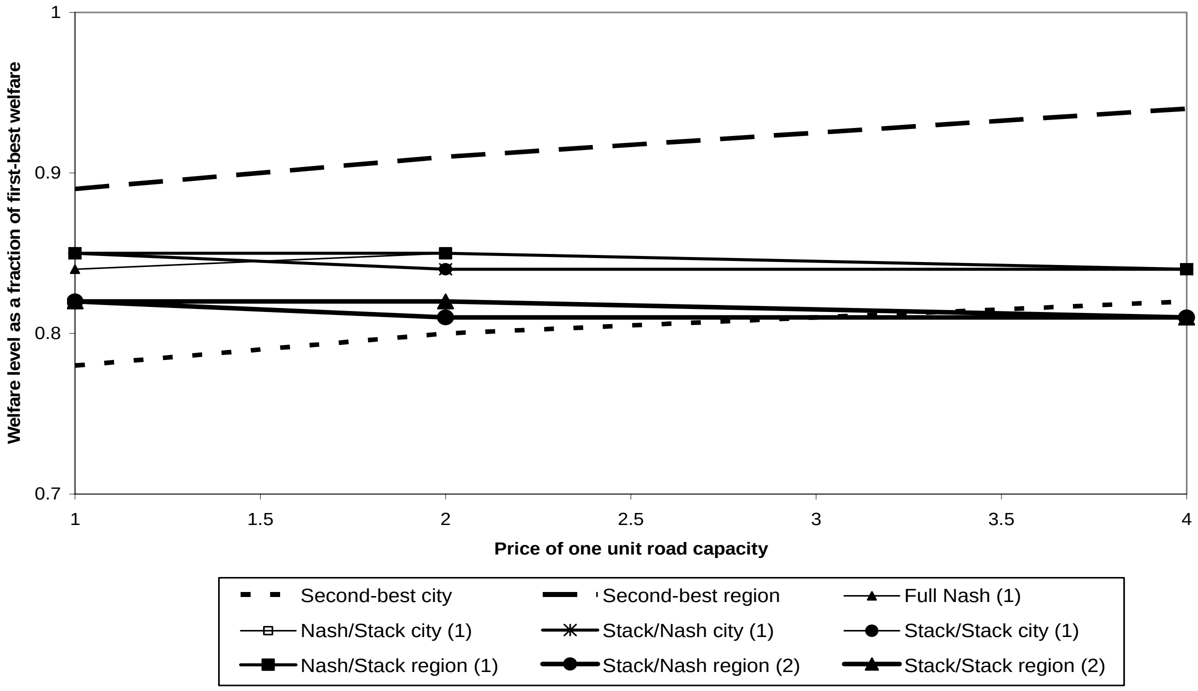


Figure 7.6: Welfare level for various situations as a fraction of first-best situation with varying prices of road capacity

7.4 Conclusions

In this study we have analysed policy interactions between an urban and a regional government with different objectives (namely maximisation of their own citizens' welfare) and two policy instruments (toll and capacity) available. We considered a simple serial network with two roads. This setting is relevant in practice since many cities experience congestion problems, while it is often commuters residing in a region that suffer from congestion and who would pay city tolls. Using a simulation model, we investigated the welfare consequences of the various regimes that result when both governments compete, and take sequential decisions on prices and capacities with the aim to maximise their local social surplus. The first-best situation is a useful benchmark, and can be regarded as a situation of optimal instrument choice by a central government, or as the result from policy coordination.

Our analysis gives some useful insights into the joint pricing-capacity decisions with two governments involved. Competition between governments may not be very beneficial to overall welfare in society compared with one central government. It appears that the tendency of tax exporting is very strong in this setting where commuters have to pay road tolls set by the city government. The incentive to set excessive tolls is present in all scenarios where the city has control over this instrument.

We find that Stackelberg leadership in one or both instruments improves the welfare of the leader when compared with a game with Nash properties. Being the leader in the toll stage is more important than in the capacity game. Under Nash prices, a jurisdiction may in fact actually prefer the other government to lead in the capacity stage, rather than leading themselves. But leading in the price stage may also be more important to the one party than to the other. Factors that are of influence here are the Nash tolls set by the other government (the higher this toll, the more relevant it is to affect it), and the sensitivity of the other government's toll to one's own toll (the stronger this sensitivity, the more relevant it is to affect it).

We found that, at least in our numerical model, the relative performance of the various game regimes is rather close for a variety of parameter ranges. More precisely, there are two clusters of equilibria: one cluster in which the region leads in the price stage, and one cluster that encompasses all other game equilibria. This suggests that the main issue is not which exact type of game is played between the two actors, but much more whether there is cooperation (leading to first-best) or competition between governments, where of secondary importance is the question who is leading in the price stage (if there is a leader). Leadership in the capacity stage is nearly without consequences in our numerical model.

The performance for most game situations improves when demand becomes more elastic. The city then has less incentive to exploit its market power. The relative importance of the socially-inefficient motive for tolling (revenue extraction from regional drivers by the city) decreases compared with the socially-efficient motive (congestion internalisation). Only the "second-best region", where the city's toll is fixed at zero, does not suffer from the increased inefficiency when demand becomes more inelastic. The similarities between the different groups are robust and do not depend on the assumed demand elasticity. When the price of road investment changes, the performance relative to the optimal situation remains more or less equal for all cases.

Although it may seem attractive to national governments to deregulate and give powers to lower levels of government since they know local situations best, the outcomes of interaction may not always be promising. In our example, compared to the selected unpriced benchmark equilibrium, overall welfare is not helped very much, and in some cases may even decrease.

Toll regulation, although not considered, may seriously be considered as a useful tool to control one of the jurisdictions and improve welfare levels. This is only one among many issues for further research. Another issue that seems relevant in this context is empirical research on the welfare effects of tax competition. This is only a simple illustrative numerical example, but it remains to be seen whether the costs of non-cooperative behaviour are substantial, in other plausible settings.

Appendix 7A

List of Symbols

N	Total number of road users
N_1	Number of road users on the city link
N_2	Number of road users on the regional link
N_C	Number of drivers only using the city link
N_{R1}	Number of commuters (using both links by going from region to city)
N_{R2}	Number of drivers only using the regional link
$D_j(N_j)$	Inverse demand function for group $j = \{C,R_1,R_2\}$
c_1	Average social (=marginal private) costs on the city link
c_2	Average social (=marginal private) costs on the regional link
cap_1	Capacity of the city link
cap_2	Capacity of the regional link
W	Total welfare
W_1	Welfare of city
W_2	Welfare of region
B_j	Benefits for group $j = \{C,R_1,R_2\}$
π_1	Profits for the city
π_2	Profits for the region
p_j	Generalised price for group $j = \{C,R_1,R_2\}$
t_1	Toll on city link
t_2	Toll on regional link
p_{cap}	Price of one unit road capacity
k_i	Average free-flow user cost on route i ($k_i > 0$)
b_i	constant
ω	Index of relative welfare improvement
a_j	Absolute value of the slope of the demand curve for group $j = \{C,R_1,R_2\}$ ($a_j > 0$)
d_j	Intersection of the demand curve with the vertical axis for group $j = \{C,R_1,R_2\}$ ($d_j > 0$)

Appendix 7B

Derivation of first-order conditions for toll and capacity for the first-best situation and two second-best situations

This appendix derives analytical expressions for toll rules and investment rules for three cases: first-best (Section B.2.1), for the city when taking the regional toll and capacity as given (in Section B.2.2), and for the region when taking the city's toll and capacity as given (in Section B.2.3).

B.2.1 First-best situation

The first-best toll and capacity can be found by solving the following Lagrangian:

$$L = \int_0^{N_C} D_C(n)dn + \int_0^{N_{R1}} D_{R1}(n)dn + \int_0^{N_{R2}} D_{R2}(n)dn - N_C * c_1 - N_{R1} * (c_1 + c_2) - N_{R2} * c_2 \\ - (cap_1 + cap_2) * p_{cap} + \lambda_C (p_C - D_C) + \lambda_{R1}(p_{R1} - D_{R1}) + \lambda_{R2}(p_{R2} - D_{R2}) \quad \text{(A1)}$$

We determine the first-order conditions with respect to $N_C, N_{R1}, N_{R2}, cap_1, cap_2, t_1, t_2, \lambda_C, \lambda_{R1}$ and λ_{R2}:

$$\frac{\partial L}{\partial N_C} = D_C - c_1 - (N_C + N_{R1})\frac{\partial c_1}{\partial N_C} + \lambda_C\left(\frac{\partial c_1}{\partial N_C} - \frac{\partial D_C}{\partial N_C}\right) + \lambda_{R1}\frac{\partial c_1}{\partial N_C} = 0 \quad \text{(A2a)}$$

$$\frac{\partial L}{\partial N_{R1}} = D_{R1} - (c_1 + c_2) - (N_{R1} + N_C)\frac{\partial c_1}{\partial N_{R1}} - (N_{R1} + N_{R2})\frac{\partial c_2}{\partial N_{R1}} + \lambda_C \frac{\partial c_1}{\partial N_{R1}} \\ + \lambda_{R1}\left(\frac{\partial c_1}{\partial N_{R1}} + \frac{\partial c_2}{\partial N_{R1}} - \frac{\partial D_{R1}}{\partial N_{R1}}\right) + \lambda_{R2}\frac{\partial c_2}{\partial N_{R1}} = 0 \quad \text{(A2b)}$$

$$\frac{\partial L}{\partial N_{R2}} = D_{R2} - c_2 - (N_{R1} + N_{R2})\frac{\partial c_2}{\partial N_{R2}} + \lambda_{R2}\left(\frac{\partial c_2}{\partial N_{R2}} - \frac{\partial D_{R2}}{\partial N_{R2}}\right) + \lambda_{R1}\frac{\partial c_2}{\partial N_{R2}} = 0 \quad \text{(A2c)}$$

$$\frac{\partial L}{\partial t_1} = \lambda_c + \lambda_{R1} = 0 \quad \text{(A2d)}$$

$$\frac{\partial L}{\partial t_2} = \lambda_{R1} + \lambda_{R2} = 0 \quad \text{(A2e)}$$

$$\frac{\partial L}{\partial cap_1} = -N_C\frac{\partial c_1}{\partial cap_1} - N_{R1}\frac{\partial c_1}{\partial cap_1} - p_{cap} + \lambda_C\frac{\partial c_1}{\partial cap_1} + \lambda_{R1}\frac{\partial c_1}{\partial cap_1} = 0 \quad \text{(A2f)}$$

$$\frac{\partial L}{\partial cap_2} = -N_{R2}\frac{\partial c_2}{\partial cap_2} - N_{R1}\frac{\partial c_2}{\partial cap_2} - p_{cap} + \lambda_{R2}\frac{\partial c_2}{\partial cap_2} + \lambda_{R1}\frac{\partial c_2}{\partial cap_2} = 0 \quad \text{(A2g)}$$

$$\frac{\partial L}{\partial \lambda_C} = c_1 + t_1 - D_C = 0 \quad \text{(A2h)}$$

$$\frac{\partial L}{\partial \lambda_{R1}} = c_1 + t_1 + c_2 + t_2 - D_{R1} = 0 \quad \text{(A2i)}$$

$$\frac{\partial L}{\partial \lambda_{R2}} = c_2 + t_2 - D_{R2} = 0 \quad \text{(A2j)}$$

We can eliminate the $\lambda \frac{\partial c}{\partial N}$ terms in (A2a)-(A2c). Defining link-flows N_1=N_C + N_{R1}, and N_2=N_{R1} + N_{R2}. This leaves:

$$t_1 = N_1 \frac{\partial c_1}{\partial N_1} + \lambda_C \frac{\partial D_C}{\partial N_C} \quad \text{(A3a)}$$

$$t_1 + t_2 = N_1 \frac{\partial c_1}{\partial N_1} + N_2 \frac{\partial c_2}{\partial N_2} + \lambda_{R1} \frac{\partial D_{R1}}{\partial N_{R1}} \quad \text{(A3b)}$$

$$t_2 = N_2 \frac{\partial c_2}{\partial N_2} + \lambda_{R2} \frac{\partial D_{R2}}{\partial N_{R2}} \quad \text{(A3c)}$$

$$\Rightarrow \lambda_C \frac{\partial D_C}{\partial N_C} + \lambda_{R2} \frac{\partial D_{R2}}{\partial N_{R2}} - \lambda_{R1} \frac{\partial D_{R1}}{\partial N_{R1}} = 0 \quad \text{(A3d)}$$

Since we had (A2d) and (A2e), we find that $\lambda_C = \lambda_{R1} = \lambda_{R2} = 0$.

This gives us the following first-best conditions for the optimal tolls:

$$t_1 = N_1 \frac{\partial c_1}{\partial N_1} \quad \text{(A4a)}$$

$$t_2 = N_2 \frac{\partial c_2}{\partial N_2} \quad \text{(A4b)}$$

Both optimal tolls equal marginal external (congestion) costs on both links, as expected.
The first order conditions for capacity are as follows (substituting A2d) and (A2e) in (A2f) and (A2g)):

$$- N_1 \frac{\partial c_1}{\partial cap_1} = p_{cap} \quad \text{(A4c)}$$

$$- N_2 \frac{\partial c_2}{\partial cap_2} = p_{cap} \quad \text{(A4d)}$$

These are again familiar first-best results, equating marginal cost of capacity expansion to marginal benefits on both routes. Because $N \frac{\partial c}{\partial N} = -cap \frac{\partial c}{\partial cap}$, exact self-financing with tax rules (A4a and A4b) and investment rules (A4c and A4d) is easily established, confirming applicability of the conventional Mohring-Harwitz result.

B.2.2 Second-best: city optimises

The appropriate Lagrangian now reads as follows:

$$L = \int_0^{N_C} D_C(n)dn - N_C * c_1 + N_{R1} * t_1 - cap_1 * p_{cap} + \lambda_C\left(p_C - D_C\right) + \lambda_{R1}\left(p_{R1} - D_{R1}\right) + \lambda_{R2}\left(p_{R2} - D_{R2}\right) \tag{A5a}$$

We determine the first-order conditions with respect to $N_C, N_{R1}, N_{R2}, cap_1, t_1, \lambda_C, \lambda_{R1}$ and λ_{R2}:

$$\frac{\partial L}{\partial N_C} = D_C - c_1 - N_C \frac{\partial c_1}{\partial N_C} + \lambda_C\left(\frac{\partial c_1}{\partial N_C} - \frac{\partial D_C}{\partial N_C}\right) + \lambda_{R1}\frac{\partial c_1}{\partial N_C} = 0 \tag{A5b}$$

$$\frac{\partial L}{\partial N_{R1}} = -N_C \frac{\partial c_1}{\partial N_{R1}} + t_1 + \lambda_C \frac{\partial c_1}{\partial N_{R1}} + \lambda_{R1}\left(\frac{\partial c_1}{\partial N_{R1}} + \frac{\partial c_2}{\partial N_{R1}} - \frac{\partial D_{R1}}{\partial N_{R1}}\right) + \lambda_{R2}\frac{\partial c_2}{\partial N_{R1}} = 0 \tag{A5c}$$

$$\frac{\partial L}{\partial N_{R2}} = \lambda_{R2}\left(\frac{\partial c_2}{\partial N_{R2}} - \frac{\partial D_{R2}}{\partial N_{R2}}\right) + \lambda_{R1}\frac{\partial c_2}{\partial N_{R2}} = 0 \tag{A5d}$$

$$\frac{\partial L}{\partial t_1} = N_{R1} + \lambda_c + \lambda_{R1} = 0 \tag{A5e}$$

$$\frac{\partial L}{\partial cap_1} = -N_C \frac{\partial c_1}{\partial cap_1} - p_{cap} + (\lambda_C + \lambda_{R1})\frac{\partial c_1}{\partial cap_1} = 0 \tag{A5f}$$

$$\frac{\partial L}{\partial \lambda_C} = c_1 + t_1 - D_C = 0 \tag{A5g}$$

$$\frac{\partial L}{\partial \lambda_{R1}} = c_1 + t_1 + c_2 + t_2 - D_{R1} = 0 \tag{A5h}$$

$$\frac{\partial L}{\partial \lambda_{R2}} = c_2 + t_2 - D_{R2} = 0 \tag{A5i}$$

The first-order condition for capacity can relatively easy be derived by substituting (A5e) in (A5f):

$$-(N_C + N_{R1})\frac{\partial c_1}{\partial cap_1} = p_{cap} \tag{A6a}$$

This is equal to the first-best rule for capacity.

The derivation of the first-best expression for the toll set by the city is more tedious. Therefore, we only present the resulting expression:

$$t_1 = N_1 \frac{\partial c_1}{\partial N_1} + \frac{\frac{\partial D_C}{\partial N_C}\left(-\frac{\partial D_{R1}}{\partial N_{R1}} * \frac{\partial D_{R2}}{\partial N_{R2}} + \frac{\partial c_2}{\partial N_2} * \left(\frac{\partial D_{R1}}{\partial N_{R1}} + \frac{\partial D_{R2}}{\partial N_{R2}}\right)\right) N_{R1}}{\left(\frac{\partial D_C}{\partial N_C} + \frac{\partial D_{R1}}{\partial N_{R1}}\right)\frac{\partial D_{R2}}{\partial N_{R2}} - \frac{\partial c_2}{\partial N_2}\left(\frac{\partial D_C}{\partial N_C} + \frac{\partial D_{R1}}{\partial N_{R1}} + \frac{\partial D_{R2}}{\partial N_{R2}}\right)} \tag{A6b}$$

The first term repeats the first-best expression and is equal to the marginal external congestion cost. But the city will raise the toll beyond this level. The term is the result of the city government compromising between two toll rules: the marginal external costs, which would be optimal for the own citizens when driving in isolation; and the marginal external costs plus a demand-related monopolistic mark-up, which would be optimal if only regional drivers used the city's infrastructure. The second term in (A6b) is so complex because the demand by group R_1 depends, in part, also on cost and demand elasticity in the region. The second term is namely positive (as long as demands are downward sloping).

B.2.3 Second-best; region optimises

The appropriate Lagrangian now reads as follows:

$$\begin{aligned} L = & \int_0^{N_{R1}} D_{R1}(n)dn + \int_0^{N_{R2}} D_{R2}(n)dn - N_{R1} * c_1 - N_{R1} * c_2 - N_{R2} * c_2 - N_{R1} * t_1 \\ & - cap_2 * p_{cap} + \lambda_C(p_C - D_C) + \lambda_{R1}(p_{R1} - D_{R1}) + \lambda_{R2}(p_{R2} - D_{R2}) \end{aligned} \tag{A7a}$$

We determine the first-order conditions with respect to $N_C, N_{R1}, N_{R2}, cap_2, t_2, \lambda_C, \lambda_{R1}$ and λ_{R2}:

$$\frac{\partial L}{\partial N_C} = -N_{R1}\frac{\partial c_1}{\partial N_C} + \lambda_C\left(\frac{\partial c_1}{\partial N_C} - \frac{\partial D_C}{\partial N_C}\right) + \lambda_{R1}\frac{\partial c_1}{\partial N_C} = 0 \tag{A7b}$$

$$\begin{aligned} \frac{\partial L}{\partial N_{R1}} = & D_{R1} - c_1 - N_{R1}\frac{\partial c_1}{\partial N_{R1}} - c_2 - (N_{R1} + N_{R2})\frac{\partial c_2}{\partial N_{R1}} - t_1 + \lambda_C \frac{\partial c_1}{\partial N_{R1}} \\ & + \lambda_{R1}\left(\frac{\partial c_1}{\partial N_{R1}} + \frac{\partial c_2}{\partial N_{R1}} - \frac{\partial D_{R1}}{\partial N_{R1}}\right) + \lambda_{R2}\frac{\partial c_2}{\partial N_{R1}} = 0 \end{aligned} \tag{A7c}$$

$$\frac{\partial L}{\partial N_{R2}} = D_{R2} - c_2 - (N_{R1} + N_{R2})\frac{\partial c_2}{\partial N_{R2}} + \lambda_{R2}\left(\frac{\partial c_2}{\partial N_{R2}} - \frac{\partial D_{R2}}{\partial N_{R2}}\right) + \lambda_{R1}\frac{\partial c_2}{\partial N_{R2}} = 0 \tag{A7d}$$

$$\frac{\partial L}{\partial t_2} = \lambda_{R2} + \lambda_{R1} = 0 \tag{A7e}$$

$$\frac{\partial L}{\partial cap_2} = -(N_{R1} + N_{R2})\frac{\partial c_2}{\partial cap_2} - p_{cap} + (\lambda_{R1} + \lambda_{R2})\frac{\partial c_2}{\partial cap_2} = 0 \tag{A7f}$$

$$\frac{\partial L}{\partial \lambda_C} = c_1 + t_1 - D_C = 0 \tag{A7g}$$

$$\frac{\partial L}{\partial \lambda_{R1}} = c_1 + t_1 + c_2 + t_2 - D_{R1} = 0 \tag{A7h}$$

$$\frac{\partial L}{\partial \lambda_{R2}} = c_2 + t_2 - D_{R2} = 0 \tag{A7i}$$

The first order condition for capacity is, again, easy to derive and again equals the first-best rule for capacity (substituting (A7e) in (A7f)):

$$-N_2 \frac{\partial c_2}{\partial cap_2} = p_{cap}$$

The derivation of the first-best expression for the toll set by the region is more tedious. Therefore, we only present the resulting expression:

$$t_2 = N_2 \frac{\partial c_2}{\partial N_{R1}} + \frac{-N_{R1} * \frac{\partial c_1}{\partial N_1} * \frac{\partial D_C}{\partial N_C} * \frac{\partial D_{R2}}{\partial N_{R2}}}{-\frac{\partial D_C}{\partial N_C}\left(\frac{\partial D_{R1}}{\partial N_{R1}} + \frac{\partial D_{R2}}{\partial N_{R2}}\right) + \frac{\partial c_1}{\partial N_1}\left(\frac{\partial D_C}{\partial N_C} + \frac{\partial D_{R1}}{\partial N_{R1}} + \frac{\partial D_{R2}}{\partial N_{R2}}\right)}$$

The first term is again equal to the marginal external congestion costs on the tolled road. The second term is positive. It reflects the region's attempt to also internalise the congestion externality that regional commuters impose upon one another on the city's road, link 1, as given by the first two terms in the numerator. The correction term captures substitution effects that will make this attempt less effective than it would be if link 1 was used by regional drivers alone.

Appendix 7C

Numerical results

The following table presents the numerical results for various scenarios relative to the first-best outcomes.

Scenario		N_C	N_{R1}	N_{R2}	cap_1	cap_2	W	W_C	W_R	t_1	t_2	ω
First-best		179	358	179	1697	1697	57621	9603	48018	6.32	6.32	1
Base equilibrium		0.93	0.93	0.93	0.29	0.29	0.83	0.76	0.85	0	0	-
Second-best	**City optimises**	0.33	0.65	0.97	0.54	0.29	0.80	2.29	0.50	12.36	0	-0.19
	Region optimises	0.93	0.94	0.94	0.29	0.94	0.91	0.76	0.94	0	1.96	0.48
Full Nash		0.34	0.65	0.96	0.57	0.64	0.85	2.28	0.56	12.18	1.55	0.07
City leader	Nash prices, Stackelberg capacities	0.34	0.65	0.96	0.57	0.64	0.84	2.28	0.56	12.18	1.53	0.07
	Stackelberg prices, Nash capacities	0.33	0.65	0.96	0.57	0.65	0.84	2.28	0.55	12.34	1.52	0.05
	Full Stackelberg	0.33	0.65	0.96	0.57	0.65	0.84	2.28	0.55	12.32	1.52	0.06
Region leader	Nash prices, Stackelberg capacities	0.34	0.65	0.96	0.57	0.65	0.85	2.28	0.56	12.18	1.53	0.07
	Stackelberg prices, Nash capacities	0.41	0.58	0.75	0.52	0.66	0.81	2.03	0.57	11.04	5.19	-0.11
	Full Stackelberg	0.41	0.58	0.75	0.52	0.67	0.82	2.03	0.57	11.04	5.19	-0.11

Part III: Acceptability of transport pricing

Chapter 8

Acceptance of road pricing and revenue use

8.1 Introduction

Road transport is known to generate considerable external costs, in particular in the form of congestion, noise and emissions of pollutants. Economists have often advocated that these costs should be properly reflected in prices, otherwise over-consumption of road transport will generally result. Chapter 2 has shown that, according to standard welfare economic theory, prices should equate marginal social cost throughout the economy to obtain maximum efficiency. However, other (second-best) pricing measures may also lead to considerable welfare benefits. For example, applied congestion pricing schemes may not fully reflect all social costs of the trips involved, but may lead to considerable congestion reductions and overall welfare gains to society. Traditional forms of pricing policies in road transport, such as vehicle taxes, will often be too crude to achieve anything near the welfare gains that a more targeted and refined system of road pricing would yield.

Despite the transport economists' preference for more refined road pricing, it is only rarely implemented in practice. Apparently, the implementation of congestion pricing (let alone marginal cost-based pricing) is not as straightforward as it may seem after calculating the welfare gains. Indeed, significant barriers can be identified that may prevent a smooth and easy implementation of pricing policing. As a result, all sorts of constraints can be identified that prevent a regulator from charging the prices that it ideally would like to set. This chapter discusses these barriers and pays specific attention to one of the most relevant constraints nowadays: that of public acceptance.

Congestion pricing schemes have the double consequence of discouraging transport use, at least at certain times on certain parts of the network, and of transferring cash from private persons to other (often public) parties. The latter fact is particularly likely to be a major impediment to its public and hence political acceptability. Therefore, to render pricing schemes politically and publicly acceptable, it is probably required to 'recycle' the revenues generated, in such a way that most population subgroups are at least equally well off. Such redistribution schemes appear by no means unfeasible, but in the process of redistribution large parts of the initial efficiency gain may in important cases be lost (e.g., if there is a 'non-zero shadow price of public funds').

This chapter aims to explain with a literature review why road pricing often meets a lot of criticism and what the role of revenue use might be in this. This provides a useful benchmark for our empirical work presented in the next chapter. We start from a situation with optimal pricing. This ideal for policy makers gives rise to many barriers (that all play a role in less unrealistic situations), which will be discussed in Section 8.2. Section 8.3 addresses the acceptance barrier in more detail; it discusses both public concerns and some practical implementation experiences. Section 8.4 reports whether revenues from road pricing may be used to increase acceptance levels and the possible interaction with efficiency objectives. Finally, Section 8.5 concludes.

8.2 Barriers to road pricing

Optimal charges should vary in line with variations in marginal external costs caused by individuals. Since transport externalities include a large variety of effects, first-best optimal individual charges may have to vary over many dimensions (see Verhoef, 2000). This would, in practice, require the use of electronic road charges, ideally using sophisticated technologies that can monitor actual emissions, place and time of driving, driving style and prevailing traffic conditions. It is clear that there may be various barriers that would hinder the implementation of such first-best pricing policies in practice. First-best pricing is therefore mainly used by researchers as a benchmark, to compare the results of more realistic second-best pricing measures with that of the optimal situation.

It is one thing to compute first-best prices for a transport model and calculate the resulting social benefits. But it is quite a different thing to design an efficient pricing scheme for a real-world situation, as required for actual implementation. The transport analyst has full control over his model, whereas a regulator faces all sorts of constraints that may prevent him designing and implementing the desired pricing scheme. We will now discuss the most prevalent barriers to the implementation of first-best pricing, many of which also apply to pricing measures in general (this draws on Verhoef, 2002). We will distinguish three main categories of barriers, indicated in Table 8.1 (adapted from Verhoef, 2003), and some sub-categories.

Table 8.1 Classification of barriers to transport pricing

1 Technological and practical barriers

2 Acceptability barriers
- *2a* Public
- *2b* Political (see also below under 3c)
- *2c* Business

3 Institutional barriers
- *3a* Organizational structures
  - * On the 'regulator's side'
  - * On the 'regulatees' side'
- *3b* Political (see also above under 2b)
- *3c* Legal

Adapted from Verhoef (2003)

8.2.1 Technological and practical barriers

As indicated, road pricing should ideally involve charges that vary continuously over time, place, route chosen, driving style, type of vehicle and its technical state, driving style, etc. But it is clear that the resulting pricing scheme may be too complex to be understood by car drivers, and may require more sophisticated pricing and monitoring technologies than are currently available. For instance, for realistic road pricing schemes, one would expect differentiation over user classes to be possible only for a crude distinction into passenger cars, vans and trucks; over time up to the level of a few time-intervals during the peak and one level outside it, at a maximum; and tolls to be charged only on a few main roads (e.g. main highways) in the network.

From a recent study in the Netherlands, it appears that the technology for a nation-wide kilometre charge is, in principle, available (see Ubbels et al., 2002). However, the study foresaw that it may take some additional time to test the reliability even for a relatively simple nationwide system that 'only' determines the time and location of the vehicle. The development of systems that would vary charges over other aspects, such as driving style and emissions, would of course take longer. It is presumably a good strategy, when starting with a relatively simple system (allowing only for a crude time and place differentiation), to choose

a technology that would, in principle, allow for a future further sophistication of price differentiation.
In some sense, the technological barriers (as sketched above) can be interpreted as ‘financial barriers’: the required technologies may exist, but to date be too expensive to offer attractive possibilities.
Other practical barriers that can be distinguished would be insufficient: knowledge on marginal external cost figures, inadequate transport models and procedures for predicting equilibrium levels of second-best optimal road taxes, and so forth. For these reasons, provided tax levels do not have to be fixed for a long period of time, it is to be expected that deviations between predicted and actual behavioural responses may lead to the adaptation of initial tax levels.

8.2.2 Acceptability barriers

It is broadly believed that probably the greatest barrier to implementation is public, and linked to this political, acceptability (Jones, 1998). Empirical findings have shown that acceptability of transport pricing measures is generally low, and that acceptance is assumed to be one of the major factors influencing effectiveness of implementation of a system (Schade and Schlag, 2003). These issues will be discussed further in Section 8.3.
In brief, public attitude surveys have identified a wide range of concerns about innovative proposals to charge drivers more directly instead of the current taxes on ownership and purchase of cars. For instance, drivers find it difficult to accept that they should pay for congestion. Furthermore, the public often thinks that it is not needed, unfair, and not effective. Also local businesses may be opposed to the implementation of (congestion) charging schemes, mainly motivated by a fear of losing patronage. These concerns may lead to the abandonment of schemes. Alternatively, acceptability concerns may create a situation in which, for instance, a constraint on the maximum level of charges is pre-specified.
Finally, there is a clear correspondence between public and political acceptability in a democracy – where the chances of being re-elected depend on the extent to which voters appreciate the policies implemented. Politicians’ perceptions of the public acceptability of transport pricing schemes – in particular for their specific voter population – may of course affect the position they take in transport pricing issues.

8.2.3 Institutional barriers

Various types of institutional barriers can be distinguished. One category of institutional barriers arises when the organisation of government bodies is such that there is no single regulator that can set all transport (-related) prices and taxes so as to maximise social welfare throughout the system. An example is where a local or regional government either cannot affect some transport charges that are set by a higher level government (e.g. fuel taxes), or has to accept lower and/or upper limits on charges allowed, set by a higher level government. Another example, analysed earlier in Chapter 7, is when the government in one jurisdiction cannot affect the prices charged by a neighbouring jurisdiction, even though trans-boundary traffic and/or externalities are relatively important. The two governments may then end up in some form of tax competition.
Comparable problems may arise when public transport is operated by a private party who is relatively free in choosing prices and service levels but does so in a socially non-optimal way, or when private toll roads exist in an otherwise publicly controlled road network (Chapter 6 analyses price setting in such a setting).
Furthermore, the efficiency of transport pricing may be maximised only if other government bodies – for instance, the Ministry of Finance – were to adjust taxes (e.g. on labour) and subsidies (e.g. on commuting cost tax deductions) that are outside the control of the transport

authority in charge of the transport prices – for instance, the Ministry of Transport. Indeed, transport has – arguably more than any other economic activity – direct links with numerous other economic sectors and markets. This means that the transport regulator typically would have to take into account that a (change in) transport prices may affect the equilibria on numerous other markets, many of which will be distorted and might thus call for an upward or downward adjustment of these transport prices. Among the most important of these other markets would typically be the labour market, where relatively high marginal tax rates may lead to a serious undersupply of labour, calling for a downward adjustment in transport taxes if its price effect dominates the labour supply decision, or an upward adjustment if the revenues are used to lower labour taxes and this revenue effect appears to dominate. Another example is freight transport for goods that create environmental pollution in their production process, typically calling for an upward adjustment in transport prices, as this might offer an indirect way of taxing a polluting firm's output. The existence of inefficiencies in the various markets 'served' by transport thus create constraints that should be taken seriously in setting transport prices. Institutional barriers arise when these other taxes – and related policies – are the domain of government bodies other than the transport authority in charge of the transport pricing scheme.

In all such cases, institutional barriers may prevent optimal pricing from being attainable. But institutional barriers may also arise on the 'regulatees' side'. In particular, the regulatees may be organised in powerful lobby organisations such as automobile associations, labour unions, chambers of commerce, etc. Moreover, these organisations may join forces in their opposition against transport pricing implementation.

Political barriers were mentioned above as a sub-type of acceptability barriers. Of course, political barriers can also be viewed as a specific type of institutional barriers. This underlines that the distinction between the different types of barriers need not always be crystal clear, in particular when there are interactions between different barriers. In any case, it is not inconceivable that, in democracies, especially where coalition governments are in office, the level of charges and the design of a pricing scheme may become political issues much more than economic questions. In such cases, deals between political parties that accept the implementation of marginal cost-based pricing may create limitations on the types of charges and the flexibility that can be implemented.

Finally legal barriers may be distinguished as a specific type of institutional barriers, as it may not always be possible to charge the ideal prices on the basis of legal arguments. For instance, suppose that the law implies that the level of taxes should be predictable to the tax payer. If congestion is to some extent unpredictable (which it is in reality, e.g. due to weather conditions or road works), the optimal congestion charge would vary too, not only over the day, but also between days. A legal barrier could then exist that prevents the latter type of variation from being implementable.

8.3 Acceptability of road pricing

We have seen that the regulator may face different types of constraints ranging from practical (and technical) ones to institutional and acceptability constraints. However, we have now reached the situation where the major barriers to the successful implementation of transport pricing strategies relate largely to lack of stakeholder and political acceptability, rather than to technical or administrative problems. Since raising prices is generally disliked by the respective user group, the acceptance of pricing policies is often low. This section discusses some general issues appearing in the literature when it comes to acceptance of road pricing. Moreover, practical experiences of three case studies (one of which failed) may provide some useful lessons that can help explain the level of acceptance.

8.3.1 Acceptability and the implementation of road pricing

Several research projects have considered road pricing measures and policies as promising attempts to solve urgent traffic problems. Still, many attempts have not yet reached implementation. The lack of public acceptability is recognised as one of the main obstacles to the implementation of road pricing (Schade and Schlag, 2003). The following reviews important issues which contribute to the level of acceptability.

It is vital for the design of any transport pricing measure that, in addition to devising a technically robust system, an understanding of the reason for implementation has to be realised by the public and politicians. Despite the fact that these groups regard traffic problems in cities as a very important and urgent issue, people may have several concerns about road pricing. Besides the views and intentions of the persons affected by the measure, those of responsible political agencies as another key group have also to be taken into account. Politicians may feel that transport problems have to be solved by using some form of pricing measure. They are often initiators of the measure, which may be adapted to specific local circumstances. Therefore, the opinions and the acceptability on the local political level are of great importance for the implementation of specific measures. The TransPrice project concludes that the lack of political willingness to implement charging measures stems from the electorate's perceived low acceptability for such measures (TransPrice, 1999).

Despite the fact that political acceptability is necessary, we will now focus on public concerns about pricing measures. The policy maker should consider these before implementing pricing measures of any kind. The concerns often mentioned include (Jones, 1998):

- It is difficult for drivers to accept the notion that they should pay for congestion, it seems irrational and inappropriate;
- Car users feel that urban road pricing is not needed: it is a publicly provided good that is free at the point of use;
- Pricing will not lessen congestion: it is an ineffective measure because drivers will be inelastic to road charges;
- The measure will result in unacceptable privacy issues: this issue played an important role in the discussion on kilometre charging in the Netherlands;
- Road pricing will face implementation problems such as unreliable technology and boundary issues;
- Road pricing is considered to be unfair.

In order to address these concerns and to obtain some level of acceptability and make a transport pricing measure more likely, policy makers should consider some general rules. Research, for instance, suggests that the use of revenues is important. Verhoef (1996) asked morning-peak road users about their opinion on road pricing. An overwhelming majority (83%) stated that his or her opinion depends on the allocation of revenues. The opinion of businesses, on the other hand, seems to depend very much on the perceived effectiveness of the measure with regard to time savings. An analysis of the economic effects of road pricing in the province of Utrecht (the Netherlands) indicates that companies are positive as long as time savings are expected to compensate for road pricing costs (see PATS, 1999). However, these businesses do have their doubts as to whether road pricing would be really effective and decrease congestion levels.

Taking these research issues into account, a number of guidelines to a more successful implementation can be suggested (CUPID, 2000):

- Pricing strategies should be perceived as very effective solutions. The effectiveness of road pricing may be high but this is not guaranteed and depends on the definition of objectives. These objectives must be highly valued by the public. Moreover, people must also believe that their change in behaviour will contribute to reaching these objectives;

- Revenues should be clearly hypothecated and alternatives have to be provided. People want to get something for their money. Jones (1998) even states that road pricing is not publicly acceptable unless the money raised is hypothecated for local transport and environmental projects. Clearly defined objectives and funding targets were needed to obtain public approval and, hence, implementation;
- Fairness issues have to be considered, the system must be perceived as fair in terms of personal benefits and costs. The use of revenues together with the charging structure is important to influence the distributional impacts in the desired direction (taking the vertical and horizontal equity concepts discussed in Chapter 2 into consideration). Governments could use the revenues to reduce taxation, or they could target particular disadvantaged groups or locations, as is done in Switzerland (Banister, 1994). However, the question still remains whether the public can be persuaded that equity concerns have been accommodated. Guiliano (1993) argues that, no matter how the revenues are distributed, some individuals may still be worse off, since congestion tolls do not lead to strict Pareto improvements.

These issues reveal that it is necessary to develop an intelligent communication strategy. Clearly describing the problem (the presence of externalities in the case of road pricing) and the solutions to this problem, together with the objectives seems appropriate. We will not enter into this discussion since this is more of a psychological type of approach to increase acceptance.

The level of acceptance may be explained by the type of measure; higher charges are generally less acceptable, and the type of revenue use also makes a difference. A stated preference study in the UK reports that also other design features have impact. Acceptability increases when the scheme is limited to the central area of the city, and using cordon-based charges rather than continuous charging regimes (Jaensirisak et al., 2005). Other factors, not directly linked to the measure itself, may also be important. Steg (2003) identifies several factors that affect the acceptability of transport pricing. People's problem awareness, the attitude towards car driving, mobility-related social norms and the perceived effectiveness of the measure are identified as important in explaining the level of support. In addition, Rienstra et al. (1999) find that the acceptance of policy measures increases if people are more convinced about the effectiveness of such measures.

Acceptability of road pricing also depends on personal features such as age and income. Following economic theory, it is to be expected that high income earners may be less opposed to price measures to reduce congestion than people with lower incomes, because their value of time is higher. Verhoef et al. (1997) do indeed find that income as well as the willingness to pay for time gains has a significant and positive impact on the opinion on road pricing. Other factors, such as the expectation to be compensated, the perception of congestion as a problem and trip length, are also important in explaining the public's opinion. Jaensirisak et al. (2005) find that road charging is more acceptable to non-users, those who perceived pollution and congestion to be very serious, those who considered current conditions unacceptable, and those who judged road pricing to be effective. Rienstra et al. (1999) have analysed the support (together with perceived effectiveness and problem perception) for transport policy measures in general (not in particular for road pricing). They find that several personal features and the perceived effectiveness have a significant impact on the respondent's support for policy measures in transport. While gender and type of household do not seem to have an impact on support levels for transport measures, these tend to be higher when the educational level and age becomes higher. Car and driving licence owners support transport measures significantly less. Of all measures, car drivers have the least support for price measures. The authors find no significant impact of the level of income on the support for price measures.

8.3.2 Lessons from practical experiences

Road user charges have been used as funding mechanisms in many countries. Well-known examples include the toll roads in France, Italy and Spain, the tolls for bridges and tunnels in the U.S. and, more recently, the distance related charges for freight vehicles in Switzerland and Germany. Differentiated road pricing that aims for congestion reduction has less often been implemented. For many years, the only example of congestion pricing was Singapore. But today there is more experience to draw from, since other cities have implemented or made quite detailed plans that have made progress towards political approval.

Below, we discuss acceptance issues by means of some practical experiences with different forms of road pricing. Road pricing has for instance been implemented in Oslo, London and in several locations in the U.S.; and it is interesting to analyse how the acceptance hurdle has been overcome there. So far Stockholm has been less successful, although implementation is foreseen depending on the success of a recently started trial. We have included the Swedish case here to see whether public opposition was the bottleneck.

The Oslo Toll Ring

Toll cordons have been operated in three Norwegian cities for some time (Bergen, Oslo and Trondheim). A fourth cordon toll scheme, in the Stavanger-region, went into operation in April 2001 (Larsen and Østmoe, 2001). Oslo was confronted with unsatisfactory high traffic flow levels (significant delays) and local environmental problems. For the purpose of dealing with these problems by constructing new infrastructure, authorities decided to seek the required additional resources from users. The toll ring was designed primarily to generate revenues to finance desired transportation infrastructure improvements (with a minor share going to public transportation). Congestion management was not among the objectives aimed at by low and flat tolls. Differentiating the toll rates by time of day has been proposed in Oslo, the only city in Norway where congestion at present will make it worthwhile to use pricing as a measure to affect demand. These proposals have, however, been turned down by politicians in power.

The political process towards implementation was difficult in Oslo. Four years before implementation, agreement between Oslo City Council and Akershus County Council led to the approval of tolls to finance roads and other transport infrastructure. Formal political approval was obtained two years later, just before the Norwegian Parliament had changed the law. After this principal political approval, the discussion continued on local issues such as fairness and the location of toll booths (who should pay to enter the city centre?). Moreover, the spending of revenues was an issue because the Labour party demanded more funding for public transport. In the end, an agreement was reached as a result of two different factors (CUPID, 2000):

- Supporters of road users were satisfied by the availability of new road infrastructure, while those against road construction agreed with the reduction in the number of cars entering the city caused by the toll charges;
- The warning of the national government that investments would possibly be terminated in case of local disagreement. This fear of losing national grants made municipal politicians willing to make a compromise.

Political acceptability took some time, and so did public acceptability. Despite the fact that tolls already existed in Norway before the opening of the Oslo toll ring (tolls on bridges and tunnels connecting the islands to the mainland were common), the attitude of the majority of the population was negative towards the proposal (around 70%; see Table 8.2). This initial opposition was also expressed by threats of sabotage. However, this picture changed after opening. When the system had been operative for one year, the opposition reduced to 64%. The proportion supporting the toll system has steadily increased over time; from 30% before opening to 46% in 1998. Most people now seem to accept the cordons as a fact of life, like parking fees and other restrictive measures, but opposition is still substantial. A contributing factor to the high initial opposition may have been a belief that the tollgates would be new bottlenecks in road systems (Larsen and Østmoe, 2001). This turned out not to be the case, and opposition dropped some percentage points.

Table 8.2: Development of public attitudes towards the Oslo toll ring (in percentages)

	1989 (before tolling)	1990 (after tolling)	1991	1993	1996	1998
Positive attitude	30	36	38	41	45	46
Negative attitude	70	64	62	59	55	54

Source: PROSAM (2000)

In the end, the main explanations for the feasibility of this Norwegian example lie in its simplicity and the political support from the central government. The only purpose of the tolling schemes has been to raise money locally for transport projects. Hence, the benefits (improving infrastructure) were quite obvious both to politicians and the public. These objectives have been clearly communicated to the public and were easy to understand (well-articulated and widely shared). This was facilitated by the already existing experience with tolling.

London: Congestion charging

London introduced a congestion charging scheme in its central area in 2003. This scheme requires each vehicle to be charged a fixed amount (£5, later raised to £8) for crossing the cordon into the city centre. It was part of a wider transport strategy which aimed to reduce traffic congestion and improve car journey time reliability. The scheme would also raise revenue for investment in public transport including an upgrade of the underground and improvement of bus services. So far the key findings suggest that the scheme can be considered successful in terms of congestion reduction. After a year, traffic circulating within the zone had decreased by 15%, and traffic entering the zone by 18%, during charging hours (TfL, 2004). Of the car driver trips no longer crossing into the charging zone per day, 50 to 60% have switched to public transport, and furthermore changed routes (about 25%) or made other changes like destination changes or trip timing adjustments.

Several issues have made the issue of congestion in London a key political and public concern. Banister (2003) mentions, among others, that it is accepted that there is no alternative strategy to addressing congestion apart from demand management. In addition, there was political support from the national government (providing the enabling legislation) and a local politician (the Major of London). Revenue use was also a public and business concern. There does seem to be public support for the scheme provided that the revenues are invested in public transport improvements (with a 51% level of support among Londoners in 2001, and 35% against) (Banister, 2003). Tfl (2004) reports that in December 2002 40% of the Londoners supports the congestion charging scheme (and 20% is neutral). It is not clear whether revenue use has been specified in this latter survey. Fact is that support levels have increased after opening of the scheme in February 2003 with 10 to 20% (Tfl, 2004).

Public support through extensive consultation and engagement, and political support (with a Major committed to congestion charging) have contributed to the successfulness of implementation. Other beneficiary factors included the reliable technology, the area for implementation, and an already adequate public transport alternative. The importance of these local conditions is confirmed by the failure of similar attempts elsewhere in the U.K. Meanwhile the London scheme is scheduled to expand westward.

Stockholm: The Dennis Package

Sweden's interest in road pricing has arisen in a different context from Norway's. Sweden has little history of toll finance of roads, bridges or tunnels. But it does have a strong environmental lobby stressing the negative effects of traffic on sustainability, especially in inner cities. Political debates have been going on from the late 1980s, about the ability of city centres to accommodate the car, while restraining congestion, pollution and noise. The environmental movement demanded a major switch of resources from road-building to public transport. To resolve the dispute, in 1990 the government decided to appoint three special negotiators for Stockholm, Goteborg and Malmo, who were charged with developing a coordinated approach to urban transport planning, including investment and finance (Farrell, 1999). Stockholm received the most attention, and this led to a programme of road and public transport investments which came to be known as the Dennis package (named after the chief government negotiator). This package (agreed in 1992) had increased accessibility, an improved environment and better conditions for economic development as its objectives. Road pricing was used to finance the road investments and to limit road use. Unlike in Oslo, the toll revenues were not used to fund public transport. Tolling would be implemented on a ring road and a north-south bypass route west of the city. The toll ring would apply a toll to inbound traffic only, and would require 28 toll stations (Small and Gomez-Ibanez, 1998). The proposed tolls were significantly higher than the Oslo tolls.

Modelling studies suggest that the toll ring would complement the bypass routes' goal of reducing motor vehicle travel in inner Stockholm, and would mitigate the effects of additional traffic caused by the construction of the new roads (Johansson and Mattson, 1994). Despite these positive results and the endorsement of the Dennis agreement by the three main parties, problems encountered in implementing it led to its collapse in 1997. Although there was severe public opposition to part of the inner-ring construction, the main reasons for the breakdown of the agreement were (OECD, 2001):

- Alternation of the parties in power in successive elections, short terms of office (three years), and the fact that different levels of government (national, county and city councils) all had different priorities;
- Lack of consultation with users;
- The 'top down' agreement between the political parties was on an all or nothing basis, which did not allow changes or prioritisation of objectives or projects.

In addition, the package emphasised projects rather than policies (identified projects were expected to increase the public transport operating deficit) and it failed to address the issue of subsidies. There was an almost complete independence of road and public transport components. The operating and maintenance costs of the roads programme would have been financed from national taxation and tolls, whereas the funding of the proposed public transport projects was unclear (Farrell, 1999).

Local circumstances may have an important impact on the success of a scheme. These circumstances have in this case proved to make the proposed package unacceptable. The Dennis package is now seen as a missed opportunity for the development of an integrated urban transport plan. This suggests that the window of opportunity may be a narrow one, even in environmentally-conscious countries, such as Sweden, and confirms the need for a permanent, financially independent and politically aware organisation to steer such plans through the implementation phase.

Despite opposition against road pricing, Stockholm recently began a trial in January 2006. All owners of vehicles registered in Sweden are to pay a congestion charge if they drive into or out of the city centre of Stockholm on weekdays between 06.30 -18.29. The charge varies in steps over time. Shortly after the end of the experiment (July 2006) a referendum about permanent implementation will be held in the City of Stockholm.

Value Pricing in the U.S.: S.R. 91 Express Lanes

As throughout the world, policy makers in the United States have expressed interest in applying some form of marginal cost-based pricing to congested roads. Before 1989, only some implementation studies were carried out, which produced favourable findings to support the concept, but failed largely because of local community opposition. But after 1989, new California legislation (Assembly Bill 680) authorised activities to develop creative road pricing projects. It was intended to attract private capital to investments in highway projects. The first project implemented under this act is the State Route 91 (SR 91) Express Lanes.

Two lanes were added to the original four lanes in each direction. While the original freeway lanes remain untolled, users of the new express lanes must pay a fee, except for motorcycles and high-occupancy vehicles (HOVs). The SR 91 operating company chose to implement a variable toll schedule, which was called "Value Pricing" from a marketing point of view. Whereas all other value pricing projects in the US are operated by public organisations, a private company ran the SR 91 project until the beginning of 2003 (when the SR 91 franchise was sold to the public transportation authority of Orange County).

Initially, the project met some resistance from people living in Riverside County, who would have to pay most of the tolls, even though it adds new capacity and the original lanes remain free of charge (Small and Gomez-Ibanez, 1998). The reason is that it substitutes for an originally planned single HOV lane in each direction. This objection was partially ameliorated by the decision to make the lanes free of charge for vehicles with three or more occupants. But, in general, the project received favourable ratings in opinion surveys being carried out among peak-period travellers during several periods over time. The surveys addressed the public's opinions about travel conditions, variable toll pricing, and the other innovative technical and institutional features of this project (for an overview, see Sullivan, 1998 and 2000).

Commuters in the SR 91 corridor generally approve toll-financed lanes to bypass congestion (approval percentages in the 60%-80% range), in the first survey conducted just before opening. The approval percentages for toll lane users were 5%-10% higher than for non-users, with different variation among vehicle occupancy categories. However, approval of variable tolls, which has consistently lagged behind approval of toll financing in general, decreased significantly from its high point of 55%-75% in 1996 to the 30%-50% range in 1999. This approval of variable tolls depends very much on the trip characteristics of commuters, and not so much on socio-economic differences. For instance, among single-occupied vehicles, a very large difference in approval (53% v. 28%) was observed between recent toll lane users and non-users. The idea of varying tolls depending on the severity of congestion bypassed was not very popular before the start of the project (about 45% of the commuters). However, a year after opening this percentage had increased to the 60%-75% range. In addition, firms in the area of the toll lane were asked for their opinion. Overall, the companies were of the opinion that the new lanes improved the ease and reliability of travel, not only for employees but also for customers, suppliers and the firm's own work-related travel. For the most part, respondents to the business survey expressed levels of approval for the various features of the toll lanes in the same range as the commuters.

A more general review of all value pricing projects, which were successfully implemented in the United States, suggests that such projects often share several key attributes. Many of these are likely to play a role in enlarging the level of public acceptability for the following reasons (Sullivan, 2002):

- Considerable attention was paid to effective advertising and public relations;
- Project advertising and public relations emphasised the benefits to be gained by travellers, primarily time savings and improved reliability, creating superior travel options not previously available;
- Benefits were identified to the public in simple, tangible terms, and evidence of their existence was clear after implementation;
- Traveller participation has been optional; if people did not want to use the pay lanes, they could avoid them.

Communication has been an important tool in creating public acceptance. For instance, at the national level it was recognised that using the rather academic title of ‘congestion pricing’ elicited negative emotions. ‘Value pricing’ provided a more positive way to identify the same notion. Another illustration is the positive labels of the toll collection technologies such as Fastrak (Californian projects) and Quickride (Houston). In addition, extensive marketing and public relations initiatives were conducted.

However, there are also some issues that negatively affect the success of a project. The experiences point to the presence of influential project adversaries (pointing at inequity); the perception that schemes are only implemented to generate revenues for facilities that are already paid for; and the concern that the scheme will technically not work or not deliver the promised benefits.

The case study results confirm that a clear communication strategy contributes to a positive attitude of the public. Effective advertising, as used in the United States, is only one example of this. Furthermore, a strong political will with equal priorities among the different government levels is also beneficial to implementation (e.g. the recent case of the London congestion charge confirms this). Finally, it is found that approval rates change over time. In fact, opposition rates have decreased due to improved conditions.

8.4 The importance of revenue use: efficiency and acceptability

Pricing instruments may provide governments with stable and significant revenue sources. The distribution of this money is an important consideration in road pricing programme development. Revenues may broadly be used in three ways (CUPID, 2000):

- They can remain within the road transport sector and therefore benefit those who pay them as directly as possible (e.g. new road infrastructure investments, reduction in vehicle taxes);
- Revenues could be used to finance other parts of the transport sector in a comprehensive strategy to deal with particular transport problems. Congestion charging revenues may, for instance, be used to finance a substitute for road transport such as public transport;
- Alternatively, these revenues can be used to fund general public expenses, in which case there is no hypothecation to the transport sector. This would allow reductions of other taxes that are currently used for the public financing of infrastructure, but are largely unrelated to the costs of infrastructure use.

The destination and distribution of the revenues from pricing instruments may affect acceptance levels, but the use of revenues may also be important to the overall efficiency of a scheme. This section starts with a review on the welfare implications of revenue use. Then, empirical results on the consequences of different revenue allocations for acceptance levels will be discussed.

8.4.1 Revenue Use and Economic Efficiency

Economists have long recommended using congestion pricing to manage traffic flows more rationally. The attention in these studies has focused on the effects and level of efficient charges, and not so much on the spending of the revenues. In terms of making traffic flow more efficient by reducing travel demand, it does not matter how revenues are allocated. But it is possible that the generated revenues are used in a way that decreases the initial obtained welfare gains, or even cause reductions in welfare overall. Hence, revenue use is important from a welfare perspective.

For economic efficiency reasons, revenues should be used in a way that does not distort the transport sector and brings the maximum benefit to society. Economists have often advocated that an important candidate for such compensation would be the use of road pricing revenues to reduce general labour taxes. Therefore, it could be questioned whether investments in transport, and road transport in particular, are appropriate uses of transport tax revenues. This is in direct contrast with more popular hypothecation schemes where revenues from road pricing are directly linked to the financing of particular transport projects ("visible results"). Politicians are acutely aware of public distrust regarding the introduction of new taxes, when the revenue is used to contribute to the general treasury pot.

Below, we discuss the relation between revenue use and economic efficiency as it appears in the literature. We may distinguish between three different approaches to the welfare economic analysis of the use of road toll revenues. First, we look at the link between pricing policy and infrastructure policy. It is often claimed that the revenues from a congestion tax should be used to finance investment in road infrastructure. This can be very efficient. Economic theory argues that optimal congestion toll revenues are exactly sufficient to fund optimal road capacity under certain conditions. This is a straightforward use of toll revenues, but only applies as a strict equality under certain theoretical conditions. Secondly, road pricing has been incorporated in partial equilibrium models. Finally, revenue use can induce important general equilibrium effects, as spending of revenues in other sectors may have an important impact on the overall efficiency of a pricing measure. The results suggest that hypothecation of revenues to public transport, often advocated from an acceptability perspective (funding the substitute), may not always be very efficient. Lowering (distortive) taxes in other markets may, on the other hand, be one of the most efficient solutions.

Pricing and cost recovery

Building and maintaining road infrastructure entails costs. These costs can be recovered from the infrastructure users. In many countries, the charges that are currently levied are not related, or only partly so, to the actual costs of providing or using the infrastructure. Infrastructure costs consist of two elements: the capital cost and the operating and maintenance cost. The capital invested in the provision of road infrastructure gives rise to a fixed cost, independent of the actual use of infrastructure. Maintenance expenditures may vary with traffic volumes, but also other factors such as weather conditions and geographical settings play an important role.

The implementation of pricing measures raises revenues that may be used to fund infrastructure costs. Economic theory argues that marginal cost pricing is important for the efficiency of the transport system, since it gives individual users an incentive to reduce the underlying costs, as cost savings are rewarded by lower charges. Ideally, these marginal cost charges should recover overall infrastructure and road use costs. But marginal cost pricing certainly does not necessarily mean that given revenue targets will indeed be met exactly (Verhoef, 2002). If significant parts of the total costs are not use-dependent (as is the case with capital costs), then marginal cost pricing alone will generally not lead to full cost recovery. This may make it very difficult for private investors in road infrastructure to set charges based on marginal costs.

However, economic theory suggests that, under certain circumstances, revenues of marginal cost prices may indeed be exactly sufficient to cover capacity costs, provided certain technical conditions are fulfilled. This is also known as the self-financing theorem, developed by Mohring and Harwitz (1962). The theorem applies under the following conditions: 1) in addition to optimal tolling, the capacity of the road must be chosen optimally; 2) there is constant returns to scale in road construction and maintenance; 3) the trip cost function is homogenous of degree zero in traffic volume and capacity; and 4) road capacity can be increased in small increments (Yang and Meng, 2002).

Constant returns to scale in construction intuitively means that the costs of building a road is proportional to capacity. The third condition indicates that, when engineering capacity and traffic flow were doubled, unit travel times would remain the same. The congestion toll not only internalises the external congestion costs, but it also covers the average fixed cost (Hau, 1998). The attractiveness of this solution lies not only in its optimality (of capacity and use of the road) of economic efficiency. It also means that no extra funds (i.e. through distortive taxes) have to be found elsewhere, and that the schedule is transparent (i.e. only users of the road pay for the costs of it, but do not pay anything more than the cost of supply).

However, this solution very much depends on the conditions mentioned. A balanced transport budget may still be distorted as soon as these are not fulfilled (e.g. when capacity can only be supplied in discrete quantities), or when a part of the capacity is already fully financed, with no (interest) costs having to be covered from current toll revenues (Verhoef, 2002). A number of studies have investigated whether self-financing continues to hold under more general assumptions than those mentioned above. The self-financing result of homogenous drivers to heterogenous ones with different values of time has been generalised by Mohring (1970) and Strotz (1964). Henderson (1985) showed that self-financing holds in a case where travellers have a choice between two modes which could be either driving or using public transport, or choosing between two roads. Later Oum and Zhang (1990) examined the relationship between congestion tolls and capacity expansion costs for airports when capacity expansion is indivisible. A more comprehensive review of congestion tolls and optimal investment can be found in Hau (1998).

The choice of road capacity has also been investigated in a second-best setting, where traffic cannot be adjusted optimally due to institutional constraints prohibiting congestion tolls. A question then is whether first-best road capacity is smaller or larger than the second-best capacity. Intuition may tell us that capacity may be smaller in the first-best case, since demand decreases after implementing tolls. However, the literature shows that the opposite may be correct (MC-ICAM, 2001). It appears that the elasticity of demand for road trips is the key element that determines the effect of congestion pricing on optimal capacity (i.e. in a situation with a high elasticity the first-best capacity is larger than the second-best capacity, while, if the elasticity is low, the imposition of road tolls leads to lower optimal capacity).

Partial Equilibrium

Economic analyses of transport pricing problems have often been performed in partial equilibrium settings. The implementation of marginal cost prices or congestion pricing has mostly been analysed from a transport sector perspective, by only looking at the welfare gains of the measure itself, taking no account of the effects of the spending of revenues. This means that the wider effects of the measure on other markets (such as the labour market) have been neglected in a partial equilibrium framework, simply because these markets have not been modelled.

Partial equilibrium theories show that, when a congestion toll (a Pigouvian tax) internalises the external costs of congestion, peak-hour usage of a roadway falls, and the level of congestion declines. The revenues are supposed to be collected by the government, but nothing is said about the spending of this money. Of course, in such a partial equilibrium setting, it is not useful to subsidise other sectors, because it is implicitly assumed that all other markets are perfectly functioning, without any distortions. The revenues may be used to fund public transport, since marginal cost pricing may not be sufficient for this industry to stay in business.

The EU-funded study TRENEN II uses a partial equilibrium model, in which only the allocation of the income of consumers over transport goods and one non-transport good is studied, keeping the level of income fixed (Proost and van Dender, 2001). They do, however, include the spending of tax revenues into their modelling work. This study values changes in tax revenue (including public transport deficits) at the marginal cost of public funds minus 1. The marginal cost of public funds relates to the efficiency cost of taxation and is an important consideration in the evaluation of alternative tax policy options (Ruggeri, 1999). Estimates vary widely, and they are sensitive to how revenues are collected and spent. Tax revenue in the TRENEN II study is returned in a lump-sum way to the individual. It is chosen to incorporate the effect of spending transport tax revenues on the labour market, because labour taxes are the most important type of taxes. The reasoning is that increased transport tax revenues may be used to lower taxes on the labour market. When there are important distortions in this second market, the indirect effects may have potentially important welfare effects. The TRENEN work shows that when this efficient use of tax revenue is guaranteed, optimal taxes in the transport sector should, in general, be higher than the marginal social costs (Proost et al., 2001). It is advocated to use tax revenues in two ways from an efficiency point of view: investments in the transport sector (i.e. new roads and public transport infrastructure), and the redistribution of income by a reduction of labour taxes. This latter destination compensates all households (in addition to the improved transport quality as a result of higher speeds in peak periods), since it is inefficient to compensate all victims individually. Note that, for the former possibility, there is no relation between the net revenue from optimal pricing in the transport sector and the need to subsidise public transport.

General equilibrium

A partial equilibrium modelling framework is useful to understand the specific effects of particular pricing measures. Most transportation models explicitly treat the congestion technology and consumers' behavioural decisions. These are, however, partial equilibrium models that do not consider the use of tax revenues in distorted economies with income distribution problems. As we have seen from the TRENEN work, broader effects on other markets can be included by expanding a model in the appropriate directions. A standard approach, for instance, to capture the interaction with the labour market is to adjust the weight given to transport tax revenues in the welfare functions used. Obviously, a general equilibrium approach, where other markets (in that case the labour market) are explicitly represented, can give a better understanding of the overall effects of transport pricing measures, including the use of revenues.

Mayeres and Proost (1997 and 2001) discuss optimal transport pricing and investment in a second-best economy, where the government is constrained to use distortionary income taxes to redistribute income. Mayeres and Proost (1997) use a simplified applied general equilibrium model, appropriate for studying the interactions between externality taxes and the rest of the tax system. They analyse the introduction of congestion taxes in the framework of the double dividend discussion. The first welfare gain corresponds to the benefit obtained through an improved externality level, while recycling the tax revenue in a lump-sum way.

The second dividend results from the optimal use of the revenue to reduce existing distortionary taxes. It is shown that the first dividend is by far the more important, and that the possibilities of obtaining large welfare gains by using externality tax revenues are limited by the equity objectives. In another study, Mayeres and Proost (2001) use a general equilibrium model to analyse marginal tax reform in the presence of externalities. The theoretical model is illustrated for a specific externality: namely, congestion caused by peak car transport. It is demonstrated that the net welfare effect of an increase in the congestion tax depends on amongst other things the efficiency effect of the tax revenue recycling. A higher tax on peak car transport increases welfare when the revenues are used to cut taxes on most other commodities used in the model or to expand road capacity (the highest welfare gain). Using the revenues to increase the subsidy of public transport is not interesting, because the welfare impact of the lower congestion level is offset by the high tax revenue cost of stimulating the consumption of already strongly subsidised public transport (Mayeres and Proost, 2001).
A recent study of Parry and Bento (2001) explores the interactions between taxes on work-related traffic congestion and pre-existing distortionary taxes in the labour market. They use a general equilibrium model to show that, when congestion pricing revenues are used to reduce (distorting) labour taxes, this can raise the overall welfare gain from that pricing measure (it may even double this welfare benefit via a net positive impact on the labour supply). Lump-sum transfers to households do not appear to be very efficient: these can easily offset the welfare gain from internalising the congestion externality. Recycling the revenues in public transport fare subsidies rather than tax cuts appears to be less efficient according to their analysis. This source of inefficiency may even be greater at more substantial amounts of traffic reductions.

8.4.2 Revenue use and acceptability

Various studies have empirically addressed the importance of revenue recycling for the level of acceptance. The results suggest that there is a difference in acceptance levels of various revenue use options, and that the acceptance of a certain pricing scheme can be influenced by choosing what to do with the revenues.
Verhoef (1996) asked for the public opinion on a number of possible allocations of revenue spending on a five-point scale, varying from a ‘very bad’ allocation of revenues to a ‘very good’ allocation. The allocation objectives that are in the direct interest of the road users received most support, as may be expected. Road investment, together with lower fuel and vehicle taxes (variabilisation) received the highest average score. General purposes, such as general tax reductions and the government budget in general, obtained least support from morning-peak road users.
The importance of the use of the funds in gaining or losing public acceptance for a pricing measure has also been demonstrated by a survey in the UK. People were asked about their attitude to a series of measures that would reduce urban traffic problems. When asked about road pricing as a stand alone measure, only 30% responded in support of charging road users to enter highly congested urban areas (Jones, 1998). The respondents were then offered a package that includes a charge on entering a zone that was then used to fund better public transport, traffic calming, and better facilities for walking and cycling. This resulted in a 57% support for the package. A similar result was found in particular for London. A single measure was supported by 43% of the public, whereas 63% accepted the scheme when revenues were used for purposes approved by respondents. Hypothecating revenues increases public support.
The AFFORD study conducted an empirical survey on the public acceptability of different pricing strategies in four European cities: Athens, Como, Dresden and Oslo (Schade and Schlag, 2000). They investigated the attitudes of the respondents regarding how to use the

revenues arising from road pricing. It was found that common purposes of money use like traffic flow and public transport improvements are favoured by the vast majority of respondents. Lowering vehicle taxes is also supported by the people, whereas lower income taxes is not acceptable as a revenue spending target. This is the way revenues should be used according to the public. The expectations concerning how revenues actually will be used are rather different, however. Around 70% of the respondents expect that the money will be used for state or municipal purposes, which are not wanted by the public (Schade and Schlag, 2000). This study has also analysed factors that influence the degree of acceptability of pricing measures. In particular, variables such as 'social norm', 'perceived effectiveness' and 'approval of societal important aims' are positively connected with the acceptability of pricing strategies (Schade and Schlag, 2003).

An interesting study by Small (1992) suggests that public and political support can be reached for road pricing, even without using all the revenues to compensate travellers, since higher user charges are accompanied by reduced travel times. He searched for a strategy whereby nearly everyone affected will find at least some offsetting benefits, and a majority will perceive the entire package as an improvement. Seven interest groups were distinguished, ranging from the travelling public and public transport users to low tax advocates. It was suggested that money should be kept in the transportation sector. Funds should be allocated about equally between monetary subsidies to travellers, substitutions of general taxes that are currently used to pay for transportation services, and new transportation services. Small illustrates this by designing a politically feasible (in terms of support from the earlier identified interest groups) congestion pricing package for Southern California (summarised in Table 8.3). His equity analysis indicates that this programme makes every class of traveller better off (combination of travel time saved, financial improvements and transportation improvement), with the greatest gains for higher income drivers and public transport users.

Table 8.3: Proposed congestion pricing revenue use for Southern California

Revenue use	***Funding***
Employee commuting allowance	25%
Fuel tax reduction	12%
Sales tax reduction	18%
Property tax rebate	16%
Highway improvements	11%
Public transport improvement	10%
Business center transportation facilities	11%

Source: Small, 1992

It would appear from the literature that using the revenue raised from pricing measures to fund alternative transport objectives, possibly in the form of an integrated package of measures may increase acceptability. However, the design of the integrated package, i.e. which measures are included and which are left out, will very much depend on local circumstances. This is confirmed by the experiences with road pricing in Stockholm (see the Dennis package discussed in Section 8.3.2). The idea of using revenues raised from pricing measures for predetermined purposes calls on the concept of earmarking. Earmarking may be justified to satisfy distributional or acceptability objectives, but it has little relation to efficiency (which is generally served best in the absence of restrictions on the use of government funds). This concept also reduces the flexibility of governments to design efficient general budgets, and therefore treasury departments normally avoid earmarking (PATS, 1999). On the other hand, public acceptance of taxes may increase if they are earmarked for a connected purpose. Note that hypothecation in the transport sector is not common, but nevertheless sometimes exists: for instance, when the funding of public transport relies on revenues from local taxes and charges (for an overview of case studies world-wide, see Ubbels et al. 2001).

8.5 Conclusions

Most countries rely on existing pricing mechanisms such as fuel duties, registration fees and parking charges. This current charging regime is, however, not very efficient. Economists have long advocated the use of more appropriate pricing tools by demonstrating the welfare gains. Nevertheless, these more efficient road pricing measures have up till now only seldom been implemented in practice. The low level of implementation is due to various barriers. Barriers may be practical in nature, but also public acceptability and the presence of different institutions with different objectives may prevent a smooth implementation. Nowadays road pricing faces not so much technical or administrative problems. Rather, it is generally acknowledged that pricing measures meet public resistance: acceptability is currently one of the major barriers to successful implementation of new and more efficient pricing measures. This chapter has analysed acceptance with specific attention for the role of revenue use.

Despite the fact that politicians and the public regard transport problems as urgent and important, people do have concerns about road pricing. These doubts are related to the perceived effectiveness of the measure, the feeling that roads are free to use, and the fact that it is an unfair measure. People seem to understand the concept, but are against the imposition of an additional tax, particularly if the revenue raised is paid to the general tax income. Decision makers should take these concerns into account when preparing the implementation of such a measure. Several guidelines have been proposed in order to come to a more successful implementation strategy. Besides an intelligent communication campaign (confirmed by the US experiences), the role of revenue spending seems to be important, especially in relation to the argument of fairness. Research has shown the importance of the use of funds in gaining or losing public acceptance. Revenues could be targeted to those persons affected by road pricing and remain within the transport sector, but also other objectives may be thought of such as new infrastructure or lower income taxes. In general, it has been found that allocation objectives in the direct interest of the road users received most support. Car drivers mainly favour a redistribution in transport (e.g. lower fuel taxes or public transport investments) and refuse general tax deductions.

Despite the fact that transport is an attractive way of spending revenues from an acceptability perspective, this does not necessarily imply that it is efficient. In contrast, acceptability objectives may even conflict with economic efficiency goals, so that there is some sort of a trade-off. For instance, the use of revenues for public transport funding is debatable from an efficiency perspective. And an efficient spending target, such as the lowering of labour taxes, is generally disliked by the public. A strategy that is both efficient and acceptable can therefore be difficult to find for policy makers. Despite the suggested presence of this trade-off, the next chapter aims to identify interesting policy directions in terms of both effectiveness and acceptance based on intentions and opinions of Dutch car drivers.

Chapter 9

What drives acceptance? An explanatory search for acceptance levels of road pricing among Dutch car commuters and car owners in general

9.1 Introduction

The previous chapter showed that pricing measures generally meet public resistance, and that acceptability is difficult to obtain. This also applies to the Netherlands. The Netherlands has a long experience in developing new road pricing proposals to reduce the increasing levels of congestion (especially in the densely populated Randstad area). Despite the severe traffic problems, none of these plans has ever been implemented mainly because of low levels of public acceptance. It is therefore interesting to analyse the acceptance of specific, policy-relevant, pricing measures. Given the importance of revenue use (as we observed in the previous chapter), we have also included this aspect in our survey. The aim is not only to determine how acceptable a road pricing measure is; it is even more interesting to explain variation in acceptance levels for the different types of measures.

We have chosen to conduct two empirical studies with different population samples. The aim of the first study was to analyse acceptance levels of road pricing measures among those travellers who regularly experience congestion (i.e. commuters with a car). It is important to know which factors influence the acceptability of road pricing, especially among these respondents. Depending on the type of measure, this group pays relatively most (because car commuters generally drive many kilometres) but may also benefit relatively most when congestion levels decrease. In order to also analyse the acceptance of road pricing among people driving less frequently, we conducted a second survey and interviewed car owners in general (not necessarily having a job or driving commuting kilometres).

This chapter reports the empirical findings of both surveys, and is organised as follows. Section 9.2 presents the results from the first survey conducted among commuters. After a short review of similar work, we continue with an explanation of the empirical survey, and present the results from our data analysis. Section 9.3 has a similar set-up, but the sample and the evaluated road pricing measures are different. Section 9.4 compares the results from both surveys, while Section 9.5 presents the main conclusions.

9.2 Acceptability and revenue use: a survey among car commuters experiencing congestion

The previous chapter indicated that public acceptability of transport pricing measures is generally low when compared with other types of transport measures such as an improvement of public transport (e.g. Bartley, 1995; Jones, 1998). Least accepted are generally all kinds of road user fees (Schade, 2003). In this first survey we focus on road user fees. We report acceptance levels and search for explanatory variables. Our analysis probably comes closest to that of Rienstra et al. (1999), Verhoef et al. (1997) and Jeansirisak et al. (2005). We also identify factors that explain the level of acceptance of road pricing and revenue use, and include in the analysis the perceived effectiveness and the value of time of respondents (only included in the survey among commuters discussed in this section). This study extends the work of Verhoef et al. by considering multiple variants of pricing measures, systematically varied over dimensions such as price levels, differentiation, and revenue use. Moreover, the individual VOT estimates are now based on a choice experiment (see Chapter 4), while in the questionnaire of Verhoef et al. these were based on open-ended WTP questions. We also include the value of schedule delay and uncertainty into the analysis in this section. The work of Rienstra analysed the support for transport measures in general, while we focus specifically on road pricing measures relevant in the Dutch policy context. The Jaensirisak study focuses on the UK situation where city centre charging may be more (policy) relevant; it does not include individual parameters such as the value of time, and they survey transport users in general.

9.2.1 Data collection and survey

The data used in this section have been obtained by conducting an Internet survey among Dutch commuters. The full questionnaire can roughly be divided into three parts. First, we asked for some socio-economic characteristics of the respondent (such as education and income). In order to analyse the behavioural responses to road pricing we developed a stated choice experiment (discussed in Chapter 4 of this thesis), which is the second part of the survey. And, finally, we asked for the opinion of the respondents on several carefully explained road pricing measures. The first and the second part were answered by 1115 respondents, whereas the third part (opinion questions) consisted of 564 respondents. This section presents the outcomes of this latter part of the survey.

The data collection was executed by a specialised firm (NIPO), which has a panel of over 50,000 respondents. Since the survey was aimed at respondents who use a car for their home to work journey and also experience congestion on a regular basis, we selected working respondents, who drive to work by car two or more times per week, and who experience congestion of 10 or more minutes at least twice a week. This resulted in a total of about 6800 possible respondents. An initial analysis revealed that a random sample would result in a relatively low number of women and lower income groups. Because income differences are important to analyse, it was decided to 'over sample' the lower income groups and create an equal number of respondents over the various income classes. The data were collected during three weeks in June 2004 (before the summer holidays).

The survey began with some general questions asking for important explanatory variables of the respondent. These variables may help explain the differences in acceptance levels. Most variables are explained in Appendix 9a. Additional variables included in our analysis are not socio-economic in nature. We have information on the perceived effectiveness of the measures, and have an estimate of the value of time (VOT) of the respondent. It is worthwhile to analyse the effects of these variables on acceptance[21]. For a discussion on the profile of this sample we refer to Section 4.2.2.

The respondent was confronted with three different types of road pricing measures. After a concise description of each measure, the respondents' opinion on various issues was asked. People could indicate the acceptability of a specific measure on a 7-point scale, ranging from 'very unacceptable' to 'very acceptable'. We also asked how effective they thought that the measure would be, both individually (i.e. would you drive less?) and in general terms (would there be less congestion and will there be smaller environmental problems?). The answers to these latter questions (also on a 7-point scale) have been included into the analysis as explanatory variables for the level of acceptance.

[21] We do not only have an estimate of the VOT of the respondent, but also the value of schedule delay (early and late) and the value of uncertainty are available. We refer to Chapter 4 for more information on the derivation of these values.

Table 9.1: Short description of the transport pricing measures presented to the respondents

Measure	Variant
1: Bottleneck passage	1A: flat toll throughout the week
	1B: coarse toll (flat within peak hours on working days)
	1C: multi-step toll during peak hours only
	1D: toll depends on actual traffic conditions
2: Kilometre charge differentiated by vehicle type	2A: Revenues to general budget
	2B: Revenues to traffic system
	2C: Lower car taxation and new roads
	2D: Revenues to public transport
	2E: Abolition of car ownership taxes
	2F: Lower fuel taxes
	2G: Revenues to improve and construct new roads
3: Kilometre charge with different charge levels and different revenue use	3A: 2.5 €cents, unclear revenue use
	3B: 5 €cents, unclear revenue use
	3C: 7.5 €cents, unclear revenue use
	3D: 2.5 €cents, improvement of road network
	3E: 5 €cents, improvement of road network
	3F: 7.5 €cents, improvement of road network
	3G: 2.5 €cents, abolish existing car taxation
	3H: 5 €cents, abolish existing car taxation
	3I: 7.5 €cents, abolish existing car taxation

Within each type of measure, we have developed a number of variants differing on: type of charge (measure 1), type of revenue use (measure 2) and level of charge plus revenue use (measure 3) (see Table 9.1). This resulted in 4 different variants for measure 1, 7 for measure 2, and 9 for measure 3 (a detailed description can be found in Appendix 9b).
All variants were randomly distributed over the respondents. This means that we obtained about 140 observations for each variant of measure 1, 80 for each variant of measure 2, and 60 for each variant of measure 3. A short introduction preceded the explanation of the measures. This was to explain that the respondent had to imagine the implementation of the measures in the Netherlands. It was also to be assumed that the privacy of car users is guaranteed, electronic equipment registers the toll and the driver can freely choose the payment method (e.g. credit card, bank transfer, etc.). The introduction to measure 2 and 3 (time-independent charges) also included an estimation of the financial consequences for an average driver (driving 16,000 km in a year), irrespective of type of revenue use.
In addition, we asked the respondents to evaluate the acceptance of different revenue uses separately (without specifying the road pricing measure). Six different revenue use options were presented to the respondent: the treasury of the government (and hence be used for purposes other than transport); new roads; improvement of public transport (e.g. increase of frequencies); a removal of existing car ownership taxes; a decrease in fuel taxation; and a decrease of income taxes. Again, for each option, a 7-point acceptability scale was used.

9.2.2 General results

Before investigating the distribution of the levels of acceptance, we begin with an overview of the average acceptance levels for each single measure. Figure 9.1 shows the mean acceptance outcomes and their confidence intervals[22].
The mean level of acceptance differs considerably between the various types of measures. Whereas all types of measure 1 (bottleneck passage tolls) can be classified as somewhat unacceptable, this is not always the case for the other measures. In particular, measures 2C (revenue use: new roads and less car taxation), 2E (abandoning of road taxation), and 2F

[22] We present 'unweighted' results. When we correct the outcomes for representativeness (on age, education and income) in order to obtain a good match with the profile of Goudappel Coffeng and create a 'weighted' sample, we find comparable results.

(lower fuel taxes) have higher acceptance levels. But, a score of 4 still means that the respondents are neutral. The patterns of outcomes for measure 3 can be easily explained by the structure of the measure (a combination of 3 different charge levels with 3 different revenue use options). Apparently, the respondents prefer revenues to be used for the abolition of car taxation over that of new road and an unclear revenue destination. A charge of 2.5 €cents is more acceptable than higher charges of 5 and 7.5 €cents, as may be expected. Measure 3G has the highest mean (4.71) which comes close to an average score of 5 ('somewhat acceptable').

These findings suggest the following interesting issues. First, given the results for measure 1, it seems that the level of acceptability does not depend on the complexity of the measure. Hence, acceptability is not necessarily a reason for starting simple. Second, measure 3 suggests that revenue use has more effect on the level of acceptance than the charge level (for the chosen range). People prefer a charge of 7.5 €cents with abolition of car taxation over a charge of 2.5 €cents with revenues hypothecated to the general treasury. This underlines the importance of the allocation of the revenues.

Appendix 9c shows the percentages of respondents who find the various measures 'unacceptable' or 'very unacceptable'. These outcomes confirm the previously described 'mean' pattern.

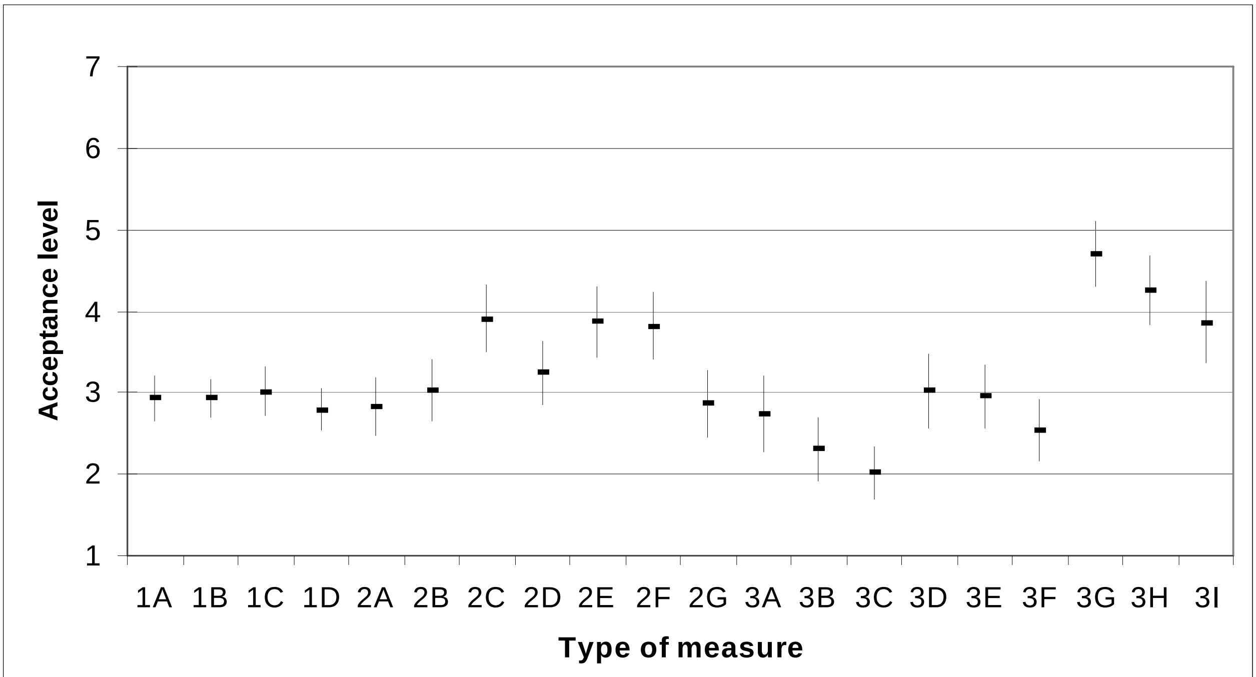


Figure 9.1: Mean and 95% confidence intervals of acceptance scores on each single measure (level 1 = very unacceptable; level 7 = very acceptable)

9.2.3 A search for explanatory variables of the acceptance levels of 3 road pricing measures and 6 types of revenue use

Various econometric techniques are available that can be used to investigate the relation between different variables. The methodology to be applied depends to a large extent on the structure of the data. Here, the aim is first to explain the level of acceptance for the various measures, where the dependent variable consists of a choice out of an ordered set of acceptance variants. Given this framework, which is similar to the situation where we studied the probability of selling the car in Chapter 5, the ordered probit (OP) technique seems again to be most appropriate (for a discussion of OP, see Maddala (1983)).

Various specifications of the model for all measures (by including variables that may be expected to have some explanatory power) have been tried. The following tables present our preferred specifications. The estimations for each type of measure have been made with the same explanatory variables in order to maximise comparability between the models.

Measure 1: Electronic toll on daily bottlenecks with fixed revenue use (new roads)
Table 9.2 presents the estimation results for measure 1. The first row presents the estimates for the threshold values (μ's) explained in Chapter 5. The second row presents all the explanatory variables that have been included in the estimation. It appears that the individual's value of time, level of education, and compensation of costs by the employer all have a significant and positive impact on acceptance. Most signs of the coefficients are as expected. For example, respondents with higher value of time tend to have higher acceptance levels of an electronic toll on daily bottlenecks. Interestingly, inclusion of the individual's value of schedule delay (early and late) and the value of uncertainty did not lead to significant results. This suggests that people find it hard to predict whether or not uncertainty will reduce under congestion pricing, and whether or not advantages in terms of schedule delay costs can be realized. Alternatively, people may have ignored these matters.

As expected, commuters who have to pay the toll themselves (no compensation) and drive many kilometres tend to find the measure less acceptable than drivers who receive full compensation and use the car less often. Income is not significant; one explanation may be that VOT and education (both correlated with income) take up the expected effect. Income indeed becomes significant (at the 5% level) when VOT and education are not included in the estimation. On the other hand, the type of measure, living in one of the three larger cities (loc1, included to compare the opinions of people located in densely urbanised areas with those in the rest of the Netherlands) and the weight of the car do not seem to have an important impact.

As already apparent from Figure 9.1, the different types of bottleneck charging measures have no significant effect on the acceptance of the respondent. It makes no difference whether it is a charge at all times (1A), a peak time charge (1B), a differentiated peak charge (1C) or a charge based on actual traffic conditions (1D), although the latter seems somewhat less acceptable than the other three (although not significantly). This suggests that the structure of measure (ranging from a flat and certain charge to a highly uncertain charge depending on traffic density) may not necessarily have an impact on the level of acceptance.

The perceived level of 'general effectiveness' in terms of (less) congestion (i.e. in Table 9.2 general effectiveness (less congestion)) has an important impact on acceptance[23]. The results suggest that respondents who think that the measure will be effective also tend to find it more acceptable. The effectiveness in terms of less environmental problems is not included in the model as this variable was highly correlated with 'effectiveness (less congestion)'. The 'personal effectiveness' (indicating whether people tend to use their car less when the measure is implemented) shows a somewhat irregular pattern. Compared with people who indicate that they do not change their behaviour (peff=1), respondents who find a personal change more likely have a higher level of acceptance. This may be explained by the 'protest voters' in group 1: "the measure is not acceptable because I will not change behaviour" or "I say I will not change behaviour because I don't want this measure implemented". An explanation of the low score of peff=7 may be that these respondents (who indicate that they will most likely drive less) find the measure not that acceptable because they perceive the consequences of changing behaviour as (very) negative.

[23] The type of measure that has been proposed has no significant impact on the level of general effectiveness (in terms of less congestion).

Table 9.2: Results of ordered probit analysis with the acceptance of measure 1 as the dependent variable

Variable	Probit ACC measure 1	Sign.
Threshold (μ's)		
μ_1	1.073 (.450)	**
μ_2	2.309 (.456)	***
μ_3	2.781 (.458)	***
μ_4	3.136 (.461)	***
μ_5	4.036 (.469)	***
μ_6	5.564 (.538)	***
Gross yearly income	8.58 E-03 (.019)	
VOT	4.26 E-02 (.010)	***
Gender (female)	-.166 (.121)	
Education (Edu1 (primary school) = base)		
Edu2 (junior general sec.)	.245 (.232)	
Edu3 (intermediate vocational)	.168 (.156)	
Edu4 (senior general sec.)	.414 (.198)	**
Edu5 (Bachelor)	.413 (.152)	***
Edu6 (Master)	.739 (.191)	***
Loc1 (3 large cities)	-.197 (.121)	
Childyes	9.92E-02 (.112)	
Age (age5 (56+) = base)		
Age1 (18-25)	-.257 (.250)	
Age2 (26-35)	-9.48E-02 (.199)	
Age3 (36-45)	-4.91E-02 (.208)	
Age4 (46-55)	-.184 (.209)	
Travel time in congestion/free flow tt	6.25E-02 (.075)	
Type of measure (measure 1D = base)		
M1A (charge of € 1)	.168 (.136)	
M1B (charge of € 2 during peak)	.167 (.128)	
M1C (peak time charge)	.134 (.133)	
Number of kilometres driven yearly	-2.92E-06 (.000)	*
Compensation of costs by employer (full compensation = base)		
Comp1 (no transport costs paid by employer)	-.310 (.163)	*
Comp2 (transport costs partly compensated)	-9.93E-02 (.108)	
Vehicle weight (Weight3 (heavy weight) = base)		
Weight1 (low weight)	.167 (.189)	
Weight2 (middle weight)	.221 (.159)	
General effectiveness (less congestion) (Geff1 = base)		
Geff2	.774 (.149)	***
Geff3	1.107 (.185)	***
Geff4	1.554 (.236)	***
Geff5	1.765 (.185)	***
Geff6	2.145 (.262)	***
Geff7	1.859 (.497)	***
Personal effectiveness (drive less yourself) (peff1 = base)		
Peff2	354 (.128)	***
Peff3	.539 (.199)	***
Peff4	.212 (.196)	
Peff5	.360 (.185)	*
Peff6	.447 (.230)	*
Peff7	2.92E-02 (.433)	
N	564	
Log-likelihood	-815.555	***
Pseudo R-square	Cox and Snell	.379
	Nagelkerke	.393
	McFadden	.142

Notes: The standard errors are shown in brackets. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively, (two-sided *t*-test).

The results suggest that acceptance need not depend on the complexity of the road pricing measure. This gives possibilities to policy makers to consider time-differentiated charges that tend to be more effective in reducing congestion. The perception of effectiveness also seems very important for the level of acceptance. Clearly explaining the objectives and expected effects may therefore be an important aspect of the communication strategy of the government.

Measure 2: Kilometre charge dependent on vehicle weight with different revenue use
Table 9.3 shows the estimation results for the second measure. Again, we see the importance of the VOT and compensation of costs by the employer. Education is not as important as for measure 1. One explanation may be that measure 2 (like 3) is more easily accepted on the basis of equity arguments, which require less intellectual effort than effectiveness or efficiency. A striking difference with the previous estimation is the difference between the (sub-) types of measure. Measures C, E and F received significantly more support than measure G, but also than the other 3 variants of this measure. This suggests that when revenues from the charge are used to lower or abandon existing car taxation (2B and 2E) or fuel taxes (2F), more public support is obtained. The weight of the car (and also the number of kilometres driven yearly) does not have a significant impact, despite the fact that this measure differentiates on this characteristic. Again, perceived general effectiveness in terms of congestion and personal effectiveness have a significant impact on the level of acceptance. We have included the effectiveness in terms of less congestion into the estimation and not the effectiveness on the environment despite its possible relevance here. These two variables are again strongly correlated and have equal results in terms of significance. The mean score on environmental effectiveness is only slightly higher than the perceived effectiveness on congestion (it is not "very probable" that congestion will decrease or that the environment will benefit from this measure). Given the nature of this measure, a greater difference might have been expected. Personal effectiveness shows almost the same (irregular) pattern that we found for measure 1, and again the same hypothesis applies here.
The analysis indicates that (as expected) revenue use is an important explanatory variable for the acceptance level. Revenue allocations that are in the direct interest of the individual are more popular. This confirms the findings of other studies such as Verhoef (1996). Characteristics of individual specific (mobility) behaviour tend to be of less relevance, except for the value of time. The perceived level of effectiveness of the measure by the respondents is important (as also confirmed by the results of Steg (2003)).

Table 9.3: Results of ordered probit analysis with the acceptance of measure 2 as the dependent variable

Variable	**Probit ACC measure 2**	**Sign.**
Threshold (μ's)		
μ_1	-.263 (.443)	
μ_2	.609 (.444)	
μ_3	.943 (.445)	**
μ_4	1.267 (.445)	***
μ_5	1.898 (.448)	***
μ_6	3.073 (.461)	***
Gross yearly income	-2.51E-02 (.019)	
Gender (female)	-7.49E-02 (.119)	
Education (Edu1 (primary school) = base)		
Edu2 (junior general sec.)	-.115 (.223)	
Edu3 (intermediate vocational)	8.12E-02 (.151)	
Edu4 (senior general sec.)	.213 (.193)	
Edu5 (Bachelor)	.260 (.149)	*
Edu6 (Baster)	.424 (.184)	**
Loc1 (3 large cities)	-7.00E-02 (.119)	
Childyes	1.23E-02 (.110)	
Age (Age5 (56+) = base)		
Age1 (18-25)	-8.21E-02 (.245)	
Age2 (26-35)	-.289 (.199)	
Age3 (36-45)	-.204 (.206)	
Age4 (46-55)	-.255 (.207)	
Travel time in congestion/free flow tt	2.05E-02 (.073)	
Type of measure (measure 2G = base)		
M2A (revenues to general budget)	-.139 (.173)	
M2B (traffic system in general)	-2.69E-02 (.178)	
M2C (lower car taxes and new roads)	.469 (.176)	***
M2D (public transport)	.138 (.172)	
M2E (abandon existing ownership tax)	.471 (.177)	***
M2F (lower existing fuel taxes)	.524 (.176)	***
Number of kilometres driven yearly	-2.55E-06 (.000)	
Compensation of costs by employer (full compensation = base)		
Comp1 (no transport costs paid by employer)	-.372 (.160)	**
Comp2 (transport costs partly compensated)	-.246 (.106)	**
Vehicle weight (Weight3 (heavy weight) = base)		
Weight1 (low weight)	.187 (.187)	
Weight2 (middle weight)	.131 (.156)	
VOT	2.37E-02 (.010)	**
General effectiveness (less congestion) (Geff1 = base)		
Geff2	.637 (.139)	***
Geff3	.887 (.168)	***
Geff4	.846 (.193)	***
Geff5	1.216 (.184)	***
Geff6	1.258 (.275)	***
Geff7	2.287 (.790)	***
Personal effectiveness (drive less yourself) (Peff1 = base)		
Peff2	.275 (.138)	**
Peff3	.400 (.180)	**
Peff4	.187 (.189)	
Peff5	.420 (.187)	**
Peff6	.242 (.244)	
Peff7	-.204 (.316)	
N	564	
Log-likelihood	-935.406	***
Pseudo R-square	Cox and Snell	.272
	Nagelkerke	.280
	McFadden	.087

Notes: The standard errors are shown in brackets. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively, (two-sided *t*-test).

Measure 3: Kilometre charge with different toll levels and revenue uses

The third measure that we have analysed consists of 9 sub-measures that combine one out of three types of revenue use with one out of three levels of a charge. Two sets of dummy variables thus define the type of measure: one for the type of revenue use and one for the level of the charge. Table 9.4 shows the results for this estimation. It is interesting to see that the level of acceptance very much depends on the way revenues are redistributed, and (but less so, for the values considered) the level of the charge (as may be expected). Higher charges are relatively less acceptable, and the abolition of existing car taxes is far more acceptable than an unclear revenue use (note the high coefficient), and somewhat more acceptable than the construction of new roads. This is consistent with finding that measure 3G (combination of low charge and abandoning of existing car taxes) is relatively most acceptable (confirmed by the results shown in Figure 9.1). It is remarkable that the weight of the vehicle has an explanatory impact here. This may have something to do with the fact that the previous measure 2B was differentiated according to weight. In indicating acceptance respondents may have compared measure 3 with that measure; and therefore people with smaller cars now find this measure less acceptable. Expected effectiveness again has a very significant impact on the level of acceptance. Commuters who indicate that the measure will be effective are less opposed to this measure. The respondents' value of time, education and personal effectiveness seem to lose importance compared with the other measures. In contrast to the previous measures, personal effectiveness is no longer significant. It is not clear what causes these differences with the previous cases.

The predictability of the charge level and the complexity of the measure may not be important (see measure 1), but the level of the charge and the revenue use is relevant. Individual characteristics are less important in explaining the level of acceptance. The differences between groups are small, which makes it difficult for governments to specify certain groups that may be compensated to increase acceptance.

Table 9.4: Results of ordered probit analysis with the acceptance of measure 3 as the dependent variable

Variable	**Probit ACC measure 3**	**Sign.**
Threshold (μ's)		
μ_1	-2.43E-02 (.440)	
μ_2	.960 (.441)	**
μ_3	1.331 (.442)	***
μ_4	1.728 (.444)	***
μ_5	2.325 (.447)	***
μ_6	3.405 (.459)	***
Gross yearly income	1.06E-02 (.019)	
Gender (female)	-.3.05E-02 (.120)	
Education (Edu1 (primary school) = base)		
Edu2 (junior general sec.)	-.156 (.233)	
Edu3 (intermediate vocational)	8.14E-02 (.154)	
Edu4 (senior general sec.)	8.38E-02 (.196)	
Edu5 (Bachelor)	.280 (.151)	*
Edu6 (Master)	.194 (.187)	
Loc1 (3 large cities)	-5.31E-02 (.122)	
Childyes	-7.00E-02 (.111)	
Age (Age5 (56+) = base)		
Age1 (18-25)	-.102 (.251)	
Age2 (26-35)	-.129 (.201)	
Age3 (36-45)	-9.25E-02 (.208)	
Age4 (46-55)	-.218 (.210)	
Travel time in congestion/free flow tt	4.58E-03 (.074)	
Charge level for measure 3 (2.5 €cents = base)		
Charge=5 €cents (dummy)	-.273 (.114)	**
Charge=7.5 €cents (dummy)	-.536 (.115)	***
Revenue use for measure 3 (unclear = base)		
Revenue use is new roads (dummy)	.270 (.118)	**
Revenue use is abandon car taxes (dummy)	1.235 (.123)	***
Number of kilometres driven yearly	-2.15E-06 (.000)	
Compensation of costs by employer (full compensation = base)		
Comp1 (no transport costs paid by employer)	-.358 (.163)	**
Comp2 (transport costs partly compensated)	-.180 (.106)	*
Vehicle weight (Weight3 (heavy weight) = base)		
Weight1 (low weight)	-.520 (.189)	***
Weight2 (middle weight)	-.335 (.157)	**
VOT	1.84E-02 (.010)	*
General effectiveness (less congestion) (Geff1 = base)		
Geff2	1.050 (.159)	
Geff3	1.230 (.185)	***
Geff4	1.090 (.218)	***
Geff5	1.605 (.205)	***
Geff6	1.779 (.284)	***
Geff7	.650 (.652)	***
Personal effectiveness (drive less yourself) (Peff1 = base)		
Peff2	4.23E-02 (.149)	
Peff3	-2.56E-02 (.202)	
Peff4	.150 (.198)	
Peff5	8.76E-02 (.204)	
Peff6	9.21E-02 (.247)	
Peff7	-.276 (.351)	
N	564	
Log-likelihood	-873.327	***
Pseudo R-square	Cox and Snell	.408
	Nagelkerke	.419
	McFadden	.145

Notes: The standard errors are shown in brackets. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively, (two-sided *t*-test).

Revenue use only
Finally, we asked the respondents for their opinion on the allocation categories of the revenues per se, so without defining the road pricing measure. Six different possibilities were evaluated on acceptance by the respondents (general budget, new roads, improve public transport, abandon existing car taxation, lower fuel taxes, and lower income taxes). The findings presented in Figure 9.2 are largely in line with the previous findings of revenue use as part of a road pricing measure. An abolition of existing car taxes is most preferred (a mean score of 5.85, a 6 is 'acceptable'), whereas the general budget is 'unacceptable'. The construction of new roads is valued rather positively here, while the acceptability of measure 2G (kilometre charge with the same type of revenue use) is considerably lower (see Figure 9.1). More than 74% of the respondents indicated that the general budget is 'unacceptable' or 'very unacceptable' (see Appendix 9c). The confidence intervals are smaller than those of the road pricing measures (see Figure 9.1), indicating less variance in the answers.

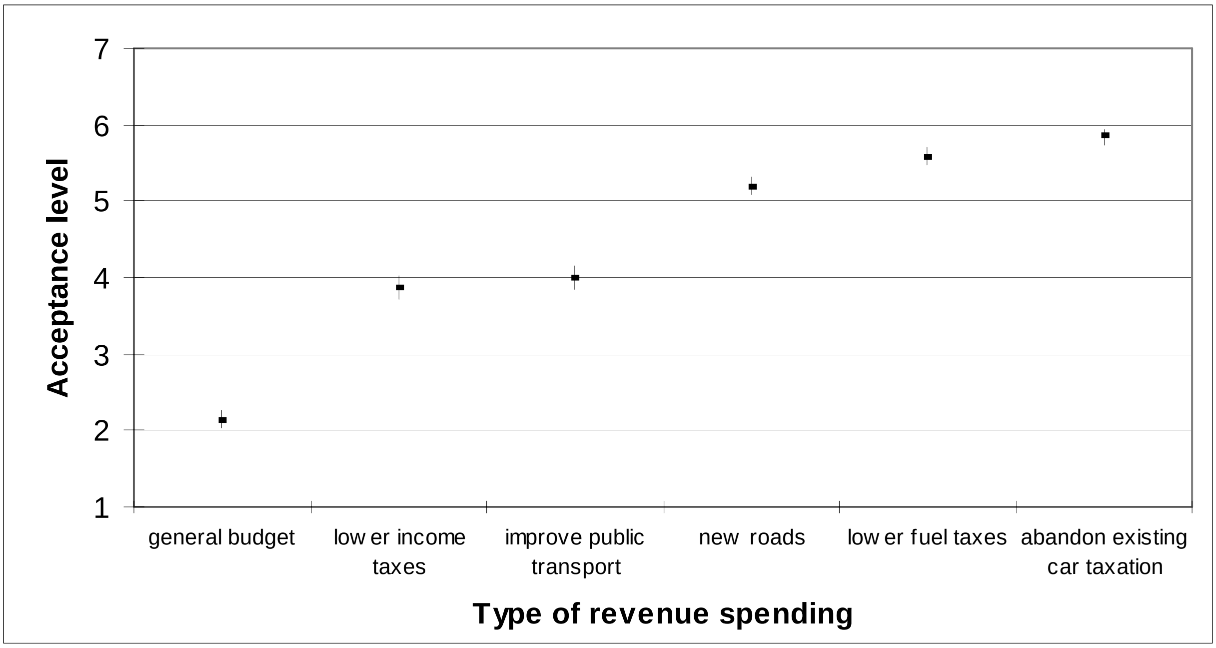


Figure 9.2: Mean and 95% confidence intervals of acceptance scores on each type of revenue use (level 1 = very unacceptable; level 7 = very acceptable)

We have carried out a similar type of (ordered probit) analysis as we did for the road pricing measures, in order to explain the acceptance levels for these types of revenue use. When policy makers want to compensate certain groups, it is useful for them to know the preferences of these groups. The estimations of the preferred results can be found in Appendix 9d. Again, for each type of revenue use the same explanatory variables have been included after having tried various specifications of the model (by including and excluding variables that may be expected to have some explanatory power).
The results differ greatly over the various types of revenue use. Income is only significant when revenues are used to lower income taxes or to construct new roads. Lower income groups dislike revenues to be used for new roads more than people with a higher income, whereas the opposite holds when revenues are used to lower income taxes. The explanation for the first finding could be that lower income people drive less. For the second finding, the higher marginal utility could be an explanation. Hence, when policy makers propose to compensate the lowest income groups by lowering income taxes they obtain most support from this category (although overall support levels for this type of measure are rather modest). Another interesting variable is the compensation of costs by the employer. As may

be expected, respondents who are not or only partly compensated have in general more support for abolition of existing car taxation than people who do not have to pay these taxes. This may also explain the disapproval of revenues being used for the general budget by people without full compensation; personal compensation is a better objective for this group. The weight of the vehicle seems important for two targets: lower fuel taxes and improvement of public transport. Owners of smaller vehicles (with lower weights) find lower fuel taxes less acceptable than others, this may be explained by the fact that this group drives relatively more fuel efficiently and consequently benefits less than people with large (and heavy) cars. The importance of the VOT for certain allocation categories (i.e. general budget and improvement of public transport) seems somewhat strange and inexplicable.
The findings on acceptance for revenue use targets are similar to earlier reported results in the literature. The allocation objectives that are in the direct interest of the road users receive most support. Improvement of public transport is less acceptable in comparison with the findings of Schade and Schlag (2000). Revenues may theoretically ideally be used to reduce distortive income taxes (which is beneficial from a welfare perspective), but support for this option from Dutch commuters is low.

9.3 Acceptance and revenue use: a survey among car owners

We conducted a second survey to assess acceptance levels of very specific, policy-relevant, road pricing measures. In this survey, variabilisation of the present tax system is the focus. Different types of a kilometre charge have been combined with two different forms of revenue spending: income tax compensation, and car tax abolition. Such a change in the tax structure will affect car users in general, not only car commuters. The sample is, therefore, different from the previous survey; all respondents are car owners. This is the relevant group when policy makers consider a reform of the road taxation system, as described by the proposed measures. It is important to know the acceptance levels of this group. Note that this sample is equal to the one that is described in Chapter 5; respondents answered both acceptance as well as effectiveness questions. A brief overview of effectiveness and acceptance scores for the measures considered is given in Section 9.3.4.
Because the objectives and the structure of the data are similar to the analysis discussed in Section 9.2, we have chosen a comparable approach in this section. The differences are the survey sample and the road pricing measures that have been evaluated. Again, we start with an explanation of the data collection including the survey sample. We apply the same methodology, which will not be explained again (see Section 9.2.3 for this explanation).

9.3.1 Data collection and survey

The data have been obtained by conducting an Internet survey among Dutch car owners. The total sample consists of 562 respondents, of whom 288 are car commuters who experience congestion on a regular basis (the respondents included in the survey discussed in the previous section). The respondents were again confronted with three different road pricing measures. First, we asked them to indicate their intentions to change their driving behaviour when these measures are actually implemented. The results from this part of the survey (on the effectiveness of road pricing) were discussed earlier in Chapter 5. Secondly, we addressed the issue of the acceptance of the three different measures. These outcomes will be analysed in this section.
The data were collected during three weeks in February 2005. The survey began with some general and personal questions, providing important information on the respondents that may help explain the differences in (self-reported) effectiveness and acceptance levels. Most variables of interest are explained in Appendix 9e, which also shows the profile of our sample (Section 5.2.2 discusses this profile).

The respondent was confronted with three different types of road pricing measures. All descriptions of the measures consisted of two major components: we explained the level of the charge and the allocation of the revenues. Furthermore, we provided each respondent individually with an estimation of the financial consequences of the implementation of the proposed measure under unchanged behaviour. Answers to previous questions allowed us to calculate the costs in the new situation. 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 current behaviour. The financial benefits depend on the type of revenue use (only for those measures where existing car taxes are abolished)[24]. This is different from the previous survey where we only presented the costs for an average driver and neglected the type of revenue use and type of car. We also explained some practical issues with the intention to minimise biases due to the more practical aspects of kilometre charging; the privacy of car users is guaranteed, electronic equipment registers the toll and the driver can freely choose the payment method (e.g. credit card, bank transfer, etc.).

Table 9.5: Short description of the road pricing measures presented to the respondents

Measure	Variant
1:Kilometre charge with different charge levels and different revenue allocations	1A: 3 €cents, abolition of car ownership taxes 1B: 6 €cents, abolition of existing car taxation (purchase and ownership) 1C: 12 €cents, abolition of existing car taxation and new roads 1D: 3 €cents, revenues used to lower income taxes 1E: 6 €cents, revenues used to lower income taxes 1F: 12 €cents, revenues used to lower income taxes
2:Kilometre charge differentiated according to time (2A) or weight of the vehicle (2B)	2A: 2 €cents with multi-step (morning and evening) peak-time charge, revenues used to abolish car ownership taxes 2B: differentiated according to weight of the car, revenues used to abolish existing car taxation
3: Peak and off-peak kilometre charge, different revenue allocations	3A: 2 €cents outside peak times and 6 €cents in peak, abolition of car ownership taxes 3B: 4 €cents outside peak times and 12 €cents in peak, abolition of existing car taxation 3C: 8 €cents outside peak times and 24 €cents in peak, abolition of existing car taxation and new roads 3D: 2 €cents outside peak times and 6 €cents in peak, revenues used to lower income taxes 3E: 4 €cents outside peak times and 12 €cents in peak, revenues used to lower income taxes 3F: 8 €cents outside peak times and 24 €cents in peak, revenues used to lower income taxes

Table 9.5 shows the various measures that have been composed: 6 different variants for measure 1, 2 variants for measure 2, and again 6 variants for the third measure (a more detailed description can be found in Appendix 9f). All variants were randomly divided over the respondents, and each respondent evaluated one variant of each measure (so three in total). This means that we obtained at least 88 observations for each variant of measure 1, 282 for measure 2A and 280 for measure 2B, and at least 88 for each variant of measure 3.

9.3.2 General results

Before investigating the distribution of the levels of acceptance, we begin with an overview of the average acceptance levels for each single measure. Figure 9.3 shows the mean acceptance outcomes and the confidence intervals.

[24] The benefits from paying less car taxation depend on the type of car that the respondents own (fuel and weight). We have estimated averages for nine categories (a combination of three fuel types and three weight categories), for an abolition of car ownership taxes (MRB) only, and for an abolition of all existing car taxation (MRB and BPM).

The mean level of acceptance for all different measures varies around 3, on a scale of 7, which was described, in words, as 'somewhat unacceptable'. This is similar to what we found for the measures discussed in the previous section, despite the differences in structure. The variation in answers given by the respondents is very small. Measure 1F (a charge of 12 €cents, with revenues allocated to lower income taxes) is least popular and classified as unacceptable, whereas even the most acceptable (or better: least unacceptable) measures, 1A and 1B, are below the neutral category.
The patterns of outcomes for measures 1 and 3 may, in the first place, be explained by the structure of the measure. Increasing charge levels (measure 1A to 1C, 1D to 1F and measure 3A to 3C, 3D to 3F) are generally less acceptable. The exceptions of 1B (relative to 1A) and 3C (relative to 3B) may be explained by the fact that the increase in charge levels is more or less off-set by increased compensation levels.
The allocation of the revenues is the other characteristic of the measures that may explain the difference in acceptance between these sets of variants. In most cases, the respondents seem to prefer revenues being used for the abolition of car taxation over that of lowering income taxes. The only exception is measure 3E, which is more popular than measure 3B. Appendix 9e shows the percentages of respondents who find the various measures 'unacceptable' or 'very unacceptable'. These outcomes confirm the previously described 'mean' pattern. For instance, measure 1F and measure 3F are least acceptable, not only on average acceptance but also in terms of the number of respondents (about 70% of the respondents) who find these "unacceptable" or "very unacceptable"). This figure drops below 40% for measures 1A, 1B and 2B; these measures are clearly more popular.

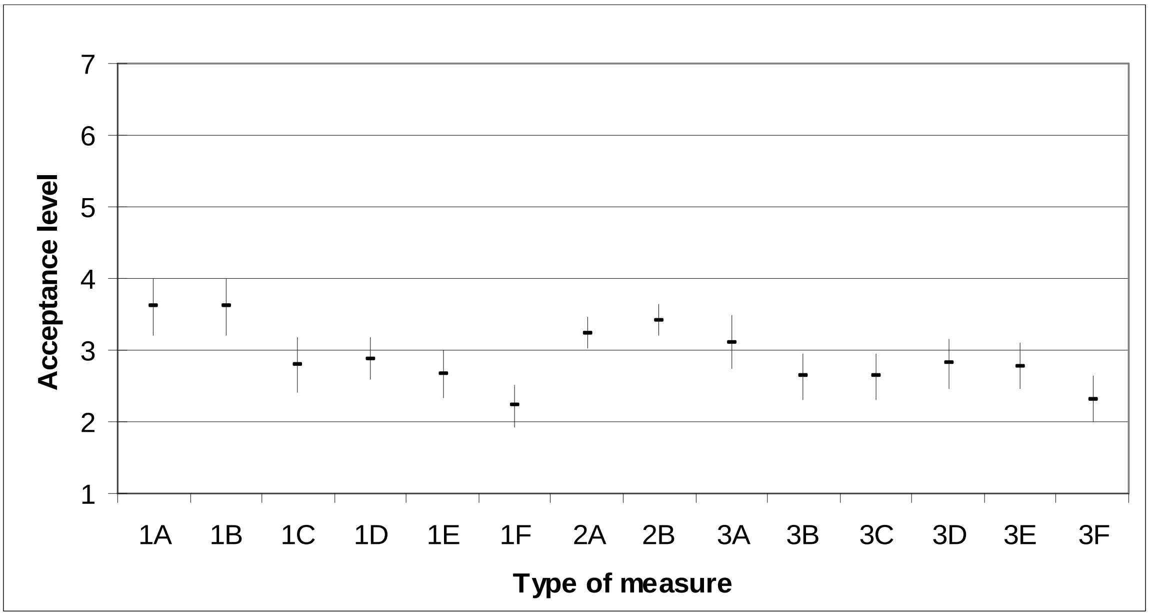


Figure 9.3: Mean and 95% confidence intervals of acceptance scores on each single measure (level 1 = very unacceptable; level 7 = very acceptable)

9.3.3 A search for explanatory variables of acceptance levels for 3 road pricing measures
We applied the same (ordered probit (OP)) technique as we did in the previous section to analyse the data. Again, we tried various specifications of the model for all measures (by including and excluding variables that may be expected to have some explanatory power). The following tables present our preferred specifications.

Measure 1: Flat kilometre charge and varying revenue use

Table 9.6 presents the estimation results for measure 1. The first row presents the estimates for the threshold values (μ's) explained above. The second row presents all explanatory variables that have been included in the estimation. It appears that the type of measure (in terms of charge level and revenue use) is very important for the level of acceptance. The signs of the coefficients are as expected: the measures with a kilometre charge of 3 and 6 €cents are more acceptable than the 12 €cents measure. Allocating the revenues to lower the income taxes is less popular than a decrease of current car taxation. This result corresponds with previous findings (see also the results of the other questionnaire), which may be explained by the lower perceived costs for the individual. We have estimated the financial benefits from an abolition of road taxes, and presented this to the respondents together with the estimated costs from the charge. Unfortunately, this was not possible for the other type of revenue use (lower income taxes).

The weight of the car and the number of kilometres driven yearly are also significant. Respondents owning a heavy car find this measure relatively more acceptable than people with smaller cars. This may be explained by the impact of the type of revenue use, since current Dutch car taxation is differentiated according to the weight of the car. Owners of heavier cars pay relatively more taxes and benefit more than other car owners. But this only holds for three of the six variants. Assuming that heavier (and more expensive) cars are owned by higher income people, this is the same group that benefits relatively more from an income tax reduction. This may also explain the importance of weight for the other three variants (D to F). It seems rather plausible that people who use the car intensively (driving many kilometres) are relatively more against a kilometre charge than others. It is this group that will pay most.

The perceived level of 'general effectiveness' in terms of (reducing) congestion has (again) an important impact on acceptance. The results suggest that respondents who think that the measure will be effective also tend to find it more acceptable (note that the base is different from the previous survey, which explains the negative signs here). Since we have information on the self-reported behavioural changes of the respondents (in terms of the proportion of trips that will be changed), it is also possible to include 'personal effectiveness' into the analysis. The 'self-reported behavioural change' dummy is not significant, suggesting no difference in impact on the level of acceptance between respondents who do and do not expect to change their behaviour. We also found this also for a similar type of measure (measure 3) in the previous survey.

The highest income group (inc4) is slightly more positive about the measure than the other income groups. While income seems not to be very important, employment is. People who have a job are more opposed to the measure than others. This group may also use the car for commuting reasons (not every employed person makes commuting trips by car, about 9.5% of this group uses another mode), and our data confirms that commuters in most cases drive more kilometres. It is also this group that tends to experience congestion relatively more often, so the employment dummy may include this effect. However, we included a separate variable accounting for the number of times in congestion. The effect is modest (with the expected sign), but becomes stronger when the employment dummy is left out of the analysis, thus confirming our previous suspicion. Apparently this group does not expect the measure to be effective, even though they may benefit relatively most from reduced levels of congestion. We did test the impact of the compensation of costs by employers, but this was not important. The same holds for education, which is also correlated with income.

Table 9.6: Results of ordered probit analysis with the acceptance of measure 1 as the dependent variable

Variable	Probit ACC measure 1	Sign.
Threshold (μ's)		
μ_1	-3.451 (.739)	***
μ_2	-2.617 (.737)	***
μ_3	-2.214 (.736)	***
μ_4	-1.827 (.735)	**
μ_5	-1.360 (.733)	*
μ_6	-.285 (.732)	
Age	-.003 (.004)	
Income (inc5 (do not know/won't say) = base)		
Inc1 (< € 28,500)	.226 (.280)	
Inc2 (€ 28,500-45,000)	.314 (.276)	
Inc3 (€ 45,000-68,000)	.299 (.280)	
Inc4 (>€ 68,000)	.523 (.291)	*
Type of measure (charge, dummy 12 €cents = base)		
charge 3 €cents	.606 (.114)	***
charge 6 €cents	.486 (.114)	***
Type of measure (revenue use)		
Dummy income taxes	-.457 (.093)	***
Number of kilometres driven yearly	-7.27E-06 (.000)	**
Vehicle weight (dummy weight3 = base)		
Weight1 (low weight)	-.408 (.134)	***
Weight2 (middle weight)	-.306 (.116)	***
General effectiveness (less congestion) (Geff7 = base)^		
Geff1	-2.341 (.642)	***
Geff2	-1.917 (.639)	***
Geff3	-1.763 (.649)	***
Geff4	-1.462 (.668)	**
Geff5	-1.321 (.653)	**
Geff6	-.948 (.734)	
Self-reported behavioural change (dummy = yes)	.057 (.099)	
Employed (dummy = yes)	-.494 (.148)	***
Residential location (south = base)		
Loc1 (3 large cities)	-.238 (.150)	
Loc2 (rest west)	-.166 (.124)	
Loc3 (north)	-.126 (.201)	
Loc4 (east)	-.231 (.134)	*
Weekly number of times in congestion	-.030 (.017)	*
N	562	
Log-likelihood	-917.490	***
Pseudo R-square	Cox and Snell	.250
	Nagelkerke	.258
	McFadden	.081

Notes: The standard errors are shown in brackets. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively, (two-sided *t*-test). ^ For comparison reasons (measure 2B has no geff7 observations) we use geff7 as base (and not geff1).

Resuming, we may conclude that characteristics of the measure (level of charge, allocation) and mobility-related behaviour have an impact on the level of acceptance. Variabilisation with low kilometre charges are less opposed. Acceptance levels tend to be lower among people that often experience congestion. This is also the group who does not believe in the effectiveness of the measure. Policy makers may therefore target their communication strategy on this group when explaining the objectives and reducing opposition.

Measure 2: Kilometre charge differentiated according to time (2A) or weight of the car (2B)

The two variants of measure 2 are very different: a flat fee with a bottleneck charge during peak hours (2A), and a charge differentiated according to the weight of the vehicle (2B). For this reason, we have estimated two models, a separate one for each variant. There is also a significant difference in acceptance levels between these two variants. When estimating one model for the whole data set, it appears that the bottleneck charge (2A) is less acceptable than measure 2B (as suggested by Figure 9.3). This may be due to the considerable costs involved for peak-hour drivers (48% of the respondents who evaluated measure 2A indicated that they encounter a bottleneck at least once). Table 9.7 presents the estimation results for both variants. There are similarities but also some differences between the two variants. Both measures are a kilometre charge, so it is not so surprising that the number of kilometres driven is significantly important, with frequent car users being less supportive. A similar result is found for the number of times that respondents experience congestion. This may be somewhat surprising because measure 2A affects peak hour drivers relatively more and might therefore be less acceptable to drivers who experience congestion.

Table 9.7: Results of ordered probit analysis with the acceptance of measure 2A and 2B as the dependent variable

Variable	**Probit ACC measure 2A**	**Sign.**	**Probit ACC measure 2B**	**Sign.**
Threshold (μ's)				
μ_1	-4.426 (1.221)	***	-.218 (.889)	
μ_2	-3.568 (1.216)	***	.633 (.890)	
μ_3	-3.071 (1.214)	**	1.090 (.891)	
μ_4	-2.629 (1.212)	**	1.533 (.891)	*
μ_5	-2.152 (1.210)	*	2.001 (.893)	**
μ_6	-1.091 (1.208)		3.227 (.906)	***
Age	.004 (.005)		-.004 (.006)	
Income (inc5 (do not know/won't say) = base)				
Inc1 (< € 28,500)	.299 (.334)		1.748 (.661)	***
Inc2 (€ 28,500-45,000)	.023 (.325)		1.951 (.661)	***
Inc3 (€ 45,000-68,000)	.134 (.329)		1.861 (.663)	***
Inc4 (>€ 68,000)	.353 (.354)		2.037 (.675)	***
Number of kilometres driven yearly	-2.34E-05 (.000)	***	-9.38E-06 (.000)	***
Vehicle weight (dummy weight3 = base)				
Weight1 (low weight)	-.687 (.191)	***	.241 (.197)	
Weight2 (middle weight)	-.428 (.167)	***	-.072 (.169)	
General effect. (less congestion) (Geff7 = base)				
Geff1	-3.132 (1.113)	***	-.828 (.447)	*
Geff2	-2.663 (1.111)	**	-.334 (.442)	
Geff3	-2.168 (1.120)	*	-.204 (.478)	
Geff4	-1.946 (1.126)	*	.287 (.503)	
Geff5	-2.003 (1.115)	*	.230 (.522)	
Geff6	-1.472 (1.132)		0^	
Self-reported behavioural change (dummy = yes)	-.158 (.147)		-.176 (.155)	
Employed (dummy = yes)	-.275 (.210)		-.073 (.215)	
Residential location (south = base)				
Loc1 (3 large cities)	-.180 (.233)		-.145 (.202)	
Loc2 (rest west)	.216 (.180)		.310 (.175)	*
Loc3 (north)	-.165 (.272)		-.111 (.304)	
Loc4 (east)	.005 (.191)		-.066 (.195)	
Weekly number of times in congestion	-.049 (.025)	**	-.054 (.023)	**
N	282		280	
Log-likelihood	-461.738		-481.436	
Pseudo R-square	Cox and Snell	.333	Cox and Snell	.214
	Nagelkerke	.342	Nagelkerke	.219
	McFadden	.110	McFadden	.065

Notes: The standard errors are shown in brackets. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively, (two-sided *t*-test). ^ Geff7 is for all respondents 0, so for measure 2B Geff6 + Geff7 = base.

It is counterintuitive that the weight of the car is important for measure 2A and not for 2B (differentiated according to weight of the vehicle). Measure 2B might have been expected to be more acceptable to small vehicle owners because of the lower charge level, but our results do not confirm this. The allocation of revenues differs between the two measures, and the

abolition of purchase taxation (included in measure 2B) may explain why we do not find this effect. We do find the opposite effect (more acceptance among heavy vehicle owners) for measure 2A, similar to what we found for measure 1. The explanation may be the same. The importance of income for measure 2B can be explained by the relatively few respondents of the fifth (reference) income category who have a relatively low level of acceptance.
Again we see the importance of the perceived general effectiveness in terms of congestion (with lower acceptance levels among those who think that the measure will not be very effective), but only for measure 2A. On average, it would be expected that the bottleneck measure is more effective in solving congestion than measure 2B. Respondents who do not believe in the effectiveness of measure 2A tend to find the measure less acceptable.
While a bottleneck charge may be more effective, it is not more acceptable. Those who think that the measure is not effective are also indicating that this measure is not very acceptable; protest voting may be involved here. Remarkable from the analyses is that policy makers can not necessarily count on more acceptance among small vehicle owners when considering a weight-based kilometre charge. The type of revenue allocation may be of crucial importance here. Again, for both measures here, the importance of the group who drives many kilometres and often experience congestion is significant.

Measure 3: Peak and off-peak kilometre charge and different revenue allocations
The third measure that we have analysed consists of 6 sub-measures. The charge depends on time of driving, and revenues are allocated to lower income taxes or to abolish fixed road taxation. The charge levels differ considerably, ranging from an extra peak-period charge of 6 €cents per kilometre to one of 24 €cents. The results in Table 9.8 indicate that, as may be expected, the lowest charge level is more acceptable than the highest charge level. The difference with the 12 €cent level is not significant. The impact of revenue use is less obvious. The earlier conclusion in Section 9.2.3 and the above measure 1 for this survey that income tax reductions are less popular is not confirmed here.
The weight of the vehicle again has an explanatory impact. Effectiveness has only a significant impact for the group who finds the measure very ineffective: these respondents are generally more opposed than the rest. The financially most-affected respondents, those experiencing daily congestion, find the measure less acceptable. Employed people, in general, also tend to find this measure less popular, many of them being car commuters. In contrast with the results from the previous measures, the number of kilometres driven has no explanatory importance. When we test the importance of education (replacing income), it appeared that higher educated people find the measure more acceptable at the 1% significance level.
This measure is really targeted at reducing congestion with high peak-charge levels. Acceptance levels are generally lower when charge levels increase. The results for this measure suggest that there may exist some sort of a limit after which increasing the charge no longer matters. There is no significant difference between a peak charge of 12 €cents and one of 24 €cents. The individuals who potentially benefit most from reduced congestion levels are again also most opposed, probably because of the high financial burden when behaviour is not changed. Effectiveness therefore seems a crucial point of attention in communication when high (time-differentiated) charge levels are considered. The importance of revenue allocation with this type of measures seems to decrease.

Table 9.8: Results of ordered probit analysis with the acceptance of measure 3 as the dependent variable

Variable	**Probit ACC measure 3**	**Sign.**
Threshold (μ's)		
μ_1	-1.637 (.529)	***
μ_2	-.759 (.527)	
μ_3	-.370 (.527)	
μ_4	.149 (.527)	
μ_5	.805 (.529)	
μ_6	1.618 (.541)	***
Age	-9.76E-06 (.004)	
Income (inc5 (do not know/won't say) = base)		
Inc1 (< € 28,500)	.154 (.283)	
Inc2 (€ 28,500-45,000)	.301 (.280)	
Inc3 (€ 45,000-68,000)	.311 (.282)	
Inc4 (>€ 68,000)	.376 (.295)	
Type of measure (charge, dummy 24 €cents = base)		
charge 6 €cents	.424 (.113)	***
charge 12 €cents	.133 (.115)	
Type of measure (revenue use)		
Dummy income taxes	-.060 (.094)	
Number of kilometres driven yearly	-4.64E-06 (.000)	*
Vehicle weight (dummy weight3 = base)		
Weight1 (low weight)	-.288 (.136)	**
Weight2 (middle weight)	-.299 (.118)	**
General effectiveness (less congestion) (Geff7 = base)		
Geff1	-1.444 (.382)	***
Geff2	-.589 (.377)	
Geff3	-.389 (.394)	
Geff4	-.044 (.401)	
Geff5	.101 (.387)	
Geff6	.080 (.404)	
Self-reported behavioural change (dummy = yes)	-.018 (.098)	
Employed (dummy = yes)	-.355 (.149)	**
Residential location (south = base)		
Loc1 (3 large cities)	-.137 (.156)	
Loc2 (rest west)	.042 (.127)	
Loc3 (north)	-.039 (.204)	
Loc4 (east)	.066 (.137)	
Weekly number of times in congestion	-.071 (.017)	***
N	562	
Log-likelihood	-857.254	***
Pseudo R-square	Cox and Snell	.302
	Nagelkerke	.313
	McFadden	.106

Notes: The standard errors are shown in brackets. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively, (two-sided *t*-test).

9.3.4 Effectiveness and acceptance

We not only know the acceptance scores for the three different road pricing measures discussed here; from Chapter 5 we also know the effectiveness scores. It is interesting to compare the measures and find out whether there is a trade-off between effectiveness and acceptance. Figure 9.4 illustrates the differences in the scores for all 14 different variants. Effectiveness of a measure is here defined as the number of trips that will be adjusted for all travel purposes (as indicated by the respondents) as a percentage of the total trips made. The acceptance scores are the mean scores that follow from Figure 9.3. Note that we can only make this comparison for the group of car owners, and that effectiveness is the self-reported effectiveness (and not the perceived level of effectiveness).

The pattern weakly suggests a trade-off between acceptance and effectiveness. The measures with high charge levels (1F and 3F) have low acceptance scores and rather high effectiveness levels. The opposite holds for measures 1A and 1B. Interesting exceptions are measure 3A and 2A, both time-differentiated measures with relatively low charge levels. These seem to be relatively effective and acceptable (although still not ‘very acceptable’).

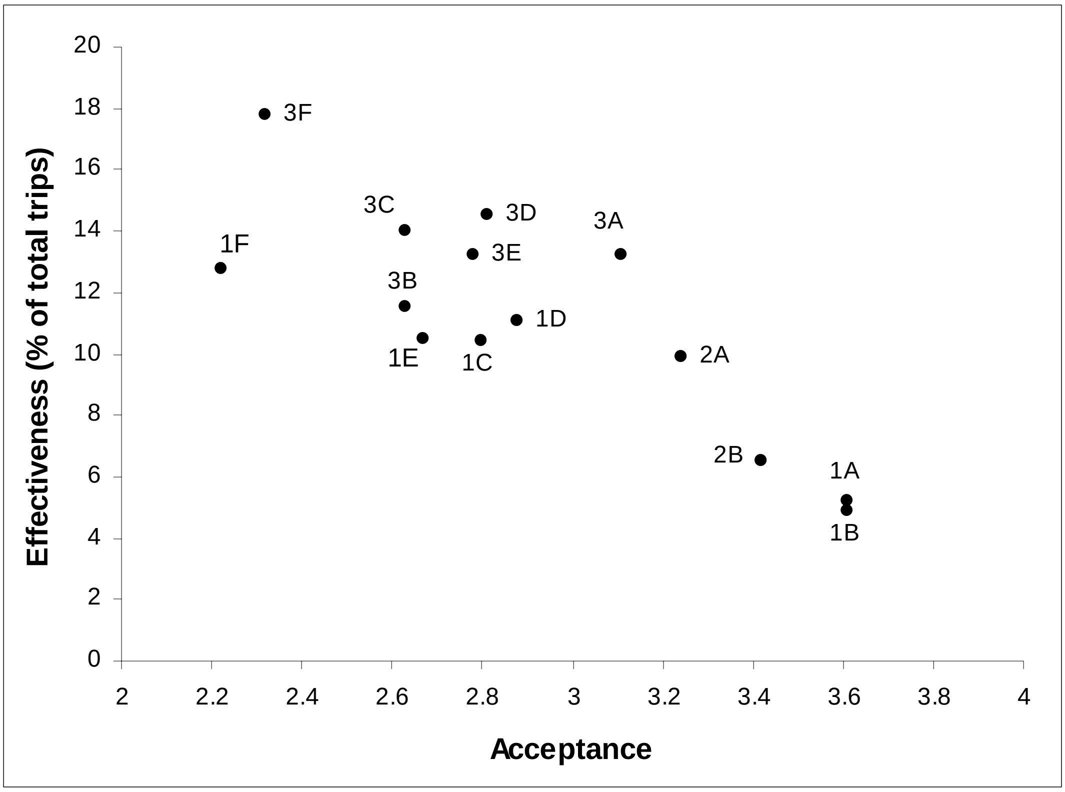


Figure 9.4: Effectiveness and acceptance scores for the different variants

9.4 Overview and comparison

After a discussion of such a variety of measures, it is useful to summarise and compare. We focus on the differences between the two surveys. The first three measures were evaluated by car commuters experiencing congestion, whereas the latter three measures were assessed by car owners in general. Besides differences in sample size and type of sample, also different types of measures have been evaluated. Moreover, in the ‘car owner’ survey we provided the respondents with a more refined cost estimation when revenues were used to abolish car taxation. Table 9.9 shows the most important results for both surveys.

Despite the described differences in surveys, we did find comparable mean scores: most measures are not very acceptable. Variabilisation in the car commuters survey (measures 3G, 3H, and 3I) seems slightly less unacceptable, which may be explained by the somewhat lower charge levels compared with all measures in the second survey among car owners. The difference in charge levels may also explain why findings of the survey among car owners indicate that car commuters are slightly less positive. Characteristics that apply to this group, such as the weekly number of times in congestion, being employed, and the number of kilometres driven, have a significant and negative impact on the level of acceptance. Somewhat higher charge levels weaken the slightly more positive attitude of the sample. This also suggests that the general public, who uses the road less often, seems less opposed.

Both surveys confirm that respondents who indicate that the measure will be effective in reducing congestion tend to find the measures more acceptable. In contrast, vehicle weight only matters for car owners, and compensation of costs was only significant with commuters (note that 17.3% of the respondents were not employed in the second survey). The value of time was only available for respondents in the first survey.

Table 9.9: Comparison of both surveys

	Commuters (N=564)	**Car owners (N=562)**
Measures evaluated	• Diverse • Revenue use included (also separately)	Kilometre charges combined with two types of revenue use
Mean acceptance score	Not very acceptable ('3'), with variabilisation more acceptable	Not very acceptable ('3'), not much variation
Statistical findings	• Charge level and revenue use important (abolition of transport-related taxes more acceptable) • VOT positive impact • General effectiveness positively related to acceptance • Compensation of costs relevant	• Charge level and revenue use somewhat less important • General effectiveness positively related to acceptance • Vehicle weight relevant • Weekly number of times in congestion and number of kms driven less positive

9.5 Conclusions

Despite the fact that politicians and the public regard transport problems as very urgent and important, people nevertheless have concerns about road pricing, resulting in low acceptance levels. But the literature suggests that there is some level of variation in the level of acceptance depending on issues such as the type of measure proposed and the way in which revenues are used. In addition, individual aspects such as the perceived (low level of) effectiveness of the measure have an impact on acceptance levels, as we observed in the previous chapter.

In this chapter, we have analysed support levels for different road pricing measures (systematically varied over dimensions of charge level, differentiation, and revenue use) many of which are seriously considered by Dutch policy makers. We have questioned two different groups of respondents: commuters who regularly experience congestion, and car owners in general. The importance of individual characteristics of the respondent and the type of price measure for explaining the acceptance levels were tested statistically.

We find (for both surveys) that the implementation of road pricing is generally considered as 'not very acceptable'. However, the average acceptability of quite a few measures considered is only one point (out of 7) below neutral, which is less dramatic than outright disapproval. A flat kilometre charge (with low charge levels) and revenues used to lower existing car taxation are most acceptable.

When we look at the impact of the structure of the measure, we find that charge level and revenue use matter. Higher charges are generally less acceptable, as may be expected. Interestingly, it seems that the complexity of a measure does not affect the levels of acceptance. This suggests that policy makers may consider more differentiated pricing schemes instead of a rather simple flat fee without losing acceptance. The first survey reveals that road pricing is more acceptable when revenues are used to decrease fuel taxes or to abolish existing car taxation; indeed those targets that are in the direct interest of the respondent (car driver). The second survey weakly suggests that a decrease of existing car taxes is more acceptable than a decrease in income taxes. These findings on revenue use targets are largely confirmed when we do not present the type of measure, and ask directly about the acceptance of various ways to redistribute the revenues. Dutch car commuters find it almost acceptable when policy makers decide to use the revenues to compensate the car drivers by abandoning current car taxation. This option outperforms all other revenue destinations in terms of acceptance. By far the least attractive option is the public treasury.

Most of our findings for the importance of individual characteristics are in line with the results of the previous literature. The results of the survey among car commuters (where we included information on the individual's VOT, value of schedule delay and uncertainty) show that education, the VOT of the respondents, and financial compensation (part or full) by the employer are important explanatory variables. Higher educated people, as well as respondents with a higher VOT, seem to find road pricing measures more acceptable than others. The same holds for people who receive financial support for their commuting costs. Both surveys confirm that the perceived effectiveness of the measure (in terms of less congestion) does have an important (positive) impact on the support levels. An intelligent communication strategy explaining aims and intended effects is therefore of importance. In contrast, we found no effect between self-reported effectiveness (in terms of changing car trips) and support levels.

The difference in results between both surveys seems to be in mobility-related characteristics of the respondent. The number of kilometres driven and weight of the car do not matter when the sample consists of all car commuters. These issues do become relevant, however, when car owners (including those who use the car less often) are interviewed. Those affected most (driving many kilometres, often experience congestion) tend to find road pricing less acceptable. Compensation of costs by the employer was only of significance in the survey among car commuters.

It is clear that policy makers will face some level of opposition when considering road pricing for implementation, which makes the job not easy. But the empirical work done in this chapter suggests that there are important factors that determine the level of social acceptability such as the structure of the measure. For instance, there seems to be scope for variabilisation. But we should not forget that acceptance is only one issue: effectiveness and equity are also important when road pricing is considered. We can confirm that acceptable measures may not always be effective and vice-versa. However, we also find that time-differentiated measures, which can be effective (see Chapter 5) and efficient, are not necessarily less acceptable than other measures.

Appendix 9A

Explanation and population share of explanatory (dummy) variables of data for survey among car commuters (N=564)

Variable	Type	Levels
Gender	Dummy	Male (75.2%); Female (24.8%)
Age	Dummies	Age1: 18-25 (7.3%); Age2: 26-35 (39.7%); Age3: 36-45 (28.2%); Age4: 46-55 (18.1%); Age5: 56+ (6.7%)
Education	Dummies	Edu1: primary (15.6%); Edu2: junior general secondary (MAVO) (6.0%); edu3: intermediate vocational (MBO) (24.8%); edu4: senior general secondary (HAVO/VWO) (9.4%); edu5: Bachelor (31.9%); edu6: Master (12.2%)
Income (gross yearly)	Continuous	
Residential location	Dummies	Loc1: 3 large cities* (17.9%); loc2: rest west (33.9); loc3: north (3.7%); loc4: east (23.9); loc5: south (20.6%)
Family size	Dummies	Fam1: 1 person (23%); fam2: 2 (31.6%); fam3: 3 (18.3%); fam4: 4 (18.3%); fam5: 5 (7.6%); fam6: 6 (1.2%)
Number of children younger than 11	Dummies	Childno: 0 (72.5%); childyes: 1 or more (27.5%)
Type of measure	Dummies	Measure 1A to 1D; 2A to 2G (see app. 9b)
Measure 3: charge level	Dummies	Charge=2.5 €cents; charge=5 €cents; charge=7.5 €cents
Measure 3: revenue use	Dummies	Revenue use is unclear, revenue use is new roads, revenue use is abandon car taxes
VOT	Continuous	
Vehicle weight	Dummies	Weight1: low (< 1000 kg, 22.7%); weight2: middle class (1000-1250 kg, 67.2%); weight3: heavy (>1250 kg, 10.1%)
Number of kilometres driven yearly	Continuous	
Compensation of costs by employer	Dummies	Comp1: none (11.9%); comp2: partly (43.8%); comp3: completely (44.3%)
Travel time with congestion/free flow travel time	Continuous	
General effectiveness (will this measure lead to less congestion)	Dummies	Geff1: very unlikely; geff2: unlikely; geff3: a little unlikely; geff4: not likely, not unlikely; geff5: a little likely; geff6: likely; geff7: very likely
Personal effectiveness (will this measure make you drive fewer kilometres)	Dummies	Peff1: very unlikely, peff2: unlikely, peff3: a little unlikely, peff4: not likely, not unlikely, peff5: a little likely, peff6: likely, peff7: very likely

* Amsterdam, Rotterdam and The Hague

Appendix 9B

Description of first set of measures evaluated by car commuters

Measure	Variants
1. Electronic toll on daily bottlenecks (independent of bad weather); revenues hypothecated to construct new roads and improve existing roads	A) charge of € 1.00 at all times B) charge of € 2.00 on working days, during peak hours: 7.00-9.00 and 17.00-19.00, no charge on other times C) peak-time charge: 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) D) charge depends on traffic density, more congestion means a higher charge with a maximum of € 5,00
2. Kilometre charge depending on weight of the car (heavy cars are less environmentally friendly). Light cars pay 4 €cents per kilometre; middle weight cars pay 5 €cents per kilometre; heavy cars pay 6 €cents per kilometre. Monthly (extra) costs for the various types of cars based on average kilometrage were presented to respondent.	A) Revenues hypothecated to general budget of the government B) Revenues hypothecated to the traffic system in general, this may include new roads or improvement of public transport C) Revenues used to lower existing car taxes and improve or construct new roads D) Revenues hypothecated to public transport E) Revenues used to abolish existing car ownership taxes F) Revenues used to lower existing fuel taxes G) Revenues used to improve roads and construct new road infrastructure
3. Kilometre charge with different allocations of revenues	A) charge of 2.5 €cents per kilometre; revenue use unclear B) charge of 5 €cents per kilometre; revenue use unclear C) charge of 7.5 €cents per kilometre; revenue use unclear D) charge of 2.5 €cents per kilometre; revenues used for new and better roads E) charge of 5 €cents per kilometre; revenues used for new and better roads F) charge of 7.5 €cents per kilometre; revenues used for new and better roads G) charge of 2.5 €cents per kilometre; revenues used to abolish existing car taxes (ownership and purchase) H) charge of 5 €cents per kilometre; revenues used to abolish existing car taxes (ownership and purchase) I) charge of 7,5 €cents per kilometre; revenues used to abolish existing car taxes (ownership and purchase)

Appendix 9C

Percentage of respondents ranking measures and revenue allocations as 'unacceptable' or 'very unacceptable' (for both surveys)

Type of Measure (commuters survey)	% of respondents	Type of revenue use	% of respondents
1A: flat toll throughout the week 1B: coarse toll (no toll outside peak) 1C: multi-step toll during peak hours only 1D: toll depends on actual traffic conditions	53.6 51.5 52.9 55.9	General budget New roads Improve public transport Abolish existing car taxation Lower fuel taxes Lower income taxes	74.3 8.6 31.0 3.2 5.3 33.5
2A: km charge/general budget 2B: km charge/traffic system 2C: km charge/car taxation and new roads 2D: km charge/public transport 2E: km charge/car ownership taxes 2F: km charge/fuel taxes 2G: km charge/improve and construct roads	52.3 50.0 28.6 48.3 35.5 37.2 53.9		
3A: 2.5 €cents, unclear revenue use 3B: 5 €cents, unclear revenue use 3C: 7.5 €cents, unclear revenue use 3D: 2.5 €cents, improvement of road network 3E: 5 €cents, improvement of road network 3F: 7.5 €cents, improvement of road network 3G: 2.5 €cents, abolish existing car taxation 3H: 5 €cents, abolish existing car taxation 3I: 7.5 €cents, abolish existing car taxation	59.3 75.0 81.5 55.2 48.6 60.6 13.6 18.0 32.3		

Type of Measure (survey among car owners)	% of respondents
1A: 3 €cents, car ownership taxes	36,5%
1B: 6 €cents, ownership and purchase taxes (car taxation)	39,4%
1C: 12 €cents, car taxation and new roads	58,0%
1D: 3 €cents, income taxes	48,5%
1E: 6 €cents, income taxes	59,3%
1F: 12 €cents, income taxes	71,7%
2A: 2 €cents + multi-step toll, car ownership taxes	44,0%
2B: weight differentiated charge, car taxation	38,6%
3A: 2/6 €cents (off-peak/peak), car ownership taxes	49,0%
3B: 4/12 €cents (off-peak/peak), car taxation	57,1%
3C: 8/24 €cents (off-peak/peak), car taxation and new roads	58,8%
3D: 2/6 €cents (off-peak/peak), income taxes	53,1%
3E: 4/12 €cents (off-peak/peak), income taxes	54,3%
3F: 8/24 €cents (off-peak/peak), income taxes	69,3%

Appendix 9D

Ordered probit analysis with revenue use only as a dependent variable

Variable	Revenue use: general budget		Revenue use: new roads		Revenue use: improve public transport	
Threshold (μ's)		Significance		Significance		Significance
μ_1	-3.51E-02 (.288)		-2.712 (.297)	***	-.510 (.268)	***
μ_2	.728 (.289)	**	-2.186 (.283)	***	.167 (.267)	***
μ_3	.987 (.290)	***	-1.784 (.278)	***	.406 (.267)	***
μ_4	1.259 (.292)	***	-1.345 (.275)	***	.734 (.268)	***
μ_5	1.783 (.299)	***	-.691 (.272)	**	1.332 (.270)	**
μ_6	2.674 (.351)	***	.492 (.272)	*	2.030 (.276)	*
Income (gross yearly) (inc4 = base)						
Income 1 (less than €28,500)	6.74E-02 (.151)		-.451 (.145)	***	8.66E-02 (.142)	
Income 2 (€28,500-€45,000)	4.31E-04 (.143)		-.360 (.137)	***	1.163E-02 (.134)	
Income 3 (€45,000-€68,000)	-2.07E-02 (.147)		-.265 (.140)	*	.129 (.137)	
Gender (female)	7.94E-02 (.151)		-.137 (.115)		3.342E-02 (.113)	
Loc1	-.136 (.125)		7.236E-03 (.116)		6.312E-02 (.115)	
Age (Age 5 (56+) = base)						
Age1 (18-25)	4.65E-02 (.249)		-.490 (.240)	**	-.257 (.236)	
Age2 (26-35)	-7.72E-02 (.195)		-.275 (.195)		-7.023E-02 (.184)	
Age3 (36-45)	-.151 (.200)		-.324 (.192)	*	-.149 (.188)	
Age4 (46-55)	-4.49E-02 (.210)		-.407 (.202)	**	-.236 (.197)	
Number of kilometres driven yearly	-2.67E-02 (.000)		-1.129E-06 (.000)		1.930E-06 (.000)	
Compensation of costs by employer						
Comp1 (no transport costs paid by employer)	-.447 (.166)	***	-.128 (.152)		-.104 (.151)	
Comp2 (transport costs partly compensated)	-.203 (.108)	*	-.179 (.102)	*	-.152 (.100)	
Vehicle weight (weight3 = base)						
Weight1 (low weight)	.155 (.195)		-1.984E-02 (.249)		.544 (.180)	***
Weight2 (middle weight)	.168 (.163)		9.005E-02 (.151)		.354 (.180)	**
VOT	2.20E-02 (.010)	**	9.026E-02 (.009)		2.24E-02 (.009)	**
N	564		564		564	
Log-likelihood	-795.618	**	-899.676	**	-1054.943	**
Pseudo R-square	Cox and Snell	.035	Cox and Snell	.051	Cox and Snell	.044
	Nagelkerke	.037	Nagelkerke	.053	Nagelkerke	.045
	McFadden	.012	McFadden	.016	McFadden	.012

Notes: The standard errors are shown in brackets. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively, (two-sided *t*-test).

Variable	**Revenue use: abandon existing car taxation**		**Revenue use: lower fuel taxes**		**Revenue use: lower income taxes**	
Threshold (μ's)		Significance		Significance		Significance
μ_1	-2.324 (.317)		-2.233 (.299)	***	-.715 (.270)	***
μ_2	-1.854 (.295)	**	-1.771 (.286)	***	.169 (.267)	
μ_3	-1.660 (.290)	***	-1.487 (.282)	***	.468 (.268)	*
μ_4	-1.154 (.284)	***	-1.107 (.279)	***	.797 (.268)	***
μ_5	-.586 (.281)	***	-.598 (.277)	**	1.304 (.270)	***
μ_6	.504 (.281)	***	.622 (.277)	**	2.121 (.278)	***
Income (gross yearly) (inc4 = base)						
Income 1 (less than €28,500)	1.21E-02 (.148)		.174 (.146)		.421 (.142)	***
Income 2 (€28,500-€45,000)	-3.73E-02 (.139)		.171 (.137)		.225 (.134)	*
Income 3 (€45,000-€68,000)	.180 (.144)		.297 (.141)	**	.241 (.137)	*
Gender (female)	-2.86E-02 (.118)		3.323E-02 (.117)		6.70E-02 (.113)	
Loc1	-7.317E-02 (.120)		-.242 (.118)	**	-.287 (.115)	**
Age (Age 5 (56+) = base)						
Age1 (18-25)	-.430 (.246)	*	-5.82E-02 (.244)		.456 (.236)	
Age2 (26-35)	-.221 (.194)		-4.95E-02 (.191)		.449 (.185)	*
Age3 (36-45)	-7.54E-02 (.199)		-.129 (.195)		.374 (.189)	**
Age4 (46-55)	-6.23E-02 (.209)		2.18E-02 (.205)		7.03E-02 (.198)	**
Number of kilometres driven yearly	1.17E-06 (.000)		-1.43E-06 (.000)		-2.660E-06 (.000)	*
Compensation of costs by employer						
Comp1 (no transport costs paid by employer)	.411 (.159)	***	.436 (.158)	***	9.84E-02 (.150)	
Comp2 (transport costs partly compensated)	.249 (.105)	**	.120 (.103)		-6.45E-02 (.100)	
Vehicle weight (weight3 = base)						
Weight1 (low weight)	-.199 (.187)		-.506 (.187)	***	2.80E-03 (.179)	
Weight2 (middle weight)	-3.52E-02 (.156)		-.284 (.156)	*	7.56E-02 (.179)	
VOT	4.85E-03 (.010)		4.87E-03 (.010)		1.24E-02 (.009)	
N	564		564		564	
Log-likelihood	-777.800	*	-830.182	**	-1041.136	***
Pseudo R-square	Cox and Snell	.040	Cox and Snell	.045	Cox and Snell	.062
	Nagelkerke	.043	Nagelkerke	.048	Nagelkerke	.063
	McFadden	.015	McFadden	.015	McFadden	.017

Notes: The standard errors are shown in brackets. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively, (two-sided *t*-test).

Appendix 9E

Explanation and population share of explanatory (dummy) variables of data set for the survey among car owners (N=562)

Variable	Type	Levels
Age	Continuous	
Employed	Dummy	Employed (82.7%); Not employed (17.3%)
Income (gross yearly)	Dummies	Inc1: less than € 28,500 (21.4%); Inc2: € 28,500-45,000 (31.5%); Inc3: € 45,000-68,000 (28.5%); Inc4: more than € 68,000 (15.7%); Inc5: do not know or won't say (3.0%)
Residential location (region)	Dummies	Loc1: 3 large cities* (16.0%); loc2: rest west (31.9); loc3: north (6.6%); loc4: east (23.1); loc5: south (22.4%)
Vehicle weight	Dummies	Weight1: low (<1000 kg, 28.3%); weight2: middle class (1000-1250 kg, 47.2%); weight3: heavy (>1250 kg, 24.6%)
Number of kilometres driven yearly	Continuous	
Weekly number of times in congestion	Continuous	
General effectiveness (how probable is it that this measure lead to less congestion)	Dummies	Geff1: very unlikely (percentages differ depending on measure); geff2: unlikely; geff3: a little unlikely; geff4: not likely, not unlikely; geff5: a little likely; geff6: likely; geff7: very likely
Type of measure (charge)	Dummies	Dummy charge 3 €cents (measure 1) Dummy charge 6 €cents (measure 1) Dummy charge 12 €cents (measure 1) Dummy charge 6 €cents (measure 3) Dummy charge 12 €cents (measure 3) Dummy charge 24 €cents (measure 3)
Type of measure (only for measure 2)	Dummy	Dummy measure 2
Type of measure (revenue use)	Dummy	Dummy road taxes (revenues are used to lower existing road taxes (1A, 1B, 3A,3B) and construct new roads (1C and 3C)) Other: income taxes (revenues are used to lower income taxes, measures 1D to 1F and 3D to 3F)
Self-reported behavioural change	Dummy	Dummy Change (respondents that indicate to adjust behaviour for at least one trip purpose, 35.8%), No change (64.2% indicate they will not change)

* Amsterdam, Rotterdam and The Hague

Appendix 9F

Description of second set of measures evaluated by car owners

Measure	Variants
1: Flat kilometre charge, with different revenue allocations	**A**: 3 €cents, revenues used to abolish car ownership taxes (MRB) **B**: 6 €cents, revenues used to abolish existing car taxation (purchase (BPM) and ownership (MRB)) **C**: 12 €cents, revenues used to abolish existing car taxation and construct new roads **D**: 3 €cents, revenues used to lower income taxes **E**: 6 €cents, revenues used to lower income taxes **F**: 12 €cents, 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 €cents, additional multi-step 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 €cents per kilometre; middle-weight cars pay 6 €cents per kilometre; heavy cars pay 8 €cents 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 €cents outside peak times and 6 €cents in peak on working days (7.00-9.00 and 17.00-19.00), abolition of car ownership taxes **B**: 4 €cents outside peak times and 12 €cents in peak on working days (7.00-9.00 and 17.00-19.00), abolition of existing car taxation **C**: 8 €cents outside peak times and 24 €cents in peak on working days (7.00-9.00 and 17.00-19.00), abolition of existing car taxation and new roads **D**: 2 €cents outside peak times and 6 €cents in peak on working days (7.00-9.00 and 17.00-19.00), revenues used to lower income taxes **E**: 4 €cents outside peak times and 12 €cents in peak on working days (7.00-9.00 and 17.00-19.00), revenues to lower income taxes **F**: 8 €cents outside peak times and 24 €cents in peak on working days (7.00-9.00 and 17.00-19.00), revenues used to lower income taxes

Chapter 10

Synthesis

10.1 Overview and conclusions

Road transport is known to generate considerable external costs, in particular in the form of congestion, emissions, accidents and noise. Governments may use different types of measures to deal with these problems, pricing being one of them. Most countries use a number of coarse pricing mechanisms, such as fuel duties, registration fees, and parking charges. This current charging regime is, however, not very efficient. Economists have advocated the use of more targeted pricing tools for a long time. Nevertheless, these more efficient road pricing measures have up till now only seldom been implemented in practice. The low level of implementation is nowadays caused not so much by technical or administrative problems. Rather, it is generally acknowledged that pricing measures are likely to meet public resistance and that acceptability is one of the major barriers to the successful implementation of new and more efficient pricing measures. Policy makers are therefore very much interested in ways to find pricing measures that are both efficient and acceptable at the same time.

This thesis has considered this trade-off by looking at the effects of a wide range of feasible road pricing policies. The effects studied included the behavioural responses, as well as acceptability issues of various road pricing measures and tax recycling schemes. Also important for the effects of the price measures is the institutional organisation. Competition between (public or private) institutions may have important implications. Therefore, the evaluation of road pricing measures carried out in this study has considerable implications for policy formulation.

In Chapter 1 we explained the aim of this study which could be achieved by answering the three research questions raised:

- What behavioural responses to transport pricing can be expected to occur, and what does this mean for the design of first-best and second-best pricing schemes?
- What implications can institutional issues have for the design and effectiveness of road pricing? What is the impact of regulating private involvement in road pricing and investment; and what are the implications of different levels of government setting road tolls and choosing road capacity?
- What factors determine the social acceptability of transport pricing; what role does the allocation of revenues play here; and what are the most important trade-offs that have to be made between the efficiency and social acceptability of pricing schemes and revenue allocation schemes?

In order to comply with the aim of the study and answer these questions it was necessary to start with the economics of transport pricing in Chapter 2. The theoretical economic background on transport pricing discussed in that chapter was fundamental to understand the rest of this thesis. It appeared that there are many transport pricing objectives, but economists will usually argue that the pursuance of economic efficiency should take precedence. First-best prices equate marginal social costs, which will only prevail as a market equilibrium under certain conditions, i.e. all other markets also have efficient pricing, there are no constraints on transport prices, and market failures are non-existent. However, optimal pricing is not very realistic in practice. The transport market has some characteristics which make it very unlikely that the market, without regulation, will set transport prices equal to marginal social costs. Therefore, social welfare is not optimised. Governments may want to intervene and set more efficient prices. This is not straightforward, as the regulator may face several barriers and constraints (e.g. technical or political in nature) which prevent it from setting optimal prices (e.g. technical or political in nature). Obviously, the regulator then has to resort to ‘second-best’ pricing: setting available prices optimally under the constraints applying.

Nowadays, therefore, the focus is more on the effects of, more realistic, second-best pricing, as we did in this study. The first research question addressed this issue by asking what behavioural responses can be expected when road pricing measures are implemented in practice. An overview of the previous literature, discussed in Chapter 3, provided a first indication of possible effects and sensitivity. We found that many responses have been studied, ranging from departure time choice to people’s locational choices. The empirical and theoretical (modelling) literature suggests that road pricing is in potential very effective, but much depends on the type of price measure. Price sensitivity is also influenced by other factors, such as the quality and the price of alternative modes and destinations, and the type of trip and traveller (e.g. business trips are relatively less price elastic than social trips). While economists (and traffic engineers) might be convinced about the effectiveness of road pricing, psychologists tend to be more sceptical.

The empirical research presented in Chapter 4 confirms the effectiveness of road pricing. Car commuters are willing to pay to save travel time, and to reduce their uncertainty in this travel time. We also find that respondents (car owners) prefer car use in the new situation (which involves paying a charge and/or changed departure times) over the public transport alternative. The significant values we have found for concepts such as the value of time, the value of schedule delay early, and the value of uncertainty suggests that these values may be considerable. Commuters seem to be willing to pay about €9 to save one hour of travel time. They attach less value to arriving too early or to uncertain travel times. Another survey, asking car owners about their likeliness to change behaviour after several pricing measures, suggests that about 10% of the trips presently made by car will be adjusted. This level of sensitivity, described in Chapter 5, is in line with previous findings. We have also found that commuting trips are hard to replace. However, people do consider the alternative of non-motorised transport (in particular for visits) and are likely to change departure time when a time-differentiated measure is implemented. Car ownership has also been addressed, because it is not evident from previous research what will happen after variabilisation (replacement of existing tax structures that are independent of car use with a kilometre charge). We find that people are not very eager to give up their car. We may conclude from this that changes in departure time choices are most likely to occur, at least if a time-differentiated measure is implemented. Route change, mode choice and trip suppression are less popular.

Part II presents a theoretical analysis of (second-best) situations where different institutions are responsible for setting road prices. In an efficient world, there needs only to be one operator who sets optimal tolls on every link of the network. But this is not very realistic: there are, for instance, different levels of government that set different prices, and, more recently, private parties are also receiving attention as possible parties for setting road tolls. Private involvement in road construction and road tolling may be attractive to governments, but the literature suggests that some form of regulation is recommended to limit welfare losses from market power abuse. In this connection, first, chapter 6 analysed whether an auction, where private organisations may bid for road construction and operation, might be an interesting tool for governments when some form of control over private road operators is wanted. The results show that an auction can indeed be an attractive instrument for governments, although much depends on the auction rule. It appears that, when capacity and tolls are chosen freely by the private parties (and they maximise profits), considerable welfare losses may result in the setting studied (a two-link network). However, when choosing the right type of regulation in an auction, second-best welfare levels can almost be obtained (but not without a subsidy).

The second institutional issue of interest focuses on the implications of road pricing when different levels of government are responsible for different policy instruments that affect users from both jurisdictions, resulting in a variety of interaction effects. Again, we have included not only pricing as a policy instrument, but also capacity choice. This is studied in Chapter 7. We find that competition between governments may not be very beneficial to overall welfare in society compared with one central government. It appears that the tendency of tax exporting is very strong in this setting where commuters have to pay road tolls set by the city government. The incentive to set excessive tolls is present in all scenarios where the city has control over this instrument. We conclude that, although, at first, it may seem attractive to national governments to deregulate and give powers to lower levels of government, since they know local situations best, the outcomes of interaction may not always be desirable when accounting for policy competition.

Part I and Part II show that road pricing can be an attractive instrument to policy makers: it can be effective, and it provides revenues. One important barrier, however, is that of acceptability. The literature review described in Chapter 8 says that acceptance levels are generally rather low, but that this can be influenced by the type of revenue use. In Chapter 9, we have verified these results for different pricing measures by conducting two empirical studies: one amongst commuters and one amongst car owners. Our findings are line with the literature, most measures are generally not very acceptable and revenue use does matter. The third research question asks for explanatory factors of social acceptance. In this context, the type of measure is important. Kilometre charges with low price levels and tax recycling to lower (or abolish) existing car taxes are relatively most acceptable. Next, education, followed by the value of time of the respondents, the expected effectiveness of the measure, and financial compensation (in part or in full) by the employer are important explanatory variables. We have paid explicit attention to the role of revenue use because of its proven relevance. We find that Dutch car commuters think most positively about the abolition of current car taxation. On the other hand, lower fuel taxes and new roads are slightly less acceptable. A reduction in income taxes and the financing of the public treasury are generally not attractive options.

10.2 Policy recommendations

One of the main aims of this study is to derive policy conclusions for the design and implementation of road pricing measures. Aggregating our findings we can formulate the following recommendations that may help to make policy makers less empty-handed when it comes to the implementation of road pricing in reality.

First, the results from Chapter 4 indicate that the value of time for Dutch commuters that policy makers use nowadays in cost-benefit analysis, is in line with our finding for commuters who experience congestion. This study has also found considerable monetary values for scheduling costs and uncertainty, making it worthwhile to consider their inclusion in cost-benefit analysis. However, when scheduling costs are taken into account, it is unnecessary to include uncertainty, and it is therefore recommended to include only one of these concepts.

Variabilisation, the replacement of fixed car taxation with a kilometre charge, is currently a relevant policy in the Netherlands. This measure can be effective for various trip purposes (with up to 15% of the trips adjusted), but much depends on the design of the price measure. Variabilisation with a low flat fee seems not to be very effective in changing car behaviour. When policy makers want to affect peak-time (commuting) road traffic, a time-differentiated charge seems most appropriate. Nevertheless, governments should be aware that the implementation of these (time-dependent) charges most probably leads to driving at other times, especially for commuting trips. Although commuting trips are generally insensitive (working at home or not making the trip are not serious options for most of the respondents), there does seem to be some level of flexibility which allows scheduling of trips. According to Vickrey's bottleneck model (1969), such rescheduling of trips can greatly contribute to efficiency, even if total demand remains constant.

When considering implementation of road pricing, policy makers should be aware of factors that possibly affect the effectiveness of this measure. Our study among commuters suggests for instance that compensation by employers affects their behaviour, with those who are fully compensated willing to pay more to save travel time. Similarly, we found that effectiveness levels increase when car owners have the possibility to work at home. Road pricing as part of a wider policy package with supplementary measures (e.g. improving possibilities to work at home or fiscal disincentives for compensation) may then be interesting to politicians. While the effectiveness may be enhanced, it is uncertain what happens with efficiency. This needs a more careful evaluation of costs and benefits including for instance the responses of firms (e.g. the response of firms to a disincentive of cost compensation may lead to compensation of only specific groups of employees potentially affecting productivity levels).

Road pricing can have considerable consequences for road usage, but it may also affect car ownership (and indirectly also road use). The effects of road pricing and revenue recycling on the car stock are an as yet unsettled issue, given the mixed results in the literature. Our results indicate that car ownership will only change in a modest way: not very many people are willing to give up their car. However, it seems that there are more possibilities to influence the composition of the car stock. The weight-differentiated charge has more effect on heavy vehicle owners, and the results also indicate that respondents seriously consider buying a smaller (more fuel-efficient) type of vehicle.

An important issue for policy makers is the trade-off between effectiveness and acceptance. More effective pricing measures are generally less acceptable to the public. Our findings seem to confirm this rule, at least for the Dutch situation. For instance, variabilisation with a low kilometre charge and abolition of car taxation is most acceptable. But, at the same time, this measure appears not to be very effective. A time-differentiated kilometre charge with revenues used to compensate income taxation is rather effective (in terms of trips adjusted). However, acceptance of this measure is generally low ('not very acceptable'), and tax recycling to reduce income taxation is relatively unpopular compared with other spending objectives. An interesting measure for policy makers would, of course, score positive on both aspects. Although still 'not very acceptable' overall, a time-differentiated kilometre charge where revenues are used to abolish car ownership taxation seems to perform relatively best in this context. This measure is rather effective, can be efficient, and in addition, the type of revenue use is relatively acceptable to commuters.

Hence, it is important for policy makers to know that acceptance can be influenced. Revenue use and price level (although not definitely confirmed) seem to be important, but the level of acceptance is also explained by personal factors. Both surveys indicate that the perceived effectiveness of the measure (in terms of less congestion) does have a positive impact on the support levels. This emphasises the relevance of an intelligent communication strategy that explains aims and intended (and expected) effects.

The involvement of private firms in the provision and tolling of road infrastructure may nowadays seem realistic and attractive to governments, but is not without risks. We were in particular concerned with the dilemma caused by the fact that private operators – potentially bringing efficiency improvements – will be primarily (or exclusively) concerned with profit maximisation. Our findings, however, indicate that the associated welfare losses can be mitigated by optimising the design of auctions for the right to privately build and operate a certain road, in terms of the criterion or indicator that is used to identify the winning bid. Any auction – or, indeed, any other selection mechanism – to choose between competing potential private road operators will affect the eventual characteristics of the road to be built and the

tolling scheme to be applied. Auctioning can therefore be a useful tool to policy makers, but again much depends on the design.
The final recommendation follows from our analysis of governmental competition. Although it can be attractive for national governments to deregulate and give powers to lower levels of government since they know the local situations best, the outcomes of such interaction are not necessarily desirable. It is shown that overall welfare is not helped very much, and in some cases can even be lower than without pricing. Toll regulation for instance, although not included in the analysis, should seriously be considered as a tool to control one of the jurisdictions, and to improve overall welfare levels.

10.3 Research agenda

We began our study with the words that there are a great number of blind spots in our knowledge and understanding of the optimal design and possible consequences of pricing policies in transport. We have addressed and analysed some issues, and may thus have contributed to a better understanding of road pricing policies. However, there still remain many interesting issues to be solved. In the following, we mention some intriguing issues and possible future directions of research that result from our work.
A first point we want to raise is that, although much of the empirical work focuses on the Dutch situation, most of the findings are also relevant to policy makers outside the Netherlands. However, it is uncertain whether or not these results can be generalised to other countries. For example, the availability (e.g. of public transport) and the inherent popularity of alternatives (e.g. cycling) differs between countries; the spatial structure may be different, and many other factors may cause further deviations. Although it would be tempting to present, for example, the conclusion on the importance of time differentiation of charges for effectiveness in commuting as a more general result, we cannot draw such conclusions from our study and therefore leave it as material for further (local) study.
The modelling analyses of Part II provide useful insights, but we should not forget that these focus on two specific second-best cases and include various simplifications, which leaves ample scope for further research. We have indicated the most pressing simplifications. Candidates for future research include overcoming the static nature of the models, and the issue that competing firms or governments are identical, and – for example – have identical capacity cost functions. We have also concluded that toll regulation may seriously be considered as a useful tool to control one of the jurisdictions and improve welfare levels. This is not considered in this thesis and is another issue for further research. One more issue that seems relevant in this context is empirical research on the welfare effects of tax competition. This is only a simple illustrative numerical example, but it remains to be seen whether the costs of non-cooperative behaviour are substantial in other plausible settings.
These modelling studies consider only few out of many interesting second-best road pricing issues. The relevance of second-best research is clear given the constraints of first-best pricing. Existing literature on intersectoral issues shows the importance of the relation with the labour market. A reform in transport pricing may therefore have considerable consequences on the labour market, in particular when revenues are used to reduce distortionary labour taxes. We have shown that revenues used to reduce income taxes are more effective than other ways. Road pricing and labour tax reduction may be therefore be interesting to policy makers. However, more information about the size of the welfare effects, consequences for the governmental budget, impacts on equity and institutional issues (e.g. coordination) is needed.
Another interesting issue addressed in this study is the effect of variabilisation on car ownership. The impact on car ownership is ambiguous due to the change in costs (lower fixed costs and higher variable costs). People without a car may decide to purchase one after

variabilisation, as cars become cheaper to own. Theoretically one may expect that this will lead to an increase in car ownership. However, studies have shown some mixed results on this. This suggests that it is not completely clear what can be expected; much depends on the price structure and the type of revenue allocation. Variabilisation tends to increase car ownership, while road pricing alone seems to have a (mild) limiting effect on the car stock. We have analysed car ownership, but only for those who already own a car. It would also be interesting to study behaviour of people who do not own a car. The decrease in car taxation may lead to increased car ownership levels, and more kilometres driven. Given the few studies done, and the uncertainties in effect sizes, there is scope for further research on this issue.

We find that revenue use for reduced income taxation is more effective in reducing trips, though less acceptable, than the abolition of car taxation, while in both cases the financial compensation was presented as equal. 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 tell the respondents how much they would receive due to the reduced labour tax, while we could make an estimate for the vehicle taxes. If respondents were pessimistic about 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. Follow-up research on this phenomenon might be useful and interesting.

We used a stated preference type of approach to determine important transport policy concepts such as the value of time and uncertainty. Stated preference studies like these may suffer from various biases, e.g. due to the hypothetical nature of the alternatives evaluated and the inclusion of concepts such as reliability. The derived values provide a useful estimate, but should be regarded only as an indication. This is particularly true for the value of uncertainty. Depending on the specification and presentation to the respondents, this parameter has different estimates. Given the importance of reliability in recent policy documents, further advances in studying reliability should have priority. Comparisons with revealed preference estimates from other countries would also be helpful in this perspective.

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Nederlandse samenvatting (Summary in Dutch)

Mobiliteit is van essentieel belang voor de hedendaagse samenleving. Het goederenvervoer zorgt ervoor dat mensen producten kunnen kopen in de winkels. Het personenvervoer stelt mensen in staat om de dagelijkse activiteiten te ontplooien, zoals naar het werk te gaan of winkels en andere sociale of recreatieve voorzieningen te bezoeken. De voordelen van een goed functionerend transportsysteem kunnen uiteenlopend zijn: efficiënte mobiliteit levert een bijdrage aan economische welvaart, en draagt bij aan een verbeterde concurrentiepositie van een land of regio. De Nederlandse overheid stelt bijvoorbeeld recent dat een goed functionerend verkeers- en vervoerssysteem en een betrouwbare bereikbaarheid van deur tot deur essentieel zijn om de economie en internationale concurrentiepositie van Nederland versterken.

Echter, de toenemende vraag naar mobiliteit zorgt er voor dat een efficiënt functionerend transportsysteem niet meer vanzelfsprekend is. Er is grote druk op de beschikbare infrastructuurcapaciteit. De grote vraag naar verplaatsingen op bepaalde plaatsen en tijdstippen zorgt voor aanzienlijke congestie, hetgeen zich vertaalt in tijdsverliezen voor zowel personen als bedrijven. Daarnaast zorgt de toename in mobiliteit ook voor andere problemen. Hierbij valt te denken aan geluidsoverlast van auto's of vliegtuigen, uitstoot van milieubelastende stoffen en de verkeersveiligheid.

Deze problematiek wordt onderkend door beleidsmakers. De schaal van de problemen (lokaal, regionaal, nationaal, en ook internationaal) zorgt ervoor dat diverse overheden zoeken naar passende maatregelen om de groeiende overlast van diverse vormen van mobiliteit op te lossen of in ieder geval te beheersen. Afhankelijk van de problematiek die men wil aanpakken zijn diverse maatregelen denkbaar om in te grijpen op de markt van verkeer en vervoer. Zo wordt het openbaar vervoer bijvoorbeeld in veel landen gesubsidieerd. Daarnaast bestaat diverse regelgeving binnen het autoverkeer om de veiligheid te verbeteren, zoals maximum snelheden. Prijsbeleid is een andere mogelijkheid voor overheidsregulering. Momenteel wordt prijsbeleid in feite al veelvuldig toegepast, denk bijvoorbeeld aan de belastingen op brandstof en op de aankoop of het bezitten van een (nieuwe) auto. Recentelijk wordt nagedacht over verandering van dit belastingstelsel. Andere prijsmaatregelen zouden daarbij mogelijk effectiever kunnen zijn bij de aanpak van de huidige verkeersproblematiek. Een van de maatregelen die momenteel in de (politieke) belangstelling staat is de kilometerheffing, waarbij per gereden kilometer een bepaald bedrag moet worden betaald.

Dit proefschrift stelt prijsbeleid in het autoverkeer centraal. Het onderzoek richt zich op een drietal belangrijke aspecten van eventueel nieuw in te voeren prijsbeleid. Ten eerste wordt de mogelijke effectiviteit van diverse vormen van "anders betalen" onderzocht. Mensen kunnen door de prijsmaatregel hun gedrag veranderen, en bijvoorbeeld ervoor kiezen om niet meer met de auto te gaan, maar meer met het openbaar vervoer. Onderzoek naar de effectiviteit kan belangrijke inzichten opleveren voor beleidsmakers omdat bepaalde maatregelen in meer of mindere mate gevolgen hebben voor bijvoorbeeld het aantal en de lengte van files.

Effectiviteit van prijsbeleid is slechts één aspect, acceptatie is misschien wel net zo belangrijk voor een succesvolle invoering. In Nederland herinneren we ons nog de sterke oppositie tegen Rekeningrijden, waardoor de politiek uiteindelijk af zag van invoering. Dit onderzoek

analyseert de mate van acceptatie van verschillende beleidsrelevante vormen van een kilometerheffing waarbij de effecten van determinanten als type prijsmaatregel, aanwending van opbrengsten en persoonlijke factoren nadrukkelijk worden onderzocht. Zowel het effectiviteits- als het acceptatieonderzoek is empirisch, en steunt op resultaten van een tweetal enquêtes.
Tenslotte wordt door modelstudies aandacht besteed aan een tweetal belangrijke institutionele aspecten die van belang zijn bij prijsbeleid. Zo bestaat de mogelijkheid voor de overheid om de private sector te betrekken bij de aanleg en beprijzing van nieuwe wegen. Dit kan voor beide partijen aantrekkelijk zijn, toch zijn er enkele belangrijke aspecten waar rekening mee gehouden dient te worden. De eerste analyse bespreekt dit vanuit het perspectief van veilingontwerp. De andere institutionele analyse richt zich op de concurrentie tussen overheden. Het kan bijvoorbeeld zo zijn dat een provincie en een gemeente de bevoegdheid krijgen om prijsbeleid op de door hun beheerde wegen te gaan invoeren. De keuze voor prijs en capaciteit van de weg kan dan gaan afhangen van gedrag van de andere overheid, en welvaartseffecten van niet-ingezeten negeren, met verstrekkende gevolgen voor de welvaart.

Theoretisch kader van prijsbeleid in transport

Op een volledig concurrerende markt wordt de prijs bepaald door vraag en aanbod. Toename in vraag en/of afname van aanbod heeft tot gevolg dat de prijs veelal stijgt. De economische theorie geeft aan dat op de lange termijn de prijs in een dergelijke markt met volledige mededinging gelijk is aan de marginale kosten. Wanneer dit voor de gehele economie geldt, is er sprake van een welvaartsmaximum. Voor het wegverkeer zou dit betekenen dat bijvoorbeeld elke link van het netwerk optimaal beprijsd dient te zijn. Natuurlijk zijn er meerdere doeleinden voor prijsbeleid denkbaar (efficiëntie prijzen verschillen van prijzen gezet door bijvoorbeeld winstmaximaliserende ondernemingen), maar economen leggen veelal de prioriteit bij efficiëntie.
De transportmarkt functioneert in de praktijk verre van optimaal. De prijs die weggebruikers betalen is vaak niet gelijk aan de marginale sociale kosten. Zo wordt bijvoorbeeld geen rekening gehouden met de congestiekosten die een extra kilometer rijden veroorzaken, terwijl deze wel aanzienlijk kunnen zijn. Daarnaast worden ook de kosten van geluidsoverlast en de uitstoot van milieubelastende stoffen niet correct in rekening gebracht bij de weggebruiker, waardoor hij of zij hier geen rekening mee houdt in de beslissing om de auto te gaan gebruiken (of niet). Naast externe kosten zijn er nog meer redenen, samenhangend met marktfalen, waardoor de transportmarkt niet efficiënt functioneert. In sommige sectoren is er bijvoorbeeld slechts één aanbieder van vervoersdiensten die veelal de neiging zal hebben om inefficiënt hoge (monopolistische) prijzen te zetten.
Marktfalen is een van de belangrijkste economische argumenten voor overheidsingrijpen in marktprocessen. De congestiekosten kunnen bijvoorbeeld in rekening worden gebracht door een heffing in te voeren. Om de welvaart te maximaliseren dient de overheid een first-best heffing in te voeren, waarbij aangetekend dient te worden dat de rest van de economie dan ook efficiënt zou moeten functioneren. Dit optimale prijsbeleid is echter praktisch minder relevant, omdat (andere) markten vaak inefficiënt functioneren en overheden vaak tegen andere beperkingen aanlopen wanneer (optimaal) ingegrepen moet worden. Daarom wordt tegenwoordig veel onderzoek en aandacht besteed aan meer realistisch ‘second-best’ beleid: optimaal prijsbeleid onder de geldende (beperkende) omstandigheden. Prijzen zijn dan veelal wel gebaseerd op marginale kosten, maar niet identiek daaraan. Recent onderzoek heeft uitgewezen dat welvaartsverliezen van second-best beleid, ten opzichte van de first-best benchmark, aanzienlijk kunnen zijn.

Effectiviteit

Afhankelijk van het type prijsmaatregel kunnen verschillende gedragseffecten optreden. Een kilometerheffing naar tijd en plaats kan er bijvoorbeeld voor zorgen dat automobilisten hun vertrektijdstip aanpassen, een andere route kiezen, of met de fiets of het openbaar vervoer reizen. Een overzicht van eerder economisch onderzoek naar de effectiviteit van prijsbeleid in het autoverkeer geeft aan dat de omvang van effecten aanzienlijk kan zijn. Empirisch onderzoek naar bijvoorbeeld het effect van de brandstofprijs of parkeertarieven heeft uitgewezen dat, afhankelijk van het motief van de trip, minder gebruik wordt gemaakt van de auto en meer van andere modaliteiten. Ook laten praktijkvoorbeelden zoals London en Singapore zien dat congestieheffingen aanzienlijke gedragseffecten tot gevolg kunnen hebben. In London is het autoverkeer binnen de centrumzone afgenomen en het gebruik van het openbaar vervoer toegenomen, terwijl in Singapore (tijdstipafhankelijke heffing) de vertrektijdstipkeuzes zijn veranderd.
Naast zulke praktijkervaringen wordt ook gebruik gemaakt van modellen om (toekomstige) effecten van prijsbeleid te voorspellen. Met name in situaties waar nieuwe vormen van prijsbeleid worden voorgesteld (zoals in Nederland) kan dit zeer inzichtelijk zijn. Uit dit soort onderzoek is voor bijvoorbeeld Nederland gebleken dat variabilisatie (invoering kilometerheffing met afschaffing van de huidige wegenbelasting (MRB en BPM)) kan leiden tot een afname van autogebruik met ongeveer 11% in vergelijking met een toekomstige situatie zonder verandering. Psychologen zijn over het algemeen minder overtuigd van de omvang van de effecten prijsbeleid in het autoverkeer. Deze discipline hanteert andere theoretische concepten en kijkt meer naar individuele kenmerken van reizigers, zoals motivatie, gewoonten en normen waarbij men dan concludeert dat het autogebruik moeilijker is te beïnvloeden.
Hoofdstuk 4 en 5 presenteren twee verschillende empirische analyses om de effectiviteit van verschillende vormen van beleidsrelevante prijsmaatregelen in het autoverkeer te onderzoeken voor de Nederlandse situatie. Hierbij wordt de Stated Preference methode toegepast, waarbij voor toekomstige situaties naar de gedragsreacties van de respondenten wordt gevraagd. In de eerste analyse hebben we ons gericht op automobilisten die dagelijks in de file staan. Deze groep werd gevraagd om een voorkeur uit te spreken voor alternatieven van een verplaatsing, die verschilden op kenmerken als reistijd, kosten, en onzekerheid. Hieruit bleek dat het woon-werkverkeer bereid is om geld te betalen voor reistijdwinsten en het verminderen van onzekerheid. De schatting van de tijdswaardering bedraagt ongeveer €9, waarbij de waarde van onzekerheid en te vroeg aankomen hieronder ligt en voor te laat arriveren hierboven. Openbaar vervoer werd niet als alternatief geprefereerd, wat deels kan worden verklaard uit het feit dat de steekproef alleen huidige auto woon-werkers betrof.
In de tweede analyse, beschreven in hoofdstuk 5, werd na de beschrijving van de prijsmaatregel (veelal een vorm van kilometerheffing inclusief uitleg over het gebruik van de opbrengsten) direct gevraagd naar de gedragsreacties van autobezitters. De uitkomsten vertonen natuurlijk verschillen naar motief en type prijsmaatregel, maar gemiddeld gaat ongeveer 10% van het aantal autotrips gewijzigd worden bij invoering van variabilisatie. Woon-werkverkeer is het minst gevoelig. Veel autobezitters kiezen voor de fiets en lopen voor sociale verplaatsingen, en het reizen op andere tijdstippen wanneer een tijdsgedifferentieerde heffing is voorgelegd. Het effect van variabilisatie op autobezit is nog niet helder op basis van eerdere studies. Onze resultaten geven aan dat autobezitters slechts in beperkte mate afstand zullen doen van de auto, ook bij hogere kilometerheffingen. Dit, gecombineerd met het te verwachten effect van de lagere vaste lasten onder niet-autobezitters, maakt het aannemelijk dat het autobezit in ieder geval niet sterk zal dalen, en waarschijnlijk zal stijgen.

Institutionele aspecten

Efficiënte heffingen zullen – net als externe kosten – continu moeten kunnen variëren over tenminste de dimensies tijd, plaats en type voertuig, en daarnaast op elk moment over het hele wegennetwerk moeten gelden. Buiten het feit dat dergelijke heffingen technisch en praktisch moeilijk realiseerbaar zijn, geeft de laatste toevoeging aan dat het economisch gezien wel eens beter zou kunnen zijn om een landelijke aanpak te kiezen in vergelijking met selectief op bepaalde delen van het netwerk prijsbeleid in te voeren. Verschillende factoren kunnen hiervoor verantwoordelijk zijn; in het navolgende bespreken we enkele belangrijke aandachtspunten.

Hierbij richten we ons op aandachtspunten die voortkomen uit het onvermijdelijke 'second-best' karakter dat regionaal of lokaal prijsbeleid zal hebben. Met 'second-best' wordt in de economische literatuur gedoeld op kenmerken van de beleidsinstrumenten, de institutionele setting, of de feitelijke situatie, die het voeren van theoretisch 'first-best' beleid, met heffingen gelijk aan de marginale externe kosten, ofwel onmogelijk ofwel ongewenst maken. Invoering van regionaal of lokaal prijsbeleid, op slechts een bepaald gedeelte van het netwerk en rekening houdend met de belangen van slechts een deel van de bevolking, is hier een goed voorbeeld van. Welvaartsverliezen kunnen dan aanzienlijk zijn, afhankelijk van de precieze vorm van prijsbeleid en netwerkkenmerken. Voor twee specifieke, nieuwe, situaties hebben wij de welvaartseffecten onderzocht van second-best beleid waarbij prijs en capaciteit beiden endogeen zijn.

In een denkbeeldige efficiënte wereld is er een wegbeheerder die op elk onderdeel van het netwerk een efficiënte prijs vraagt. Dit is in de huidige situatie weinig realistisch. Zo zijn de meeste wegen momenteel ongeprijsd, waardoor aanleg en tolheffing op een nieuwe weg naast de bestaande weg verschillende implicaties kan hebben. De overheid kan overwegen om een dergelijke weg privaat aan te laten leggen en te beheren, hetgeen actueel is mede omdat overheden steeds vaker geconfronteerd worden met beperkte budgetten. Daarnaast wordt vaak gehoopt dat private aanbieders efficiënter zijn dan publieke. Aangezien een private onderneming andere doeleinden nastreeft dan een publieke overheid, bestaat echter de kans, zeker in de transportsector, dat er misbruik wordt gemaakt van een eventuele monopoliepositie. Een instrument dat de overheid kan inzetten om dit risico te beteugelen is de organisatie van een veiling. Onze modelanalyse richtte zich op de welvaartsgevolgen van een veiling van wegaanleg, waarbij de private bieders vrij zijn om capaciteit en prijs (tolheffing) te kiezen. De uitkomsten van hoofdstuk 6 geven aan dat een veiling een interessant reguleringsinstrument kan zijn voor de overheid. Veel hangt echter af van de vormgeving van de veiling, met name het maximaliseringsdoel voor private bieders. Het second-best optimum kan benaderd worden, waarbij wel opgemerkt dient te worden dat een subsidie waarschijnlijk is als er sprake is van een parallelle weg zonder heffing.

Hoofdstuk 7 analyseert de situatie waar verschillende overheden zeggenschap hebben over verschillende delen van het wegennetwerk en eigen prijs- en capaciteitsbeleid mogen en kunnen voeren. Dit is in de realiteit niet onwaarschijnlijk en wijkt dus af van het optimale plaatje waarbij één beheerder alle prijzen bepaalt. Wij hebben ons gericht op de situatie waarbij een regio één weg beheert, en een andere weg wordt beheerd door een stad, waarbij inwoners van de regio de stad in gaan om te werken. Omdat beide overheden de welvaart van de eigen inwoners willen maximaliseren ontstaat beleidsconcurrentie, met negatieve gevolgen voor de (totale) welvaart. Het blijkt dat de stad de prikkel heeft om het woon-werkverkeer (inwoners van de regio) extra te belasten en zo de tol op wegen in de stad hoog te zetten (ondanks het feit dat ook inwoners van de stad deze moeten gebruiken). Deze uitkomsten geven aan dat deregulering van verantwoordelijkheden naar lagere overheden niet zonder gevaar is: beleidsconcurrentie kan onder bepaalde omstandigheden belangrijke gevolgen hebben voor de welvaart.

Acceptatie
Prijsbeleid in het autoverkeer is een interessant beleidsinstrument: het kan effectief en efficiënt zijn, zoals uit het voorgaande is gebleken, en bovendien levert het opbrengsten op. Toch is er een belangrijke factor van sterke invloed op het gehele proces van invoering van een prijsinstrument, dat in een aantal gevallen zelfs leidt tot afschaffing: acceptatie. Onderzoek, besproken in hoofdstuk 8, heeft aangetoond dat nieuwe vormen van prijsbeleid in het wegverkeer niet acceptabel worden gevonden. Dit wordt onder meer veroorzaakt door het feit dat men denkt dat de maatregel niet effectief zal zijn (men verwacht bijvoorbeeld dat de files niet zullen verminderen door prijsmaatregelen). Ook ziet men weginfrastructuur als een publiek goed waar niet voor betaald zou moeten worden en wordt er getwijfeld aan de betrouwbaarheid van het systeem. Onderzoek heeft verder uitgewezen dat de mate van acceptatie nogal kan variëren, waarbij verschillende verklarende factoren een rol spelen. Zo is de hoogte van de heffing van belang: hoe hoger de heffing, des te minder acceptabel. Daarnaast is ook de besteding van de opbrengsten relevant. Wanneer heffingsgelden worden aangewend binnen de vervoerssector (bijvoorbeeld verbetering van het openbaar vervoer) is hier over het algemeen meer steun voor dan voor aanwending buiten het vervoer, terwijl de steun verder toeneemt als het aan automobilisten ten goede komt. Belangrijk in dit geval is op te merken dat de besteding van de opbrengsten ook relevant is voor de efficiëntie van de maatregel. Zo kunnen de welvaartsbaten van prijsbeleid verder worden vergroot wanneer bestaande verstorende belastingen (op de arbeidsmarkt bijvoorbeeld) door de heffingsopbrengst kunnen worden verlaagd. Ondanks de relatief hoge mate van acceptatie, is investeren in inefficiënt openbaar vervoer vanuit welvaartsperspectief volgens sommige studies minder aan te bevelen. Tenslotte blijkt uit de praktijk dat goede communicatie en uitleg van de maatregel (inclusief doeleinden) de mate van acceptatie kan verhogen.
Hoofdstuk 9 presenteert empirisch onderzoek naar de mate van acceptatie van verschillende vormen van een kilometerheffing, en probeert deze ook te verklaren. Het onderzoek vond plaats onder filerijders en, meer algemeen, onder autobezitters. Voor beide groepen kunnen we concluderen dat de voorgestelde (beleidsrelevante) prijsmaatregelen (inclusief uitleg van gebruik van opbrengsten) 'niet erg acceptabel' worden gevonden. Toch blijkt er nog wel wat variatie in de antwoorden te zitten, met name onder de groep filerijders. Daar blijkt een lage kilometerheffing met een verlaging of afschaffing van de huidige bestaande autobelastingen (variabilisatie) een stuk minder onacceptabel te zijn. Het gebruik van de opbrengsten is ook hier bepalend voor de mate van acceptatie. Een verlaging of afschaffing van de huidige autobelastingen kan zowel als onderdeel van de prijsmaatregel, als wanneer we er apart naar vragen op de meeste steun rekenen. Een verlaging van de inkomstenbelasting en het overheidsbudget in het algemeen ('de schatkist') zijn voor veel respondenten een stuk minder acceptabel als aanwendingsdoel. Bepaalde individuele kenmerken blijken ook van invloed te zijn op de mate van steun. De tijdswaardering, bekend voor de filerijders, is bijvoorbeeld van significant belang. Zoals verwacht vinden filerijders met een hogere tijdswaardering een maatregel meer acceptabel. Dit geldt ook voor mensen die verwachten dat de maatregel effectief zal zijn in het verminderen van de filedruk. Voor beide groepen respondenten bleek dat een hogere mate van verwachte effectiviteit samenhangt met meer acceptatie. Hoewel de gemiddelde acceptatie scores voor beide groepen niet veel verschillend waren, blijkt voor de autobezitters wel te gelden dat mensen die relatief veel kilometers maken en vaak met files te maken hebben, minder positief tegenover de voorgestelde prijsmaatregelen staan.

Beleidsconclusies en verder onderzoek
Beleidsmakers in Nederland kiezen nog altijd niet voor prijsmaatregelen wanneer het gaat om de aanpak van files. Huidig prijsbeleid richt zich met name op het bezit van het voertuig en

niet zozeer op het gebruik (afgezien van de brandstofaccijns). En dat terwijl congestie toch een fenomeen is dat voornamelijk veroorzaakt wordt door intensief weggebruik op bepaalde plaatsen en tijdstippen. Toch wordt veelal gekozen voor andere maatregelen, zoals extra infrastructuur of toeritdosering. De groeiende filedruk heeft er echter toe geleid dat beleidsmakers steeds meer geïnteresseerd raken in andere maatregelen die mogelijk meer effect hebben.
Een van deze mogelijkheden, ondersteund door de verbeterde stand van de technologie, en al jaren bepleit door economen, is meer toegespitst prijsbeleid. Dit onderzoek wijst uit dat een differentiatie naar tijd inderdaad belangrijk is voor de effectiviteit van de heffing om de filedruk te verminderen. Een kilometerheffing met verhoogde prijzen in de spits geeft aanleiding voor het woon-werkverkeer om op andere tijdstippen te gaan reizen. Eerder economisch onderzoek heeft uitgewezen dat dergelijke gedragsveranderingen zeer efficiënt kunnen zijn. Echter, invoering van een vlakke kilometerheffing (en afschaffing van de wegenbelasting) heeft aanzienlijk minder effect op de autoverplaatsingen. Dit heeft alleen een bescheiden effect op verplaatsingen met een ander motief (winkelen, visite), die eenvoudiger vervangen kunnen worden door bijvoorbeeld gebruik van de fiets (veelal korte ritten). Wanneer beleidsmakers dus iets aan de files willen doen en variabilisatie met invoering van een kilometerheffing overwegen, ligt een differentiatie naar tijd en plaats voor de hand. De effecten op het autobezit van variabilisatie zijn minder eenduidig en verdienen nader onderzoek, met name onder die groep die momenteel nog geen auto bezitten en door een verlaging van de vaste kosten eventueel kunnen overgaan tot aankoop.
Tevens geven onze resultaten aan dat Nederlandse filerijders bereid zijn om te betalen voor reistijdwinsten. Deze waarde komt redelijk overeen met de waarde voor woon-werkverkeer die momenteel gehanteerd wordt bij kosten-baten studies voor nieuwe weginfrastructuur. Ook onzekerheid en te vroeg of te laat arriveren zijn gewaardeerd in deze studie. Deze kosten kunnen aanzienlijk zijn en er dient overwogen te worden om bij dergelijke evaluaties ook eventuele baten van verminderde onzekerheid, of van te vroeg of te laat op het werk komen mee te nemen. Beiden meenemen is alleen aan te raden als gecorrigeerd wordt voor dubbeltellingen.
De resultaten geven aan dat effectiviteit en acceptatie van de onderzochte prijsmaatregelen maar moeizaam samen gaan. Effectievere maatregelen (in termen van aantallen aangepaste trips) zijn in de regel in sterkere mate onacceptabel. De meest interessante maatregelen (relatief effectief en niet al te onacceptabel) zijn tijdsgedifferentieerd, met relatief lage heffingshoogten, waarbij de opbrengsten gebruikt worden om de huidge wegenbelasting af te schaffen. Daarentegen scoort een vlakke kilometerheffing beter op acceptatie, maar minder op effectiviteit. Het is uiteindelijk natuurlijk aan de politiek om hier een keuze tussen te maken. Wel benadrukt dit onderzoek nog maar eens de noodzaak om goed na te denken over de aanwending van de opbrengsten, en dit, samen met de doelstelling van de maatregel en de te verwachte effectiviteit, goed te communiceren naar het publiek. Ook de rol van de media, en andere institutionele partijen moet hierbij niet onderschat worden.
De beleidsdiscussie over anders betalen voor mobiliteit wordt in Nederland altijd op landelijk niveau gevoerd: het initiatief ligt bij de nationale overheid en alle Nederlandse automobilisten zouden een heffing per gereden kilometer gaan betalen. Toch hebben veel van de eerder genoemde problemen een sterk lokaal of regionaal karakter. Het zijn dan ook vaak regionale partijen die aandacht vragen voor verkeersproblemen en aandringen op invoeren van prijsbeleid. Het kan dan ook interessant zijn om na te denken over de mogelijkheden van prijszetting door regionale of lokale overheden. Het zal tenslotte vaak zo zijn dat (samenwerkingsverbanden van) lokale instituties meer inzicht hebben in de lokale problemen en zodoende beter weten wat er leeft. Daarnaast zijn vrijwel alle geslaagde voorbeelden van prijsbeleid gerealiseerd in een lokale context; denk aan Singapore, Londen, Amerikaanse

betaalstroken en tolwegen, Noorse tolringen, enzovoort. Onze analyse met behulp van een klein netwerkmodel geeft aan dat bij lokale initiatieven serieus met beleidsconcurrentie rekening moet worden gehouden, dit komt de welvaart op nationaal niveau doorgaans niet ten goede. Ook zijn er diverse praktische en juridische aspecten aan te wijzen die regionaal beleid op dit terrein niet eenvoudig maken, en zeker in een klein land als Nederland is het daarom misschien beter om als overheid de pijlen op een nationaal systeem te richten. Voordat regionalisering van prijsbeleid als een serieuze optie kan worden gezien zijn er in ieder geval nog wel enkele empirische en theoretische vragen te bedenken die solide beantwoording verdienen. Denk hierbij aan voorwaarden die door een nationale overheid moeten worden gezet om negatieve welvaartseffecten door beleidsconcurrentie te minimaliseren.
Tot slot nog een aantal andere overwegingen die aanleiding kunnen vormen voor interessant verder onderzoek. In de eerste plaats is ons onderzoek ook relevant voor beleidsmakers in het buitenland. Toch heeft een grote mate van het (empirische) onderzoek betrekking op de Nederlandse situatie wat eventuele generalisatie lastig maakt. De beschikbaarheid en populariteit van alternatieven (fiets) verschilt bijvoorbeeld per land. Dit is dan ook iets wat verder (lokaal) onderzocht dient te worden. Ten tweede hebben we bij onze analyses gekozen voor een bepaalde aanpak die soms beperkingen met zich meebrengt. Zo zijn bijvoorbeeld voor de institutionele aspecten relatief eenvoudige netwerkmodellen toegepast met beperkende aannames. Verandering van aannames (geen competitieve veilingen bijvoorbeeld) en modelstructuur (dynamisch, grotere netwerken) zijn interessante mogelijkheden voor toekomstig onderzoek. Daarnaast gebruiken we bij het empirische onderzoek de Stated Prefence aanpak omdat de voorgestelde prijsmaatregelen nog niet in de praktijk zijn toegepast in Nederland. Gezien de hypothetische aard van de maatregelen en voorgestelde alternatieven zijn er nogal wat onzekerheden. We hebben getracht om een zo goed mogelijke uitleg te geven van de voorgestelde maatregelen met eventuele financiële consequenties om deze onzekerheid te minimaliseren. Toch verdient een concept als onzekerheid, mede gezien de toenemende beleidsimportantie, nog nadere studie omdat verschillende benaderingen mogelijk zijn welke niet allemaal eenduidig zijn. Lopend experimenteel onderzoek richt zich juist op het combineren van Revealed en Stated Preference technieken bij het bepalen van effecten van prijsbeleid.