A political economy model of road pricing

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Abstract

In this paper, we take a political economy approach to study the introduction of urban congestion tolls, using a simple majority voting model. Making users pay for external congestion costs is for an economist an obvious reform, but successful introductions of externality pricing in transport are rare. The two exceptions are London and Stockholm, that are characterized by two salient facts. First, the toll revenues were tied to improvements of public transport. Second, although a majority was against road pricing before it was actually introduced, a majority was in favor of the policy reform after its introduction This paper constructs a model to explain these two aspects. Using a stylized model with car and public transport, we show that it is easier to obtain a majority when the toll revenues are used to subsidize public transport than when they are used for a tax refund. Furthermore, introducing idiosyncratic uncertainty for car substitution costs, we can explain the presence of a majority that is ex ante against road pricing and ex post in favor. The ex ante majority against road pricing also implies that there is no majority for organizing an experiment that would take away the individual uncertainty.

Keywords

Road pricing, acceptability of tolls, policy reform, earmarking of toll revenues, Pigouvian taxes

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1. Introduction

Although many economists consider the introduction of urban road tolling as efficiency-enhancing, there are only a limited number of cases where urban tolls were actually introduced. Reviewing the experience in cases like London and Stockholm, where pricing was implemented, one can observe two salient facts. First, the toll revenues were tied to improvements of public transport. Second, it seems that – although a majority was against road pricing before it was actually introduced, a majority was in favor of the policy reform after its introduction (Schade and Baum (2007)). In such cases, urban road tolling could only be introduced by politicians that took decisions that ran temporarily against the will of the majority.

In this paper, we take a political economy approach to study the introduction of road tolls, using a simple majority voting model. We use stylized one and two mode models in which voters decide on whether or not to introduce "optimal" road pricing and, if it is introduced, on the allocation of the toll revenues. Two alternative revenue uses are considered: subsidies to public transportation and a tax refund to all voters. We study the political outcomes both in the absence and in the presence of idiosyncratic uncertainty on the costs of switching modes for the initial car users. In introducing individual uncertainty, we follow the literature on economic reform (see Fernandez and Rodrik (1991), Jain and Mukand (2003)) to show that, although a majority may be in favor of road pricing once the uncertainty is resolved (ex post), uncertainty raises the likelihood of a negative expected benefit for initial car drivers. Hence, it increases opposition from existing drivers and may imply a majority against the introduction of road pricing ex ante. Moreover, it may even generate a majority against a road pricing experiment that would resolve the uncertainty.

Our model is deliberately simple and, although it contains no magic recipe for a successful introduction of road pricing, it does help to understand the role of a road pricing experiment and the impact of different revenue uses (tax refund, transit subsidies) on the political acceptability of road pricing.

We start in section 2 with a review of the literature on the political acceptability of urban road pricing. Section 3 sets out a simple model with only one mode to study the attitude of different groups towards urban road tolls, both without uncertainty and in the presence of individual uncertainty. Section 4 extends the model to two modes (car and public transport) and introduces a wider choice of recycling strategies, including public transport subsidies. Section 5 further extends the two-mode model to capture the attitudes of people not using any peak-period transport at all. Section 6 concludes.

2. Different approaches to political acceptability

We start the paper with some facts on the implementation of road pricing and discuss different approaches to political acceptability. The introduction of road tolls has indeed not only been studied by economists, but also by transport planners, psychologists and political scientists.

After the early introduction in Singapore, some form of urban tolling has been introduced in London, Stockholm and various Norwegian cities (Bergen, Oslo, Trondheim). Introduction was also considered in Edinburgh, but it failed. Interestingly, it seems that road pricing has been implemented in most cases against the will of a majority of voters and car drivers, but that public opinion changed after the introduction of pricing in several cities (Schade and Baum (2007)). For example, in Bergen public opinion moved from strong opposition to almost majoritarian support after the introduction (Larsen (1988) and Tretvik (2003)). In Oslo, the attitude towards the toll ring changed dramatically as well: before the introduction of pricing 40% of the population reported to be very negative; after introduction this declined to 17% in 1998 (see Schade and Baum(2007)). Moreover, Tretvik (2003) also reports a decreased opposition after implementation in Trondheim. Similar findings have been reported in London. Transport for London (2004) reports at regular intervals the public attitude on the London congestion toll, introduced in 2003. In late 2002, it was found that 40% rejected congestion charging and 40% supported it; after introduction of the charging system in 2003 only 25%–30% rejected congestion pricing and 50–60% were in favor.

Finally, as the Stockholm toll is the most recent experience, and is very well documented, it is worthwhile focusing attention on this case. Eliasson (2009) sums up the Stockholm experience. There was a congestion pricing trial from January 2006 – July 2006, accompanied by an extension of the public transport system from August 2005 onwards. The final decision to go ahead was taken by local referenda and by the national government in 2007. The road pricing trial was the result of a promise of the Green party to support a minority government of social-democrats in 2002. Opposition asked for a referendum before the trial, but this was not organized by the majority in power – as there was, according to polls, a majority against. In theory, it was only the city of Stockholm that could decide in a referendum: after the trial, it was approved 51% for and 45% against. Some neighboring municipalities organized similar referenda with outcomes 40% for and 60% against, but there was no overall majority if all votes were counted. The final decision to re-introduce charging in August 2007 was taken by a Liberal-Conservative government, earmarking the revenues to road investments and transit investments. Winslott-Hiselius et al. (2009) carefully studied public attitudes for the Stockholm trial and showed that the attitude towards congestion pricing became more favourable during the trial.

Our paper is concerned with explaining changes in voting behaviour towards road pricing before and after its introduction. Schade and Baum (2006) develop a psychological theory to explain the variation in attitude to road pricing before and after the introduction. They argue that, when there is too much difference between the tolling regime preferred by the individual and the actual regime, individuals adapt their preferences and develop a more positive attitude to urban tolling. Their theory is confirmed in a stated preference experiment. In our paper, however, we look for a political economy explanation of the change in opinion of individuals: we assume that preferences are given, but that individuals gain information about the real costs road pricing implies for them. It is shown that this is sufficient to make some of them change their opinion in a favorable way, see below.

How to overcome the resistance to a welfare enhancing reform is an issue is a topic that has received a lot of attention in economics in general. The resistance is in general attributed to either a political institution or an asymmetric information problem.

The assymetric information problem can be situated at the level of the compensation of losers in the reform (see Mitchell and Miro (2006)) who tend to ask for overcompensation that the winners are not prepared to pay. The political failure explanation is more commonly used. Here the failure can be due to the imperfect monitoring of the politicians and the influence of pressure groups (see Dixit et al,(1997)) and Coate and Morris (1999)) or can be the result of a simple majority voting game in the presence of imperfect information as proposed by Fernandez and Rodrik (1991), Jain and Mukand (2003) and Ciccone (2004). In this paper we follow the simplest and most explicit political decision making mechanism and that is simple majority voting. Obviously this does not rule out extra distortions at the level of the politicians and agencies.

In their appreciation of attitudes to road pricing, transport economists tend to focus more on the overall efficiency gains and they can be classified into two groups. There are those that believe that road pricing is not (yet) efficient because the transaction costs are still too large compared to the gain in congestion benefits (for an example see Prud'homme and Bocarejo (2005)). The second group consists of those that believe that there is a net efficiency gain and that it is the redistribution of the revenues over different groups of the population that can make the difference. King et al. (2006) believe that revenues are best claimed by city centers so that there is at least one strong advocate for the implementation of road pricing. Most authors look for a combination of reductions of other taxes, road improvements as well as public transport investments that create a sufficiently large majority (see, e.g., Small (1992)). Borck and Wrede (2005) focus on another dimension: they consider commuting subsidies that allow reducing the demand of rich households for central city housing.

3. The one-mode model

We start with a simple one-mode model. We first introduce the model and discuss the political environment. We then look at the outcomes of the political process for the case without uncertainty. In a next step, we introduce uncertainty and reconsider the outcomes of the political process. We discuss the economic implications of uncertainty for the outcomes of the political process, and consider the role of experiments in generating a majority in favor of reform. Finally, we summarize our findings.

3.1. Structure of the model

We represent the urban area as one homogenous road link that all individuals are interested in using twice a day during the peak period. In this section, the only mode of transport is the private car[1]. Individuals are indexed according to their willingness to pay (*WTP*) for road use; the individual with highest *WTP* has index 1, the lowest has index *N*.

We use a simple quasi-linear quadratic utility function with two arguments, road use and all other goods. The latter are priced at marginal cost, and there are no existing taxes. We assume all individuals are risk neutral (DISCUSS LATER RISK AVERSION AND LOSS AVERSION). Let the inverse demand function be given by (p is price, n the number of car drivers):

$$p = a - bn$$

We assume the same value of time for all users, an assumption WE RELAX LATER. The average time cost is given by the linear relation

$$ATC = d + cn$$

where d represents other driving costs and time costs at maximum speed, excluding taxes.[2] Therefore, the marginal social cost function is

$$MSC = d + 2cn$$

In our model, we use two strong assumptions to stylize political decisions. First, we assume that decisions are taken by majority voting, the simplest political system. This is an important assumption, as it excludes the politician as an independent agent. In reality, politicians may be particularly important when there is a lot of uncertainty on the outcome of certain policies (see Besley (2006) for a survey) . Second, we only consider two choices for the political system: the status quo without road pricing, and the socially

[1] Note that other types of transport are irrelevant for our purposes as long as they are priced at social marginal cost, and this cost is constant. We will show in the next section that most of the results for the one mode model also carry over to a two-mode model, allowing for public transport subsidies

[2] A linear user cost function can stand for a traditional speed-flow model or it can be derived from a bottleneck model (Arnott, de Palma and Lindsey (1993)).

optimal road toll. The reason for focusing on optimal tolling only is that, if we would allow any arbitrary level of tolls and the majority is not driving, the political system may well generate a toll that is much higher than the socially optimal level (see Dunkerley et al. (2009) for an illustration).

As can be seen from the description above, we use a partial equilibrium model of the transport market, waving away all other distortions in the transport market and in the rest of the economy (see Parry and Bento (2001), Calthrop, De Borger and Proost (2010)). These distortions exist and affect the choice of the optimal pricing policy, but they are of a second order importance when one considers, as we do in this paper, the behavior of the voters. Finally, note that in this section we assume lump sum redistribution of the toll revenues. In later sections, we consider public transport subsidies as well. Still other mechanisms could be studied, but they may again give rise to toll systems that are not optimal.

Consider the market equilibrium in the absence of socially optimal pricing. The equilibrium number of users $n°$ is found by setting price equal to the average user cost, so we have:

$$n^0 = \frac{a-d}{b+c} \qquad (1)$$

The social optimum is achieved by pricing at marginal social cost; this implies a lower road use n*, viz.:

$$n^* = \frac{a-d}{b+2c} \qquad (2)$$

These quantities are shown on Figure 2. The social optimum requires setting a tax equal to marginal external cost at the optimal traffic flow. This tax is:

$$t^* = cn^*, \qquad (3)$$

Toll revenues are then:

$$t^* n^* = c(n^*)^2$$

Let us assume here that the revenues are redistributed uniformly to all N consumers (car drivers and others); this means the government can redistribute

$$\frac{c(n^*)^2}{N} \tag{4}$$

per person. Moreover, we assume that at a zero price everyone would be driving, so that the total number of individuals (drivers plus others) N equals the number of drivers that would exist at a zero price. Finally, although they can be important for road pricing, we do not take into account transaction costs.

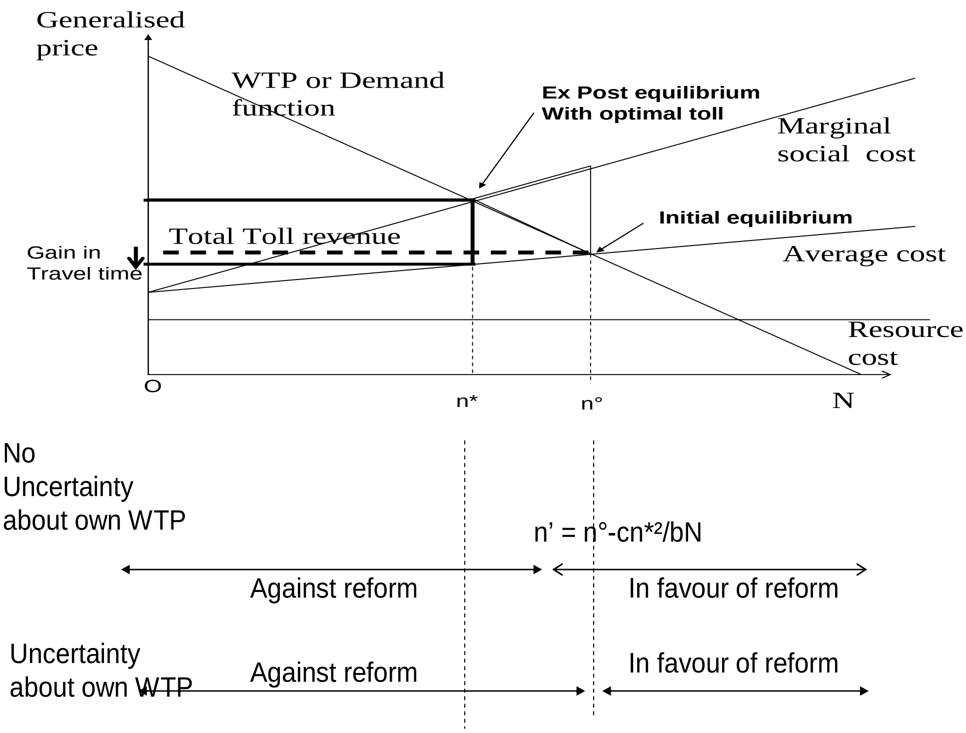

Figure 2. Equilibria with and without an urban toll

3.2. Decisions under certainty

Suppose there is no uncertainty; every individual driver knows his willingness to pay. Moreover, every initial driver knows whether or not he will be driving after the introduction of road pricing.

Consider the introduction of the optimal toll policy with redistribution as described above. First, each person that was initially not a driver (people in the interval (n^0, N)) gains the redistributed tax revenues equal to:

$$\frac{c(n^*)^2}{N}$$

Second, each person that continues to drive after introducing the tax and redistributing the revenues (people in the interval $(0, n^*)$) looses the tax paid, gains some time, and gains the redistributed tax revenues. Total gain per person is

$$-cn^* + c(n^0 - n^*) + \frac{c(n^*)^2}{N} \qquad (5)$$

The first term is the tax paid, the second term is time gain, the third term is the gain from redistribution. It immediately follows that remaining drivers are necessarily worse off. To show this, first note that:

$$-cn^* + c(n^0 - n^*) + \frac{c(n^*)^2}{N} = cn^0 - cn^*\left[2 - \frac{n^*}{N}\right] \qquad (6)$$

Now use the definitions of n^*, n^0 given above (see (1)-(2)), and note that our model assumptions imply $N = \frac{a}{b}$. Then work out (6) to find:

$$-cn^* + c(n^0 - n^*) + \frac{c(n^*)^2}{N} = -\left[\frac{c(a-d)}{a(b+2c)^2(b+c)}\right]\left[abc + db(b+c)\right] < 0 \qquad (7)$$

This is necessarily negative, so remaining drivers lose.

Third, people that no longer drive because of the tax policy (interval (n^*, n^0)) gain redistributed revenue, they lose the value of the trip (captured by willingness to pay (a-bn)), and they gain the average time cost they no longer have to make; this is given by ($d + cn^0$). Their total gain can be written

$$-\left[a - bn - (d + cn^0)\right] + \frac{c(n^*)^2}{N}$$

Some ex-drivers will be worse off, some will be better off; this depends on the position of the driver we consider in the relevant interval. People close to n^* will be worse off, people close to n^0 better off. For the former, the revenues they receive are insufficient to compensate for the loss in value associated with driving; for the latter, the value of the trip only slightly exceeded the time cost, and the revenues received are more than enough to compensate for this loss. For example, the gain for the driver at n^0 equals:

$$\frac{c(n^*)^2}{N} > 0$$

Evaluated at *n**, simple algebra shows (using the definitions of n^*, n^0) that the gain is given by

$$\frac{cn^0}{N(b+2c)^2}\left[-a(3c+2b)-d(b+c)\right] < 0$$

Since the gain is linear in *n* there exists a cutoff value n' such that all people to the left are worse off and everyone to the right is better off. This value is given by solving

$$-\left[a-bn-(d+cn^0)\right]+\frac{c(n^*)^2}{N}=0$$

for *n*. We find:

$$n' = n^0 - \frac{c(n^*)^2}{bN} \qquad (8)$$

Note that the difference is directly related to the generated tax revenues for redistribution. One further easily shows that $n^* < n' < n^0$.

Consider now a majority vote between the two alternatives considered: no road toll, or a road toll $t^* = cn^*$ with equal redistribution of the toll revenues to all individuals. Then we have the following result:

PROPOSITION 1. *Under certainty, there is a majority for an optimal road toll if* $n' = n^0 - \frac{c(n^*)^2}{bN} < \frac{N}{2}$.

A majority in favor may occur if the number of initial car users n^0 is not too close to the population *N* (e.g., a not well maintained network which is highly congested, so it has a large *d* and a large *c*), and the tax policy yields high toll revenues $c(n^*)^2$, so it is not very successful in reducing traffic levels (so still relatively high *n**). A majority against road pricing will be the case if the initial number of users n^0 is large relative to *N*, and if the tax policy reduces traffic substantially so that *n** is fairly small. This happens if car use has a very large initial market share, the road network is highly congested (reflected in a large *c*), and demand is quite responsive to toll increases.

In Figure 2, the first line under the supply and demand figure gives the number of individuals that are in favor and against the optimal urban toll. If *n'* is smaller than *N/2*, there is a simple majority to introduce the optimal urban toll.

3.3. Decisions under uncertainty (ex ante)

Now introduce uncertainty. There are several ways to do so. One source of uncertainty is the use of the toll revenues. A citizen may be unlikely to favor a toll when it is not clear how the money will be used: for direct redistribution, for beneficial projects, or for bad projects. In our one-period model, however, without any role for politicians, this is a less interesting avenue. We therefore focus on another source of uncertainty: the idiosyncratic uncertainty of the car user who does not know how easy it is to give up his car use. In the literature on economic reform (see Fernandez and Rodrik (1991) and Jain and Mukand (2003)), the uncertainty of the individual on his cost of adaptation is often used as holding up any reform of industrial sector subsidies. In our model, we can translate this as uncertainty on the exact *WTP* for car use of the initial driver. Specifically, assume initial drivers only know the fraction of drivers that will continue to use their car after the introduction of a road toll but do not know their own exact position. As initial drivers, they only know they are situated in the range $(0, n^0)$.

Suppose initial drivers vote on the basis of the expected gain in the range $(0, n^0)$. This equals:

$$\frac{n^*}{n^0}\left[-cn^*+c(n^0-n^*)+\frac{c(n^*)^2}{N}\right]+\left[\frac{n^0-n^*}{n^0}\right]\left\{\frac{c(n^*)^2}{N}-\left[a-b\left(\frac{n^0+n^*}{2}\right)-(d+cn^0)\right]\right\} \quad (10)$$

The first term is the fraction of continuing drivers times their gain per person. The second term is the fraction of people not driving anymore times the expected gain in the relevant interval (n^*, n^0). Since demand is linear, this is obtained by evaluating *n* at the mean of the interval.

To evaluate the expected gain (10), first note that the last term between square brackets can be worked out to equal:

$$\left\{\frac{c(n^*)^2}{N}-\left[a-b\left(\frac{n^0+n^*}{2}\right)-(d+cn^0)\right]\right\}=\frac{c(n^*)^2}{N}-\frac{b}{2}(n^0-n^*)$$

Substitute in (10) to get:

$$\frac{n^*}{n^0}\left[-cn^*+c(n^0-n^*)+\frac{c(n^*)^2}{N}\right]+\left[\frac{n^0-n^*}{n^0}\right]\left[\frac{c(n^*)^2}{N}-\frac{b}{2}(n^0-n^*)\right]$$

Simple algebra implies that this expression can be rewritten as

$$\frac{cn^*}{n^0N}\left(n^0N-2n^*N+n^0n^*\right)-\frac{b}{2n^0}(n^0-n^*)^2 \tag{11}$$

Now, using (1), (2) and the definition of *N*, we have

$$\left(n^0N-2n^*N+n^0n^*\right)=\frac{-bd(a-d)}{b(b+c)(b+2c)}<0$$

It follows that (11), and hence (10), is necessarily negative.

We have, therefore, shown that the expected gain for all initial drivers is negative under our assumptions. Consequently, if people vote on the basis of the expected gain under uncertainty, all n^0 people will vote against.

3.4. Implications of uncertainty

The type of idiosyncratic uncertainty introduced above has important implications. It may affect the outcome of the political process of majority voting. Moreover, it raises questions on the role of road pricing experiments that are often suggested to gain more support for road pricing, by reducing uncertainty. In the remainder of this section, we discuss these issues consecutively.

3.4.1. Conflict between ex ante and ex post political outcomes

Note that in the absence of uncertainty all voters to the left of *n’* vote against. Under uncertainty, all n^0 people will vote against. We can conclude then that:

1. Since $n' < n^0$, more voters will be against under uncertainty than under certainty.

2. If $n' < \frac{N}{2} < n^0$ a majority is against under uncertainty, although a majority would have been in favor in the absence of uncertainty.

The difference in voting behavior is illustrated on the bottom part of Figure 2: the uncertainty on the cost of giving up the car generates a larger fraction of the population against urban road tolling.

The possibility that uncertainty may imply a majority against road pricing even though a majority would have been in favor in the absence of uncertainty raises a number of interesting questions. First, what is the relation between the welfare gain of road pricing and the likelihood of having a majority in favor of the reform under uncertainty? Indeed, uncertainty means that a larger welfare gain of road pricing does not necessarily imply that it is more likely to be actually implemented. Second, how important is the 'conflict range', i.e., the range for which a majority is against ex ante but in favor ex post? In Appendix 1, we show that the answer to both questions crucially depends on the relative slopes of the demand function and the user cost function (b and c, respectively). It is shown that, except for a very price sensitive demand (low value of b), a higher welfare gain also implies a higher likelihood of getting a majority ex ante. Moreover, it is shown that the conflict range exists for a wide variety of values of (b/c); it reaches a maximum at $b=2c$.

3.4.2. Uncertainty and the role of an experiment

An obvious way to resolve the uncertainty on the cost of adaptation is to conduct a road pricing experiment, as was done in Stockholm. This raises the question whether a majority will vote in favor of having such an experiment?

Consider a rational in our simple model who is initially using his car, is uncertain about his *WTP* and has a negative expected benefit of the introduction of an urban road toll. It is easy to show that he will also have a negative benefit of an experiment on road pricing. As a consequence, if there was ex ante a majority against the toll, there will also be a majority against an experiment.

The proof goes as follows. Consider an individual that has a negative expected benefit as driver, although he would actually benefit from the introduction of road tolling because he is situated in the range (n', n^0) as defined in (8). If he votes in favor of the experiment, he would after the experiment realize that he benefits from road tolling; so would all others in the range (n', n^0). But if he votes in favor of the experiment, then after the experiment there would be a majority in favor of road tolling. The reason is that, together with the individuals in the range ($n°$,N), the group (n', n^0) then forms a majority in favor of an experiment and, after the experiment, a majority in favor of implementing the road toll. For people in the range (n', n^0), voting in favor of an experiment would, therefore, be equivalent to voting in favor of introducing road tolling. However, these people have, ex ante, a negative expected benefit. Therefore, anticipating the consequences, they will never rationally favor an experiment on road tolling.

We summarize the results of this section in the following proposition.

PROPOSITION 2*. When initial car users are ex ante uncertain on their total willingness to pay for car use, there can be ex ante a majority against a road toll and a majority ex post for car use. This happens if n°>N/2>n'. In this case there will also be no majority for a road pricing experiment that reveals the individual WTP of car users.*

4. The two-mode model

With minor adaptation, the model can be interpreted for the case with two transport modes, the private car and public transport. There are two reasons for introducing a second mode. It makes the model more realistic because, outside the US, public transport has an important share in peak urban transport trips; in addition, it allows us to discuss the role of different allocations of toll revenues (lump sum to individuals versus subsidies to public transport).

The model is illustrated using Figure 3. Let total demand N be given, divided between car demand n and public transport demand (N-n). People chose between car and public transport based on the overall generalized cost. The average cost for car transport is, as before:

$$d + cn$$

The cost of public transport for different people is measured from right to left on Figure 3. It is assumed that people face a different generalized cost of public transport due to, e.g., differences in access cost (related to, e.g., proximity to the network). People with the lowest access cost are on the right. The higher the access cost the further people are situated to the left. The cost is captured by the expression (a-bn). This expression gives the marginal cost for each individual. The marginal cost contains the sum of private access costs (time etc.) as well as the marginal resource cost of providing the service. The marginal resource cost can be decreasing (economies of scale) as long as the private access costs are strongly increasing. Figure 3 shows the analogy with the one mode case: the *WTP* for car use is now re-interpreted as the access cost for public transport; this cost increases from right to left, starting at *0* in point *N*.

We now assume that all *N* individuals want to make a trip and have to choose between car and public transport. The equilibrium is found by equating the marginal cost of public transport and the cost of car use. Depending on the pricing regime, this can be $n°$ or $n*$.

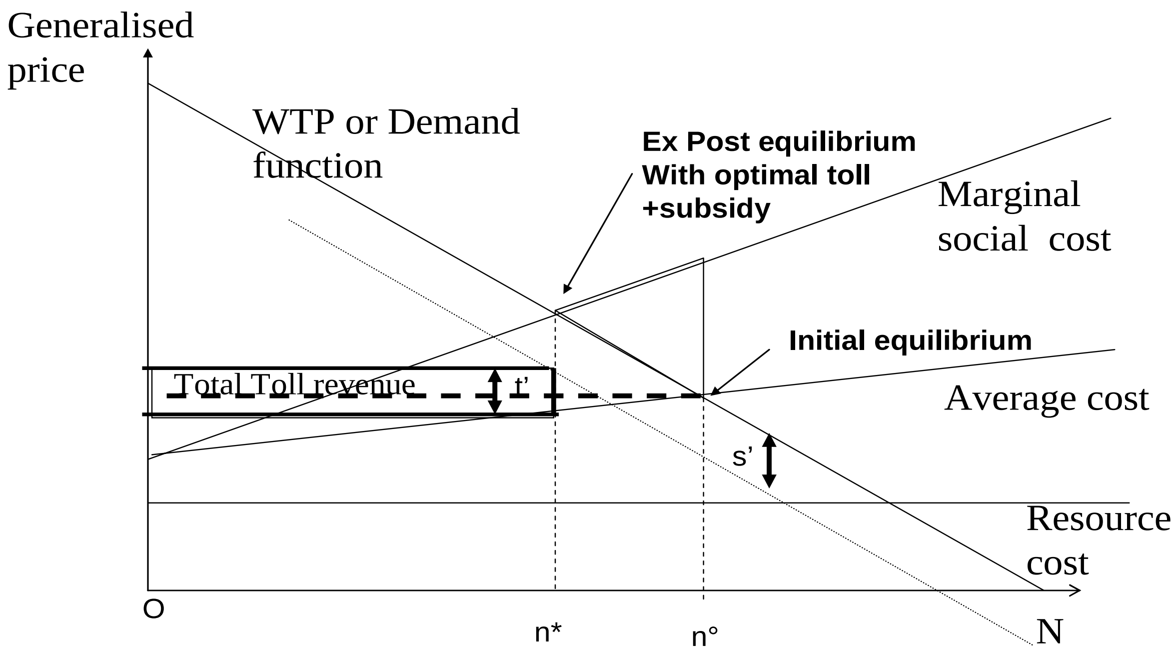

Figure 3

The welfare optimum in this setting is obtained by minimizing total user costs for all travelers. If the number of car users is *n*, then all car users face a cost (*d*+*cn*). The cost of the (*N*-*n*) public transport users depends on their access cost; given linearity of the cost function it is given by the average cost of public transport between *n* and *N*. Hence the optimal equilibrium *n* solves:

$$\underset{n}{Min} \;\; n(d+cn)+(N-n)\left[(a-bn)+(a-bN)\right]\frac{1}{2}$$

Solving this problem yields, as in the one-mode setting,

$$n^{*}=\frac{a-d}{b+2c}$$

Because we have now two travel options and all individuals have to make a trip in the peak period, we can chose between a road toll and a public transport subsidy (toll *t* for road and subsidy s for public transport), or a combination of both. User equilibrium requires

$$a - bn - s = d + cn + t$$

Using this expression and the equation for n^*, we find that the tax and subsidy combination that implements the welfare optimum must satisfy:

$$t + s = cn^*$$

In what follows we distinguish three cases.

(i) First, we impose the optimal tax on road use and have a zero subsidy for public transport (so have $t=cn^*$, $s=0$), and we redistribute toll revenues to all N people. Redistribution per person is $\frac{c(n^*)^2}{N}$.

(ii) Second, we consider an optimal tax-subsidy combination (hence, it satisfies $t + s = cn^*$) and suppose there is no formal government budget restriction: the revenue surplus of the welfare-optimal tax and subsidy package is simply redistributed to all users on a per capita basis. Redistribution per capita is then $\frac{nt - (N-n)s}{N} = \frac{n(t+s)}{N} - s$. Note, by the way, that there are an infinite number of (t, s) combinations that induce the optimal equilibrium. They all produce the same result, see below.

(iii) Third, assume an optimal toll-subsidy combination is introduced (hence, it satisfies $t + s = cn^*$), where the toll revenues can only be used to subsidize public transport. We then have the following formal budget restriction that must be satisfied at the optimum: $n^* t - (N - n^*)s = 0$. This results in a unique welfare-optimal road tax and subsidy package

$$t^* = cn^*(1 - \frac{n^*}{N}); \quad s^* = c\frac{(n^*)^2}{N}$$

In Table 1 we compare the outcomes of the three alternatives, obtained after simple algebra. Note that, for all types of people (continuing road users, continuing public transport users, people that switch from road to public transport) considered, the three alternatives produce exactly the same net gain. The implication is that the choice between redistribution and a subsidy to public transport is irrelevant in this simple two-mode model, as is the difference between cases with and without formal budget restriction. The main reason is that all individuals make (by definition) a trip, so that only the sum of tax and subsidy, $t+s$, matters. The choice between lump sum redistribution and public transport subsidies is irrelevant because all (t,s) combinations that satisfy the optimality constraint ($t+s=cn^*$) have the same net effect. The cases with and without budget restriction yield the same results as well: if there is no formal budget restriction, a higher subsidy is equivalent to a lower amount that can be redistributed. For the same reason, public transport users are indifferent. The net effect is therefore identical, and all three cases (i), (ii) and (iii) have exactly the same implications as in the one-mode case.

Interval	Tax with simple redistribution;	Tax-subsidy *(t+s=cn*)* with simple redistribution	Tax-subsidy with formal budget restriction	**Net gain (in all three cases!!)**
$0 -> n*$	*t=cn** *Red.* $\frac{c(n*)^2}{N}$	t *Red.* $\frac{n*(t+s)}{N} - s$	$t = cn*(1 - \frac{n*}{N})$ *Red.=0*	$-cn* + c(n^0 - n*) + \frac{c(n*)^2}{N}$
$n* -> n^0$	*Red.* $\frac{c(n*)^2}{N}$	s *Red.* $\frac{n*(t+s)}{N} - s$	$s = c\frac{(n*)^2}{N}$ *Red.=0*	$-\left[a - bn - (d + cn^0)\right] + \frac{c(n*)^2}{N}$
$n^0 -> N$	*Red.* $\frac{c(n*)^2}{N}$	s *Red.* $\frac{n*(t+s)}{N} - s$	$s = c\frac{(n*)^2}{N}$ *Red.=0*	$\frac{c(n*)^2}{N}$

Table 1: Effects of three policies in two-mode model

One difference with the one-mode setting must be mentioned, however. The one-mode model assumed that the total number of potential drivers *N* was the demand at a zero price, implying *N=a/b*. Using this constraint we found that continuing car drivers are necessarily worse off. In the two-mode setting considered here *N* is no longer related to the parameters of the problem, so that this result no longer necessarily applies. The net gain to continuing drivers, given by

$$-cn* + c(n^0 - n*) + \frac{c(n*)^2}{N}$$

can in fact be positive. Take the case of a tax-subsidy with budget constraint as an example. Intuitively, if there are a large number of continuing car drivers and few public transport users that need to be subsidized, then the tax per car driver will be small. If the congestion function is relatively steep, time savings for car drivers may outweigh the small tax paid. Formally, we can easily show that

$$-cn^* + c(n^0 - n^*) + \frac{c(n^*)^2}{N} < 0$$

is equivalent to

$$\frac{N - n^*}{n^*} > \frac{c}{b}$$

So if after implementation of the policy there are few public transport users and the congestion function is steep, continuing car drivers may actually be better off.

We summarize the main result of this section in the following proposition.

PROPOSITION 3. *The results for the one mode case (PROPOSITIONS 1 and 2) carry over to the two mode case. Tthe choice between a road toll t and a public transport subsidy s is irrelevant as long as* $t + s = cn^*$.

5. Extending the two-mode model: the role of voters that do not demand any peak-period transport

In this section, we extend the model by assuming there is a fixed number of (*M*-*N)* people that do not use (peak) transport at all. As before, there is a given number of transport users *N*. They can use either car (*n* people) or public transport ((*N*-*n*) people). Figure 4 illustrates the situation. Apart from the group of non-users, the setting is as before. All cost and demand functions, and hence the welfare optimum, are the same as before.

The setting described may reflect the peak-period transport problem in an urban setting. If the government is thinking about introducing a toll-subsidy package in the city, this affects car and public transport users. If the policy includes redistribution to all citizens, it also affects those people in urban areas that use neither a car nor public transport during the peak. This includes various groups that do not work (the retired, the unemployed, discouraged workers, etc.), individuals that use other transport modes (biking, walking), etc.

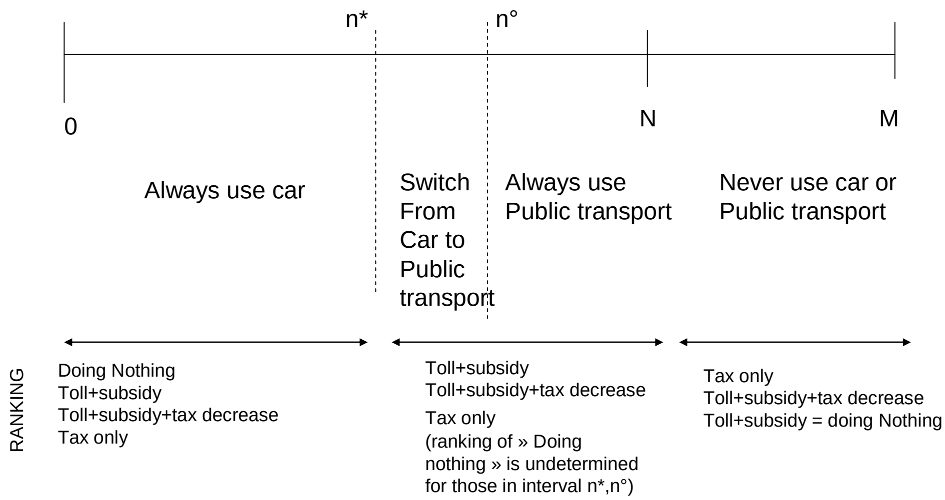

Figure 3 Ranking of alternative reforms in function of willingness to pay of individuals for car use

Within this framework, one can again compare the three options discussed above:

(1) First, the government introduces the optimal toll with simple redistribution to all citizens (hence, no public transport subsidy). This implies introducing the toll

$$t = cn^* = c\left(\frac{a-d}{b+2c}\right)$$

and redistributing the tax revenues on a per capita basis; each person now receives $\frac{c(n^*)^2}{M}$.

(2) Second, the government introduces an optimal tax-subsidy combination and it redistributes the net revenues to all M people. Hence, the tax-subsidy combination satisfies

$$t + s = cn^* = c\left(\frac{a-d}{b+2c}\right)$$

Redistribution per person amounts to

$$\frac{tn^*}{M} - \frac{s(N-n^*)}{M} = \frac{(t+s)n^*}{M} - s\frac{N}{M}$$

(3) Third, the government introduces the optimal tax-subsidy combination that also satisfies the budget restriction $tn^* - s(N-n^*) = 0$. In other words, all revenues go to public transport subsidies. Tax and subsidy equal, therefore:

$$t = cn^*(1-\frac{n^*}{N}); \quad s = \frac{c(n^*)^2}{N}$$

5.1. Decisions under certainty

The derivation of the outcomes of four options (the 3 pricing options described above and a fourth option, viz. do not introduce road pricing at all) is, for each group of individuals, derived in Appendix 2. The procedure is the same as in Section 4.

We represent the rankings of the four alternatives for each of the groups considered at the bottom of Figure 4. Note that for option 2 (road toll and public transport subsidy package with redistribution of excess revenues) it is assumed that a positive amount is lump sum redistributed (for more details, see Appendix 2). Moreover, we assume that, for continuing drivers, no road pricing at all is better than the three options with pricing.

The intuition behind the rankings then goes as follows (again, more details are in Appendix 2). First, those who continue to drive (range $0, n^*$) prefer no road pricing at all. Among the road pricing options, they prefer a tax on road use that is as low as possible. The lowest tax that guarantees the optimal outcome n^* is to use all toll revenue for public transport subsidies, because this avoids redistribution of revenues to the group of voters that use no peak-period transport at all (the group in the range *N*,*M*). Second, initial car drivers that switch to public transport (range n^*, n^0) prefer the option with maximal public transport subsidies. Whether they prefer this option above having no road pricing at all depends on their position in the given range. Third, all initial public transport users (range n^0, N) of course also prefer a maximum subsidy. What they like least is that nothing happens at all, because then they receive no benefit. Finally, the group in the range N to M prefers the solution without subsidies to public transport, as this gives rise to a maximal lump sum redistribution. What they like least is that nothing happens.

We can only guarantee a unique solution for a majority voting system if we have single peaked preferences. Note that the outcome is fully determined by the choice of one parameter: the tax rate t . The 4 options to chose from are:

Option 0 t=0 ,

Option 1 $t = cn^*$

Option 2 $t = cn^*(1-\frac{n^*}{N})$ combined with $s < \frac{c(n^*)^2}{N}$

Option 3 $t = cn^*(1-\frac{n^*}{N})$ combined with $s = \frac{c(n^*)^2}{N}$,

Using the rankings determined above (see Figure 4 and Table A4 in Appendix 2), one can easily verify that we have single peakedness of the utility function for each of the groups we consider. Again based on the rankings for the different groups, this allows us to formulate our next proposition.

PROPOSITION 4. *When not all voters use transport in the peak period, we have the following outcomes for a simple majority vote on the tax and subsidy combination:*

- *No road tolling is introduced when* $n' > \frac{M}{2}; \quad n' = n^0 - \frac{c}{b}\frac{(n^*)^2}{N}$

- A road toll whose revenues are used only for public transport subsidies is chosen when $n' < \frac{M}{2} < N$

- A road toll with full lump sum redistribution and no public transport subsidies is selected when $N < \frac{M}{2}$

5.2. Decisions under uncertainty (ex ante)

What happens under uncertainty? We can go through the analysis as developed before to show that, for each of the four policy options, there will be cases where a majority is in favor under certainty, whereas a majority is against under uncertainty. To do so, we give in Table 2, for the three policy options, information on

(a) The cutoff value such that under certainty everyone to the left is against the policy considered. These were derived in Appendix 2.

(b) The expected gain for the initial car users n^0 under uncertainty. This was calculated as in Appendix 2 (also see, e.g., (10)) for each of the policies considered. For example, for option 1 the expected gain is given by:

$$\frac{n*}{n^0}\left[-cn*+c(n^0-n*)+\frac{c(n*)^2}{M}\right]+\left[\frac{n^0-n*}{n^0}\right]\left\{\frac{c(n*)^2}{M}-\left[a-b\left(\frac{n^0+n*}{2}\right)-(d+cn^0)\right]\right\}$$

Working out leads to

$$\frac{c(n*)^2}{M}-\frac{cbn*}{b+2c}-\frac{b}{2n^0}(n*-n^0)^2$$

This is the result reported in Table 2. A similar procedure is used for the two other options.

	Option 1 Road tax with lump sum redistribution (no subsidies to public transport)	**Option 2** Road tax, revenue use for public transport subsidies and lump sum redistribution	**Option 3** Road tax used only for subsidies to public transport
Cutoff value under certainty (those to the left are against policy)	$n^0 - \frac{c}{b}\frac{(n^*)^2}{M}$	$n^0 - \left[\frac{c(n^*)^2}{bM} + s\left(\frac{M-N}{bM}\right)\right]$	$n^0 - \frac{c}{b}\frac{(n^*)^2}{N}$
Expected gain of initial car drivers n^0 under Uncertainty	$\frac{c(n^*)^2}{M} - Q$	$\frac{c(n^*)^2}{M} - Q + s\left(\frac{M-N}{M}\right)$	$\frac{c(n^*)^2}{N} - Q$

Note: $Q = \frac{cbn^*}{b+2c} + \frac{b}{2n^0}(n^* - n^0)^2 > 0$

Table 2: Comparing the three options with road taxes under uncertainty

From Table 2, we can extract three pieces of useful information. First, fewer people are against under certainty if the road tax is only used to subsidize public transport (first row of the table shows that the cut-off value of n is smaller for option 3). Second, the expected gain of initial car drivers n^0 under uncertainty is larger (or a smaller loss in case of a loss) if politicians decide to subsidize public transport (second row of the table shows that highest value is obtained for option 3). Third, assume that the expected gain of initial car drivers is negative in all three cases. Then what can we say about the probability that a different voting outcome would results ex ante versus ex post? To see this, first consider option 1 (tax only). Our findings suggest that we will have a majority in favor of this policy under certainty, but a majority against the policy under uncertainty if

$$n^0 - \frac{c}{b}\frac{(n^*)^2}{M} < \frac{M}{2} < n^0$$

Similarly, for option 2 the same will happen if

$$n^0 - \frac{c}{b}\frac{(n^*)^2}{M} - s\left(\frac{M-N}{bM}\right) < \frac{M}{2} < n^0$$

Finally, for option 3 a majority will be pro under certainty whereas a majority will be against due to uncertainty if

$$n^0 - \frac{c}{b}\frac{(n^*)^2}{N} < \frac{M}{2} < n^0$$

Simple comparison shows that for options 2 and 3 the phenomenon is more likely to occur than under option 1. So tax policies with some public transport subsidies is more likely to have the problem of majorities against ex ante and majorities pro ex post than policies with only direct redistribution. This gives our last proposition:

PROPOSITION 5. *When not all voters use transport in the peak period, there is the highest difference between ex ante and ex post majorities if road pricing is used only for public transport subsidies*

6. Conclusions and caveats

In this paper, a simple majority voting model was studied in which people vote over the introduction of peak-period road pricing; the model considered two transport modes, car transport and public transport. The revenues of road pricing could be returned lump sum to voters, or they could be used to support public transport.

The model provides an explanation for several observed phenomena associated with the introduction of road pricing in practice; the London and Stockholm experiences serve as relevant cases. The model offers a potential explanation for the empirical observation that the introduction of road pricing in these cities was combined with substantial investment and subsidies in public transport. Introducing idiosyncratic individual uncertainty about the willingness-to-pay for car use, it also explains the evolution of public attitudes towards road pricing that was observed: there was widespread opposition to road pricing before its introduction, but public support grew over time after road pricing was introduced. Our model shows that uncertainty may imply the presence of a majority that is ex ante against road pricing and ex post in favor. Finally, we show that the ex ante majority against road pricing also implies that there is no majority for organizing an experiment that would take away the individual uncertainty. This may explain the organization of experiments by the authorities against the will of the population; this was observed, among others, in Stockholm.

Our model was deliberately simple, and a number of strong assumptions were introduced, including equal values of time for all road users, the absence of risk and loss aversion, no interaction between car and public transport in the production of congestion, and a linear public transport cost function. It is clear that relaxing these assumptions complicates the analysis, but there are good reasons to believe that the main message of this paper will still hold. First, risk aversion would serve to strengthen the conclusion that ex ante majorities against road pricing may turn into majorities in favor of road pricing ex post. Second, loss aversion (in the sense of status quo bias) among initial drivers reduces the shift from car use to public transport; its main effect in the framework of our model is to make demand for car travel less elastic. Third, allowing car use to affect the time cost of public transport is likely to make public transport more attractive after introducing road pricing, but it also affects the optimal road toll. However, it does not affect the logic of the current paper.

A number of extensions may be worthwile for future work. For example, the behavior of politicians was completely absent from our model: people voted over the introduction of road pricing, but politicians’ preferences and possible lobbying by groups affected by road pricing played no role at all. This paper just focused on the simplest mechanism that is simple majority voting. Finally, other types of uncertainty could be studied, such as uncertainty about the use of the revenues or uncertainty about the effect of road tolls on traffic levels.

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Appendix 1. Implications of different political outcomes ex ante versus ex post

The possibility that uncertainty may imply a majority against road pricing even though a majority would have been in favor in the absence of uncertainty raises two further issues, discussed below.

<u>How large is the 'conflict' range?</u>

The relative range *R* where a conflict arises between the political outcome ex ante and ex post is implicitly given by:

$$R = \frac{n^0 - n'}{N}$$

To analyze the determinants of this range, note that we have, after simple algebra:

$$\frac{n^0}{N} = \left(\frac{a-d}{a}\right)\left(\frac{z}{1+z}\right)$$

$$\frac{n'}{N} = \left(\frac{a-d}{a}\right)\left(\frac{z}{1+z}\right) - \left(\frac{a-d}{a}\right)^2\left(\frac{z}{(2+z)^2}\right)$$

where $z = \frac{b}{c}$. This expresses the conflict range as function of the relative slopes of demand and congestion functions. It is then easily shown that the relevant range is at its maximum when $z=2$, or $b=2c$.

Consider a numerical example. Let $a = 10,\ d = 2$, so that:

$$\frac{n^0}{N} = 0.8\left(\frac{z}{1+z}\right)$$

This is rising in *z*. It equals 0.5 for $z \cong 1.7$. So for $z>1.7$ there is a majority against ex ante. Similarly,

$$\frac{n'}{N} = 0.8\left(\frac{z}{1+z}\right) - 0.64\left(\frac{z}{(2+z)^2}\right)$$

This is rising in *z* for all relevant values. It equals 0.5 for $z \cong 2.4$. Hence, for $z<2.4$ there is a majority in favor ex post. The conflict range involves values for z such that $1.7 < z < 2.4$. For example, if:

$$N = 100, b = 0.1, c = 0.05$$

we find

$n^0 = 53, n^* = 40, n' = 45$

Under uncertainty, 53% are against although, under certainty, 55% would have been in favor.

<u>The welfare gain of road pricing and the probability of implementation</u>

Does a higher welfare gain imply that the probability of implementation (majority in favor under uncertainty) rises, or is this not guaranteed? To investigate this issue, note that the welfare gain per person can be written as, see Figure 2:

$$\frac{WG}{N} = \frac{1}{N}\frac{1}{2}(n^0 - n^*)cn^0$$

Using the definitions of N, n^0, n^* and simple algebra, this can be rewritten as:

$$\frac{WG}{N} = \frac{(a-d)^2}{2a}\left[\frac{z}{(1+z)^2(2+z)}\right]$$

Differentiation shows that the gain per person is rising in *a* and declining in *d*. Moreover, we have:

$$\frac{\partial\left(\frac{WG}{N}\right)}{\partial z} > 0 \Leftrightarrow (1 - z - z^2) > 0$$

It follows:

$$\frac{\partial\left(\frac{WG}{N}\right)}{\partial z} > 0 \;\; iff \;\; z = \frac{b}{c} < \frac{1}{2}(\sqrt{5} - 1) \cong 0.6$$

$$\frac{\partial\left(\frac{WG}{N}\right)}{\partial z} < 0 \;\; iff \;\; z = \frac{b}{c} > \frac{1}{2}(\sqrt{5} - 1) \cong 0.6$$

Loosely speaking, this means (given the definition of *z*) that more congestibility (a higher *c* relative to *b*) raises the welfare gain per person if *z*>0.6 .

Next, note that we have a majority under uncertainty if $n^0 < \frac{N}{2}$. Using the definitions, this can be reformulated as

$$L < \frac{1}{2}; \quad L = \frac{(a-d)}{a}\frac{z}{1+z}$$

It is more difficult to get a majority for higher a and lower d. Moreover, $\frac{\partial L}{\partial z} > 0$, so that it is always 'more difficult' (in the sense that it becomes more difficult to satisfy $L<0.5$) to get a majority if z increases. More congestibility (higher c) makes it easier to get a majority, because you have fewer drivers.

Therefore, in most cases (as long as $b>0.6c$), a higher welfare gain also implies a higher probability of getting a majority under uncertainty.

Appendix 2. Derivation of preferred choices of different individuals

For the different types of people, we first discuss the effects of each of the three tax policy options separately. We then discuss for each group the ranking of four alternative policies, viz. the three road pricing options plus a fourth option which is the status quo, i.e. have no road pricing at all.

Option (1): optimal tax with simple redistribution

Results are in Table A1. They are obtained using similar derivations as before. Also using the same argument as before, continuing car drivers will be worse off provided the condition

$$\frac{M - n^*}{n^*} > \frac{c}{b}$$

holds. This means that the number of people not driving by car (public transport users plus people not demanding any transport) must be sufficiently large. Furthermore, both continuing public transport users and people not demanding any transport are all better off because they receive part of the revenues.

Interval	Net gain
$0->n*$	$-cn*+c(n^0-n*)+\frac{c(n*)^2}{M}$
$n*->n^0$	$-\left[a-bn-(d+cn^0)\right]+\frac{c(n*)^2}{M}$
$n^0->N$	$\frac{c(n*)^2}{M}$
$N->M$	$\frac{c(n*)^2}{M}$

Table A1: Net gain for option 1

Finally, people that switch from car to public transport can be better or worse off. As before, a cutoff value can be determined. We find that everyone to the left of

$$n^0-\frac{c}{b}\frac{(n*)^2}{M}$$

will be worse off. One easily shows that as long as continuing car drivers are worse off, the cutoff point will be larger than $n*$ (so between $n*$ and n^0). Also note that the cutoff point is larger than in the one-mode (or two-mode with two groups only) case.

Option 2: optimal tax-subsidy with simple redistribution

Results are in Table A2 below. Note that redistributed revenues are

$$\frac{tn*-s(N-n*)}{M}=\frac{(t+s)n*}{M}-s\frac{N}{M}=\frac{c(n*)^2}{M}-s\frac{N}{M}$$

For the group that switches from car to public transport ($n*->n^0$), fewer people will be against the policy as compared to Option 1. The cutoff value for being worse off and hence against the policy is given by

$$n^0-\left[\frac{c(n*)^2}{bM}+s\left(\frac{M-N}{bM}\right)\right]$$

Interval	Net gain
$0 -> n*$	$-cn*+c(n^0-n*)+\frac{c(n*)^2}{M}+s\left(\frac{M-N}{M}\right)$
$n*-> n^0$	$-\left[a-bn-(d+cn^0)\right]+\frac{c(n*)^2}{M}+s\left(\frac{M-N}{M}\right)$
$n^0 -> N$	$\frac{c(n*)^2}{M}+s\left(\frac{M-N}{M}\right)$
$N -> M$	$\frac{c(n*)^2}{M}-s\frac{N}{M}$

Table A2: Net gains for option 2

<u>Option 3: optimal tax-subsidy with budget restriction</u>

If all toll revenues are used to finance public transport subsidies, the net gains are as in the following Table A3. People that demand no transport at all are unaffected. Not surprisingly, therefore, we find exactly the same result as in the case of one mode (or two modes but two groups of people only).

Interval	Net gain
$0->n*$	$-cn*+c(n^0-n*)+\frac{c(n*)^2}{N}$
$n*->n^0$	$-\left[a-bn-(d+cn^0)\right]+\frac{c(n*)^2}{N}$
$n^0->N$	$\frac{c(n*)^2}{N}$
$N->M$	*0*

Table A3: net gains for option 3

Note again that continuing car drivers will be worse off as long as the number of public transport users is sufficiently large. If few public transport users need to be subsidized then the tax per car driver will be small; if at the same time savings for car users are relatively large, one understands that indeed continuing car drivers can actually be better off.

People that switch from car to train can be better or worse off. However, comparing with the previous options, fewer people will be against the policy as compared to Option 1. The cutoff is

$$n^0-\frac{c}{b}\frac{(n*)^2}{N}$$

Comparing the different options

We are now in a position to compare, for each group, which of the four available options (three road pricing options 1-2-3, plus the option of doing nothing, denoted option 0) is preferred. We bring the results together in Table A4. In the final column, we report the implied ranking of the three options from the viewpoint of each of the groups considered: continuing car drivers, people that switch from car to public transport, continuing rail users, and people not demanding transport. Note that the results boil down to what we had in section 2.2 if we assume *M=N*.

First, consider continuing drivers. Assuming that all road pricing options make them worse off (if not, they would always vote in favor and road pricing would always have a majority) they prefer option 0 (no road pricing at all) over the three others. Of the remaining options, they prefer option 3 over option 1. Although they do not get any revenues back via redistribution, they pay a lower tax under option 3; moreover, under policy 1 they have to share redistribution of the revenues with people not demanding any transport. It is also obvious that they prefer 2 over 1. To make the comparison between options 2 and 3 we need an extra assumption. To see this, note that option 3 is better than 2 if:

$$\frac{c(n^*)^2}{M} + s\frac{M-N}{M} < \frac{c(n^*)^2}{N}$$

This can be rewritten

$$\frac{c(n^*)^2}{N}\left(\frac{N}{M} - 1\right) + s\frac{M-N}{M} < 0$$

Or alternatively,

$$\left[s - \frac{c(n^*)^2}{N}\right]\left(\frac{M-N}{M}\right) < 0$$

Now let us assume that the tax-subsidy combination considered in option 2 is such that it leaves a positive net amount for pure redistribution. So we have:

$$\frac{c(n^*)^2}{M} - s\frac{N}{M} > 0 \quad \rightarrow \quad s - \frac{c(n^*)^2}{N} < 0$$

Since $M>N$, this immediately tells us that option 3 is better than option 2. So continuing car drivers have a clear ranking: they like 3 better than 2 better than 1.

Second, consider the group that switches from road to public transport. They clearly prefer options 2 and 3 (the options with subsidies) over option 1 (the option with only redistribution). Moreover, under our assumptions they are better off with option 2 than with 1: the latter only has redistribution, the former provides a direct subsidy to public transport. The ranking of option 0, having no road pricing at all, depends on the position of the individual in the range (n^*, n^0). People with $n < n'$, where

$n' = n^0 - \frac{c}{b}\frac{(n^*)^2}{N}$ is the cutoff under option 3, will prefer option 0 over option 3; the others in the relevant range prefer option 3 over doing nothing.

Third, we see that continuing public transport users prefer option 3 over 2 over 1 for the same reasons. Finally, people that demand no transport at all -- provided a positive amount is redistributed in option 2 -- will prefer 1 over 2 over 3. For all people in the range n^0, M doing nothing is the worst possible scenario, because in that case they get nothing at all.

Interval	Option (1)	Option (2)	Option (3)	Ranking (°)
$0 -> n*$	$-cn*+c(n^0-n*)+\frac{c(n*)^2}{M}$	$-cn*+c(n^0-n*)+\frac{c(n*)^2}{M}+s\left(\frac{M-N}{M}\right)$	$-cn*+c(n^0-n*)+\frac{c(n*)^2}{N}$	*0 3 2 1*
$n*-> n^0$	$-\left[a-bn-(d+cn^0)\right]+\frac{c(n*)^2}{M}$	$-\left[a-bn-(d+cn^0)\right]+\frac{c(n*)^2}{M}+s\left(\frac{M-N}{M}\right)$	$-\left[a-bn-(d+cn^0)\right]+\frac{c(n*)^2}{N}$	*3 2 1* *0 better or worse than 3*
$n^0 -> N$	$\frac{c(n*)^2}{M}$	$\frac{c(n*)^2}{M}+s\left(\frac{M-N}{M}\right)$	$\frac{c(n*)^2}{N}$	*3 2 1 0*
$N -> M$	$\frac{c(n*)^2}{M}$	$\frac{c(n*)^2}{M}-s\frac{N}{M}$	*0*	*1 2 3=0*

Table A4: Comparison and ranking of the gains for different options

(°) Option 0 is no road pricing at all. The rankings assume that continuing drivers prefer no road pricing at all over any of the road pricing options. Moreover, it is assumed that under option 2 a positive amount is available for pure redistribution. If not, all people in the range n*-N would prefer 2 over 3.