Reforming Private and Public Urban Transport Pricing

Discussion Paper

170

Roundtable

Stef Proost

Catholic University of Leuven

International Transport Forum

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Introduction

In most metropolitan areas, one is confronted with massive road congestion most often when city authorities have refrained from the implementation of road pricing for technical or political reasons. The most congested areas rely on a modal shift to public transport (PT). To mitigate road congestion issues, the quality and capacity of PT has been increased and a policy of low prices for PT introduced to make it an interesting alternative.

According to the Union Internationale des Transports Public's (UITP) (2015) database that covers 60 metropolitan areas in the world, PT's average market share increased from 34% in 1995 to 40% in 2012. PT supply (in vehicle kilometres) has increased in the same period by 30% and the seat kilometres offered has increased even more because larger vehicles have gradually replaced the older and smaller ones. Of course, increases in public transport supply aim to cater for peak demand rather than average PT demand. In some metropolitan areas (London and Paris) the market share in the peak period approaches 70% to 80%. Even with large increase in PT use, there are also several indicators showing massive congestion in PT for these areas.

Many transport policy makers believe that increasing PT supply and the continuation of a low PT price policy are the best ways of managing transport pricing. In addition, they believe these are necessary conditions to have successful road pricing that is accepted by the population. Low PT price policy is a well-known textbook example of second best pricing: when the use of cars is priced too low, it makes sense to lower the price of the substitute – here PT. But when the price of road use can be corrected via the introduction of road pricing, it may no longer be necessary to set prices of PT well below its marginal cost.

In this paper we examine how PT prices need to be set in both the absence and presence of road pricing. This is important as public transport in congested urban centres has larger market shares than private transport (ie car use) at peak travel times. Correcting prices for the small share of road users and forgetting the correct pricing for the majority of commuters that use PT would be a mistake. The three main research questions are therefore: What are the right PT prices in the absence of road pricing? Do PT prices need to be increased when road pricing is introduced? And, would the changes in PT that accompany road pricing jeopardise the public support for road pricing?

We address these questions in three steps. First, we briefly present the principles for good pricing of car use and PT with and without road pricing. Then, we analyse the possible effects of alternative private and public transport pricing scenarios for two cities: Stockholm and Paris. This gives an idea of the efficiency gains of correcting public transport prices in relation to the implementation of road pricing. Following on from this, we discuss the difficulties and strategies to obtain social and political support for a reform of private and public transport prices in metropolitan areas before making conclusions.

What are good pricing rules and principles of private and public transport?

An ideal world does not exist, but it helps to know what direction we should be aiming for in terms of prices of private and public transport. We start by looking at optimal pricing rules in this section when there are no constraints on the implementation of road pricing. Next we examine what public transport principles should look like when road pricing is not available. Then we confront the principles of good pricing with reality: how does current transport pricing look in reality?

Optimal private and public transport pricing

When a traveller decides to use his car or PT, he compares the generalised price of the two options with his willingness to pay for a given mode. In a market economy, one relies on the price signal to make sure the individual choices are in line with the cost for society. For car use, the generalised price consists of the money price (operation costs plus taxes) plus the cost of time in the vehicle plus costs of schedule delay. For PT, the generalised price consists of the fare plus time costs for access plus the in vehicle time cost, corrected for the discomfort plus the wait and schedule delay costs. For individuals to bring the cost of their travel options in line with the full social cost, one needs to adapt the tax or toll on car use and to adapt the fare until private generalised costs are in line with the social generalised costs.

Optimal pricing of private transport in metropolitan areas is well known in theory. In practice however, it remains difficult to compute the best technical implementation and the optimal toll levels. One has to deal with flows on a complex road network, the choice between cordon and zonal pricing and there is the time differentiation and the enforcement technology to consider.

There is a consensus that for a congested zone, the *optimal road toll* at time *t* equals:

$$\begin{bmatrix}\text{Road}\\ \text{toll}\end{bmatrix}_t = \begin{bmatrix}\text{Marginal}\\ \text{external cost}\\ \text{of a vehicle}\end{bmatrix} = \begin{bmatrix}\text{Marginal}\\ \text{external}\\ \text{congestion cost}\end{bmatrix} + \begin{bmatrix}\text{Other}\\ \text{external}\\ \text{costs}\end{bmatrix} = \begin{bmatrix}\sum_{\text{All road users}} \begin{matrix}\text{Cost of additional}\\ \text{delay due to}\\ \text{extra vehicle}\end{matrix}\end{bmatrix} + \begin{bmatrix}\text{Environmental and}\\ \text{accident costs}\\ \text{generated}\\ \text{by the vehicle}\end{bmatrix}.$$

The road toll is therefore higher at more congested times of the day and in more congested sections of the network. The corresponding *road capacity extension rule* is also well known: extend road capacity as long as saved travel costs exceed the investment cost. This rule holds as long as optimal road tolls are in place. The *optimal pricing of public transport* rule is less well known by the transport community[1]. A traveller when deciding on his use of PT will take into account his own time and access costs plus the fare he has to pay for the use of PT. This takes a given bus trip (from A to B) for a given bus size and analyses fare and frequency separately. Similar pricing principles exist for metro and urban rail.

The optimal bus fare for a given frequency of service is derived from the same principles as the optimal road toll:

$$\begin{bmatrix}\text{Optimal}\\ \text{bus}\\ \text{fare}\end{bmatrix} = \begin{bmatrix}\text{Marginal cost}\\ \text{of an}\\ \text{additional}\\ \text{bus user}\end{bmatrix} = \begin{bmatrix}\text{Marginal}\\ \text{external cost}\\ \text{of an additional}\\ \text{bus user}\end{bmatrix} = \begin{bmatrix}\text{Additional time cost}\\ \text{for other users due}\\ \text{to mounting and}\\ \text{alighting of an}\\ \text{extra passenger}\end{bmatrix} + \begin{bmatrix}\text{Additional}\\ \text{crowding}\\ \text{discomfort costs}\\ \text{of an additional}\\ \text{bus user}\end{bmatrix}.$$

Additional mounting and alighting costs can be neglected when there is a fixed timetable. It is interesting to note that the higher the occupancy rate of the bus, the higher the optimal fare and this is for two reasons. Firstly, more passengers in a bus means that there are more passengers suffering from crowding. Secondly, more passengers in a bus means that the level of crowding discomfort per passenger becomes more severe.

An important consequence of this pricing principle is that, for a given bus frequency, the optimal fare in the off–peak period will be much lower than in the peak period.

As the cost of an extra passenger on an almost empty bus is close to zero, a well-known and used PT pricing practice is to set off-peak prices at a very low level. Using the same reasoning, prices in the peak period, where there are more passengers per bus, should be high. However, this principle of pricing according to demand is often forgotten.

The focus on congestion in PT is not new. The OECD documented the issue in a Roundtable meeting in 2014 (OECD,2014). Additionally, Nobel Prize winner Vickrey (1955) studied New York City's subway fare structure. He found severe crowding at peak times and advocated a fare system based on marginal-cost-pricing principles replacing the fare structure that is uniform over the day and proportional to distance.

For the supply of bus services, the *second control variable to be optimised is the frequency of bus services (buses per hour for a given number of passengers).* A higher frequency allows reducing two types of user costs:

1) The expected waiting and schedule delay time because there is a higher probability that a bus passes by the bus stop and a more frequent bus schedule will more easily fit the desired departure and arrival times.

2) The crowding discomfort within each bus as, keeping the total number of users over a period constant, there will be less people in each bus with more frequent services.

The savings in user costs should ideally equal the sum of rental cost (i.e. capital cost of the bus), operation costs, air pollution, accident costs (due to extra buses) and congestion costs for other road users.

We then have the following optimal frequency rule that equates the costs and benefits of an extra bus:

$$\begin{bmatrix}\text{Benefits}\\ \text{of an}\\ \text{extra bus}\end{bmatrix} = \begin{bmatrix}\text{Reduced}\\ \text{waiting cost}\\ \text{to passengers}\end{bmatrix} + \begin{bmatrix}\text{Reduced}\\ \text{discomfort cost}\\ \text{to passengers}\end{bmatrix}$$

$$\begin{bmatrix}\text{Costs}\\ \text{of an}\\ \text{extra bus}\end{bmatrix} = \begin{bmatrix}\text{Extra congestion}\\ \text{delay to other}\\ \text{road users}\end{bmatrix} + \begin{bmatrix}\text{Rental cost}\\ \text{of an extra}\\ \text{bus}\end{bmatrix} + \begin{bmatrix}\text{Operating}\\ \text{cost ofthe}\\ \text{extra bus}\end{bmatrix} + \begin{bmatrix}\text{External}\\ \text{environmental}\\ \text{and accident}\\ \text{costs of}\\ \text{the extra bus}\end{bmatrix}$$

Optimal bus fare and bus frequency are not independent. A higher number of bus users calls, all things being equal, for a higher bus frequency.

In the peak period, there will be many passengers, and therefore a high bus frequency. The main benefit of a higher peak frequency will be the saved crowding costs and the cost savings on wait times and the costs of schedule delay. If bus frequency is already high, the main benefit of an extra bus will be the reduced crowding cost to passengers. These will be high but the cost of an extra bus will also be high for two reasons. Firstly, the extra bus will only be used at peak times so this bus is responsible for the rental capacity cost (peak load pricing). Secondly, as there are already many other users of the road at peak times (buses and cars), there is an external congestion cost for the peak bus. The high cost of an extra bus during peak time means that during this peak period when the bus occupancy remains high, the optimal fares should be high.

During off peak times, the main benefit of an extra bus will be the reduced scheduled delay cost but as there are not many passengers, the optimal frequency should be low. With very few people on the bus, the discomfort costs are very small and the optimal fare can be low.

Optimally priced buses do not necessarily generate large PT deficits. When the cost of an extra bus is more or less constant and the reduced waiting and schedule delay costs are not important (in dense cities), optimal fare revenues (or marginal discomfort costs) are close to operation and lease costs of buses. Thus, cost recovery of operation and vehicle costs should not be a big issue when private and public transport prices can be chosen freely. For urban rail and metro, there is a large fixed infrastructure cost in opening and maintaining a metro or train line, but the cost recovery argument should still hold for the variable costs.

Optimal public transport prices when private transport is under-priced

The introduction of road pricing is technically and politically difficult. Public transport price and supply are in principle easier to control by a transport authority. This brings us to the optimal "second best" price for public transport. The idea is simple: as the price of car use is too low at peak times and cannot be changed, the bus fare is decreased in the peak to encourage car drivers switching to public transport. This, however, will alleviate car congestion.

Optimal bus fares now become:

$$\begin{bmatrix}\text{Optimal}\\\text{bus}\\\text{fare}\end{bmatrix} = \begin{bmatrix}\text{Marginal external cost of}\\\text{an additional bus user}\\\text{corrected for the effects}\\\text{on car drivers}\end{bmatrix} = \begin{bmatrix}\text{Additional time}\\\text{cost for other}\\\text{users due to}\\\text{mounting}\\\text{and alighting}\\\text{of an extra}\\\text{passenger}\end{bmatrix} + \begin{bmatrix}\text{Additional}\\\text{crowding}\\\text{discomfort costs}\\\text{of an additional}\\\text{bus user}\end{bmatrix} - \begin{bmatrix}\text{Ratio of new}\\\text{bus users}\\\text{that leave}\\\text{their car}\end{bmatrix} \times \left[\begin{pmatrix}\text{Marginal}\\\text{external}\\\text{road}\\\text{congestion}\\\text{cost}\end{pmatrix} - \begin{pmatrix}\text{toll on}\\\text{cars}\end{pmatrix}\right]$$

When there is an optimal toll on cars, the third term of the above optimal bus fare formula becomes zero as the optimal car toll equals the marginal external road congestion cost. In this case we return to the optimal pricing case discussed before.

When there is no toll or too low a toll on cars, the PT price has to be corrected downwards. The downward correction will be larger when a decrease in the PT price is able to attract mainly former car users. Every former car user saves the marginal external road congestion cost. The importance of the correction term (the third term of the above optimal bus fare formula) depends on the relative success of a bus price decrease in attracting former car users. This is called the *diversion coefficient*. The diversion coefficient is defined for a decrease of the PT price as the ratio of new public transport users (who used to be car drivers) over the total number of new PT users. If, as a result of a PT price decrease, all new passengers are former car users (i.e. diversion coefficient equals to 1), the additional subsidy for PT is very efficient in solving the road congestion problem. Transport practitioners tend to be too optimistic about the value of the diversion coefficient. Unfortunately, the diversion coefficient is only in the order of 0.15 to 0.35[2]. For every 100 new passengers attracted by low PT prices, 15 to 35 are former car users, the other 65 to 85 users are new PT users that did not use a car before. A diversion ratio of

0.15 to 0.35 makes the PT price decrease less interesting as the benefit for the 65 to 85 new PT users is lower than the social cost of bus use. PT uses then becomes excessive.

In this situation, the optimal bus frequency rule will also need to take into account the possible reduction of unpriced car congestion as one of the benefits. One can expect the optimal frequency to be higher as lower PT prices bring more passengers. This type of second best bus pricing will generate a PT budget deficit because there is a deliberate subsidy that puts prices of PT below its operation costs.

Although the optimal bus fare in the peak period is now lower to reduce road congestion in the peak, there is no reason to subsidise bus use in the off-peak period as road congestion will also be during that period.

One of the other arguments to justify very low PT prices is the concern about *income distribution* of PT users. The argument is that PT is used more intensively by people with lower income and so pricing PT below its marginal social cost can be justified as a means to help these users. This argument needs to be handled with great care. First, every dollar spent on subsidies needs to be financed, so the ultimate effect of an extra subsidy for PT on the income distribution can only be assessed when one specifies how the subsidy is financed. When PT is also used by people with high income and is paid by income taxes, this more complete assessment gives a more nuanced view (Mayeres and Proost, 2001). Second, case studies in developing countries, where income differences are largest, show that there may be better ways to help people with lower income than to have very low PT prices (Serebrisky et al., 2009).

Observed public transport prices vs. optimal public transport prices

In reality, we see large public transport deficits globally. According to the UITP database (it consists of 2002 data for 52 cities), the mean recovery of operating costs by fares was 39% (ranging between 13% and 80%). The low public transport prices are often not differentiated between peak and off-peak, and there is a lot of congestion on the road, and also in public transport. In addition one finds more and more season tickets which mean almost zero fares for those who have a season ticket. What went wrong, and what is the reform of car and public transport prices that we need?

Understanding current policies is never easy as it is the result of many reforms in urban transport policy but also the contractual arrangement between the government and the PT agency. It seems that the objectives used by PT agencies are often different from the economic objectives we used to derive optimal prices and frequencies. One of the objectives used by PT agencies is to maximise PT ridership under a budget constraint. The main difference from the economic efficiency criterion is that for PT agencies any new PT user is good, it does not need to be a former car peak user that brings large associated benefits on the road system nor does it not need to be an additional off peak PT user that can be served at very low cost. Maximising ridership leads to a different urban transport pricing strategy compared to maximising economic efficiency of the transport system.

Low prices and biting budget constraints indeed lead to large ridership and heavy public transport congestion. The congestion comes from the difficulty to expand public transport supply when a revenue base does not follow: an extension of the public transport supply will generate more users but they do not pay the marginal costs of supplying the extra capacity.

We can draw a parallel between the public transport congestion problem and the road congestion problem: both transport systems tend to use uniform prices for peak and off peak periods and this results in heavy congestion at the peak times for both systems. There is more evidence than ever which suggests that additional road capacity does not really decrease the level of congestion (Duranton and

Turner, 2011; Hsu and Zhang, 2014; Pasidis, 2017), it would be interesting to know whether the same principle of eternal crowding exists for public transport capacity extensions.

Of course there are exceptions. Cities like London and Washington DC use prices that are differentiated between peak and off peak periods. In London, a single journey ticket costs more than twice as much in the peak than in the off-peak period.

Numerical illustrations for Stockholm and Paris

A numerical analysis of congested European cities such as Stockholm and Paris can explain whether applying wrong prices for public and private transport matters. We are mainly interested in two questions: Is a reform of public transport prices beneficial even if road pricing is not introduced? And does a reform of public transport prices increase or decrease the benefits of road pricing?

We make use of two numerical illustrations: one for a congested corridor in Stockholm and one for the whole of Paris. The two illustrations have different ambitions. In the illustration for Stockholm, we limit the discussion to one corridor where only cars and buses can be used. For this corridor we go into more detail on the public transport supply by explicitly optimising bus prices and frequency. For Paris we take a wider approach and cover the whole city and its different modes but simplify the frequency optimisation by using automatic frequency update rules.

Both illustrations use simple models that aim to illustrate orders of magnitude for the effects of PT pricing and road pricing.

Interaction between road pricing and public bus pricing in Stockholm

Borjesson, Fung and Proost (2017) studied one corridor that links a suburb to the Stockholm city centre. The city centre can be reached by car and bus, there is one bus lane and two car lanes. Although there is a toll on road use[3], there is still congestion on the car lanes. In the peak period, private transport has a modal share of 20%, the rest is bus transport but in the off-peak period, the car share is higher (34%). The Stockholm case is interesting because the introduction of road pricing provides good revealed preference information on the cross price elasticity between private road use and public transport.

The car tolls, bus prices and frequencies in the reference equilibrium, are given in the first line of Table 1. As one can see there is already a car toll in place and it is higher in the peak than in the off peak. Bus prices are the same in the peak and in the off-peak and 37% of bus operating costs are subsidised.

Table 1. **Effects of private and public transport pricing reform for a corridor in Stockholm**

Scenario	Road toll Peak in €/trip	Road toll Off-Peak in €/trip	Bus fare Peak in €/trip	Bus fare Off-Peak in €/trip	Frequency Peak Bus/hour	Frequency Off-Peak Bus/hour	Deficit 1000 €/day	Welfare Gain In 1000 €/day
Reference	1.80	1.00	2.18	2.18	67	48	25.86	
Optimal Bus fare	1.80	1.00	4.50	0.00	67	48	26.54	12.58
Only change frequency	1.80	1.00	2.18	2.18	92	13	15.38	22.20
Optimal toll, bus and frequency	4.31	3.32	4.90	0.97	84	20	-2.95	36.97
Zero car toll and optimal bus fare	0	0	4.10	0.00	67	48	30.19	14.12

Source: Based on Börjesson et al. (2017)

The simulation model for the Stockholm corridor is used to address three questions.

Is it efficient to reform public transport prices, now that there is already a road toll in place?

This can be seen in the "Optimal Bus fare" row of Table 1 above and the answer is yes: the peak bus fare needs to be doubled and the off peak price is set to 0. We know from the theory that uniform public transport prices are inefficient and that is what we see in Börjesson et al (2017). The public transport price reform does not change the overall PT subsidy needed (around EUR 25 000/day), but brings a clear welfare gain (EUR12 580/day) by reducing ridership in the peak that does not cover its social costs, and by encouraging ridership in the off-peak that is almost costless from a societal point of view.

Is it useful to adapt the supply of public transport, here to adapt the frequency of buses?

Yes, in the "Only change frequency" row of Table 1, we find that it is optimal to increase the frequency in the peak and to decrease the frequency in the off peak period. This can be done with less subsidies than in the reference case EUR 15 380 instead of EUR 25 860 /day and brings a clear welfare gain (EUR 22 200 /day). Optimising PT frequencies appears to be a quick win.

How low should public transport prices be set when road tolls are absent?

The "Zero car toll and optimal bus fare" row provides answer to how low the second best PT prices should be in the case of Stockholm. When road tolls are absent, one expects the public transport prices to be lower than with road tolls. However, the optimal "second-best" prices are barely lower than the prices one obtains when all prices can be controlled and are clearly higher than the PT prices of the reference case. The second best peak PT price is EUR 4.10 per trip while the optimal first best PT price is

EUR 4.90 to be compared with the current price that is only EUR 1.8 per trip. In other words, with the introduction of road pricing in 2007, one has failed to reform public transport pricing.

Comparing the welfare gain of full optimisation of road and bus prices (EUR 36 970 per day in the "Optimal toll and bus frequency" row) with the partial optimisation of public transport prices and frequencies, one sees that the majority of the maximal welfare gains come from getting public transport prices and frequency right (EUR 12 580 and EUR 22 200 respectively). This should not come as a surprise as in the peak period 80% of the trips use public transport.

Finally optimising private and public transport (see "Optimal toll, bus and frequency" in Table 1) generates a surplus (EUR 2 950 per day), illustrating our point that proper pricing of PT is not necessary more costly for the public budget.

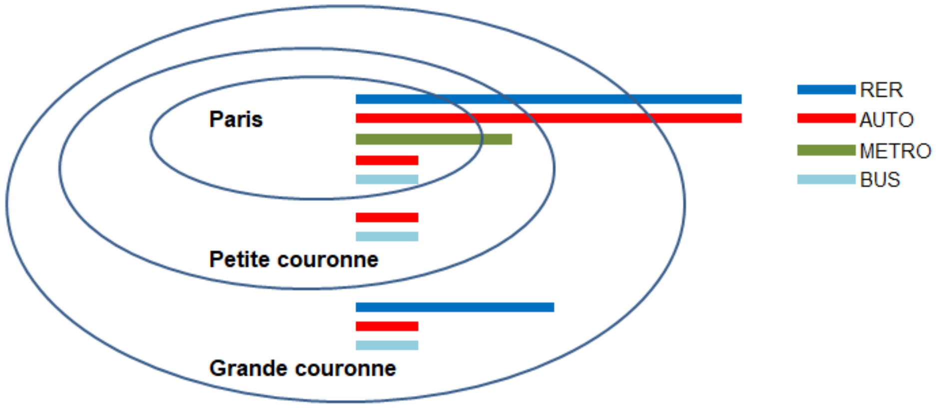
Public transport pricing and road pricing in Paris

Paris has used a policy of low PT prices and has not implemented road pricing – lately road capacity has been restricted and there are also additional restrictions on cars that emit high pollution levels. Kilani, Proost and Van der Loo (2014) analyse the benefits of introducing road pricing using different accompanying policies for PT prices. The reference year for the simulation was 2007.

Figure 1 shows that the city is modelled as a set of three concentric rings that are connected by roads, regional trains, metro and buses. A distinction is made between households with low and high income and between households with and without working members – for these four groups we know their location in one of the rings, their trips (within and between rings), the combination of modes they use and a different value of time is associated to each group. A distinction is also made between peak and off-peak periods. Initially the PT fares cover approximatively 95% (off-peak) to 65% (peak) of the marginal supply cost. There is heavy congestion in the peak period on roads but also in public transport.

We tested nine different scenarios that combine a zonal road toll of EUR 3 around the Petite Couronne and the urban centre of Paris, with a higher or lower PT fare and with or without an extension of the overall public transport seating capacity. In all scenarios we assume that any increase of ridership in public transport is matched by a two-thirds increase or decrease of operational seat capacity. This takes the form of additional buses or extra rail and metro carriages. This is in fact a shortcut for an optimal capacity and frequency adjustment that we optimised explicitly in the case study for Stockholm. In addition we assume that the net budget surplus is redistributed equally to all the users.

Figure 1. **Model representation of Paris transport modes and zones**



Source: Based on Kilani et al (2014)

This allows us to address three research questions:

Do we need to complement the introduction of zonal road pricing by an increase or a decrease of the PT fares?

Using the first three columns of Table 2, we find that *the welfare gains* of complementing the zonal road pricing *with an increase in PT peak fares is higher* than when the zonal road pricing is accompanied by a PT fare decrease. In the zonal road pricing scheme (or zonal toll), a peak toll is imposed on each car trip within the zones where congestion is the most severe. The main problem with lowering PT fare is that the increase in PT users requires additional operating costs which reduces welfare because the initial fare does not cover the marginal operating costs. An increase in PT prices works better but hurts the low income households when net toll revenues are redistributed uniformly. But when a double weighting is given to the utility change for the low income households (see the "Total welfare with double weight for low income earners" row in Table 2), the overall efficiency of a PT price increase is still higher.

The total number of trips is hardly affected by a zonal toll at the level of the Petite Couronne. The total number of car trips even increases slightly but this mainly in the non-tolled area. Adding an increase in PT peak prices to the zonal toll results in an overall decrease in trips of 1.2%.

It is often claimed that the introduction of road pricing needs to be accompanied or even preceded by a general increase of public transport capacity. In addition to the automatic operational capacity change built into the scenarios, we now add 10% more seats in the reference scenario. We do this at zero cost so that we only take into account the benefits.

Is this general increase of PT capacity (10% more seats) sufficient to capture a large part of the welfare gains of road pricing?

Comparing columns 4, 5 and 6 in Table 2, the net benefit of the capacity extension of PT is small compared to the effect of introducing road pricing (1% of the net benefits of road pricing). Furthermore, lowering PT prices decreases net benefits of PT capacity extension, while increasing PT peak prices increases the benefits. In conclusion, *a capacity increase of PT* (here 10% more seats) *cannot replace the introduction of road pricing and does not produce significant benefits even if this increase comes at zero cost.*

Do the benefits of road pricing increase strongly when road pricing is combined with a general capacity increase of PT (10% of seats)?

We find that the benefits of road pricing hardly change and that a combined introduction of road pricing and higher public transport pricing still wins. This can be seen by comparing columns 7 to 9 in Table 2.

Table 2. **Welfare effects of private and public transport price reform and of an increase in seating capacity in Paris (changes in Million EUR compared to no reform)**

Column number	1	2	3	4	5	6	7	8	9
Investment PT	No	No	No	10%	10%	10%	10%	10%	10%
Zonal toll (EUR/trip)	3	3	3	0	0	0	3	3	3
PT fare change	0%	+10%	-10%	0%	+10%	-10%	0%	+10%	-10%
Utility poor	157	-62	1271	8	-201	229	170	-49	397
Utility rich	690	121	1655	36	-500	602	749	177	1332
Toll+P revenues	1233	1277	1187	-1	35	-46	1232	1276	1185
PT revenues	241	803	+351	8	559	567	253	816	339
PT operating costs	662	317	1021	35	-275	376	719	370	1081
Total welfare	1658	1822	1470	15	173	-158	1684	1850	1495
Total welfare with double weight for low income earners	1614	1761	1445	13	153	-141	1637	1785	1467

Source: Based on Kilani et al. (2014)

More complex pricing pays off

In the previous sections simple congestion technology was used: it distinguished only peak and off-peak periods and advocated differentiating prices between the two periods for private and public transport. The use of this representation of congestion tends to underestimate the benefits of road pricing and of public transport peak pricing. An alternative representation is to assume that all peak travel (6a.m. to 10a.m. in morning for example) has the same ideal arrival time and that there is an absolute bottleneck with capacity of *s* number of vehicles or passengers per hour: whenever there are more than *s* number of users that want to access the system, these users have to queue until they can access the system. In equilibrium, users spread their departure times and each traveller has the same sum of queuing and schedule delay costs. With a uniform simple toll or fare in the peak period, one is able to reduce the number of users in the peak and send part of them to the off-peak period but there remains some queuing and schedule delay in the system. A fine toll that varies with the departure time within the peak period is able to generate a much higher efficiency gain than a simple uniform peak toll. For road congestion, this fine toll could be two or more times more efficient than a toll that is uniform over the peak period (Arnott, de Palma, Lindsey, 1993; van den Berg and Verhoef, 2011). This also holds for public transport systems. De Palma, Lindsey and Monchambert (2017) found that for a line of the Paris urban rail system (RER A), that a simple peak vs. off-peak differentiation captures only 60% of the gains of fine tolling. Fine tolling requires more sophisticated and more costly monitoring systems but this more complex tolling seems to pay off. This is also demonstrated by the higher efficiency of the more time differentiated road tolling in Stockholm compared to the day/night differentiation in London (Anas and Lindsey, 2011).

Other studies

There have been several studies looking into the optimal public transport pricing in metropolitan areas. The best known are Parry and Small (2009) and Basso and Silva (2014). They both advocate the use of low second best prices in metropolitan areas but they do this for cities without road pricing (London before road pricing) and use strong assumptions on the diversion ratio of private transport to public transport. The strong public subsidy result of Parry and Small hinges on the assumption that half of the additional PT users attracted by a PT price decrease are car users – the diversion rate would be 50%. In addition, Parry and Small studied London before it implemented road pricing. Redoing the calculations for a lower diversion ratio, the need for very low transport prices disappears. Basso and Silva also find that, once road pricing is in place, there is no need for lowered public transport prices as long as there are bus lanes.

We limited the analysis of urban transport pricing to optimising transport flows for given locations of origins and destinations of trips. There is increasing attention for the wider economic benefits of transport supply and pricing where transport pricing may trigger a change in the location of economic activity. This debate has not been settled yet but a few things stand out (Proost and Thisse, 2017). Firstly introducing road pricing will enhance location efficiency rather than prevent it. Secondly the extension of the supply of public transport within a city can relocate businesses and residents but the net economic growth effect is difficult to demonstrate, as shown by Mayer and Trevien (2017) in their analysis of the urban rail extensions in Paris.

Getting political support for the reform of urban transport pricing

Economically sound measures can only become reality with the support and determination of politicians. In theory, if the government knows the values of time, schedule delay costs, and accessibility of all its inhabitants, it can compute the individual gains and losses of a reform. When this reform generates an aggregate surplus as we advocate, the pricing reform combined with a fine-tuned redistribution of government surplus can make everybody better off.

There are two types of challenges that hinder the implementation of this ideal solution. The first is an asymmetric information problem: it is hard to know who exactly benefits and who loses. The second is the political decision mechanism: this mechanism rarely produces the “welfare optimum” decision. There is no neutral agency putting policy proposals to vote but a complex political decision process where politicians have themselves re-election objectives and behave strategically.

In a democratic market economy, there is an *asymmetric information challenge*: it is not in the interest of an individual inhabitant to reveal their values of time and their costs of changing their departure time. The dominant strategy is to complain and ask for a large compensation for any change. There is a correlation between the values of time and income but this correlation is weak (Small, Winston and Yan, 2005), and in addition public transport is also used by high income earners, so a simple combination of a reform of private and public transport prices and lower income taxes for low income earners would not be effective. Moreover, for many inhabitants it is difficult to understand ex-ante what the outcome after the price reform will be: I pay a higher toll but how much time will I gain? How can I re-organise my daily trips so as to re-optimise my travel pattern when the cost and speed of different modes has changed?

Many theories exist about the *political decision making process* that are more or less suited for the institutions of a particular country. Here we will use variants of the legislative bargaining model of Besley and Coate (2003) to help understand the political decision making process. In this model, regions and/or the federation can take decisions. The regions take decisions via majority voting. Regions also elect a regional representative that take federal decisions via bargaining with other regional representatives.

This raises two questions. *First, how do regions decide via majority voting on road pricing and public transport subsidies? Second is it best to allocate the decision power to the regions or to the federal level?*

How does a metropolitan area decide on transport pricing?

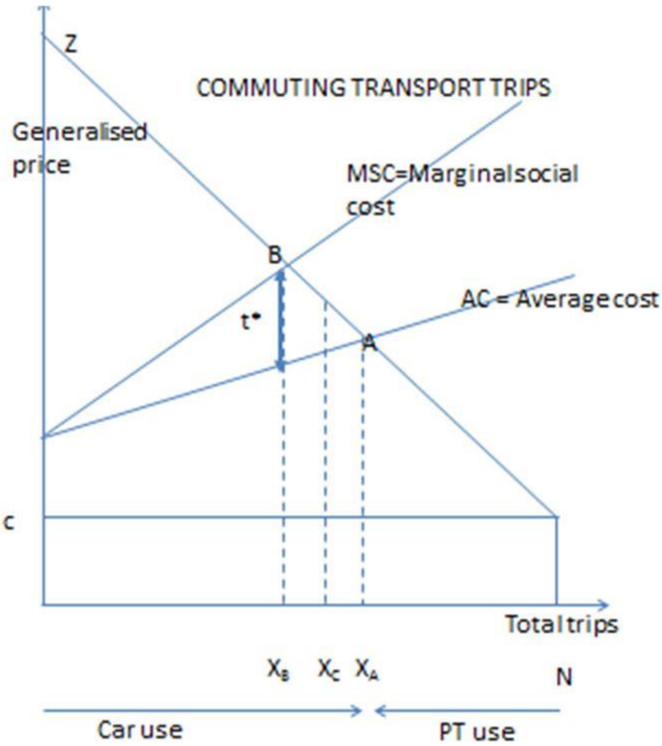
This question is analysed in three steps.

We first study the impact of a reform on different population groups assuming an equal redistribution of the net revenues of road pricing to the population and no spatial asymmetry. Next we study policy variations that use part of the revenues to lower PT prices to build a majority for road pricing. Finally we study the decisions on road pricing using spatial asymmetry.

De Borger and Proost (2012) studied public support for the introduction of road pricing starting from the assumptions that initially public transport prices are equal to the marginal cost and that the total number of trips in the peak period is constant.

We distinguish between two transport markets. We first concentrate on the commuting market where, by assumption, all commuters make a trip in the peak by selecting either the car mode or the PT mode. The commuting market is represented in Figure 2. In this market we order N individuals according to the net access and discomfort cost of using PT, those with the lowest cost of PT access are situated on the right edge of the horizontal line and these will tend to use PT. Those with the highest cost of using PT are situated on the left hand side and will be the car users. The average generalised cost of car use is given by the average cost (AC) curve and the marginal social cost is given by the (MSC) curve. The average cost is increasing because of the increasing time cost when more cars use the road infrastructure. Assume moreover that the MSC of PT is constant – this is justified in the case of a bus service in the peak period where crowding is matched with an increase in frequency. In the initial equilibrium A, X_A individuals use a car and N-X_A individuals use PT for commuting. This is socially inefficient as total commuting costs for society would be minimised when only X_B individuals would use the car. This ideal equilibrium can be reached when there is road pricing, represented by a toll t* added to the average cost of using a car.

Figure 2. **A simple transport market with two modes**



Source: Based on De Borger and Proost (2010)

This simple model was used by De Borger and Proost to show that the *ex-ante cost uncertainty* for the car drivers of switching from car to PT can explain that there can be an ex-ante majority against road pricing but an ex-post majority in favour of road pricing (as was the case in London and Stockholm).

This is easy to see when the majority of the population equals slightly less than X_A. When the revenues of the toll are redistributed to the N commuters, the drivers in the segment X_C -X_A can easily switch to PT and would, taking into account the redistributed revenues, be in favour of road pricing. So if the PT users plus those car drivers that can easily switch have a political majority, road pricing can be introduced.

However, the X_A car drivers may be uncertain about the costs of switching to PT: they may not know where they are situated along the ZA segment. The result is that the X_A-X_C drivers over-estimate the costs of switching to PT. Now all existing car drivers (X_A) will always vote against road pricing as they have a high (average) expected time gain but also pay a toll, the revenue of which is now shared with the public transport users. This explains the paradox where a majority can be in favour ex-post but not ex-ante. Contrary to common belief, there will also be a majority against an experiment with road pricing because the expected gain for all drivers is still negative ex-ante.

A second result concerns the optimal use of the revenues of road pricing. When authorities have the choice between redistributing the revenue equally to the whole population or to dedicate the revenues to lower public transport prices or higher public transport quality, it is easier to find a majority for the option where toll revenue is used for lowering the price of PT. To see why, add some individuals that do not use the private or public transport system in the peak. These individuals would share in the redistributed road toll revenues if these are not used for public transport. But all current PT users and car users will prefer to use all the toll revenues for a reduction of the PT prices. The PT users will prefer lower public transport prices above lump sum redistribution of toll revenues that are dissipated over the population at large. The car drivers would also prefer this reduction of public transport prices as it reduces the road toll.

In conclusion, focusing on the pricing of car use only, one needs a courageous mayor (London) or a minority government (Stockholm) to introduce road pricing. Introducing road pricing is one of these technically difficult decisions that one tends to leave for the successor. It is only when a politician comes to power with determination to act and who does not count on a moderate politician to do the job in the future, that the difficult decision is no longer deferred to the successor (Glazer and Proost, 2017).

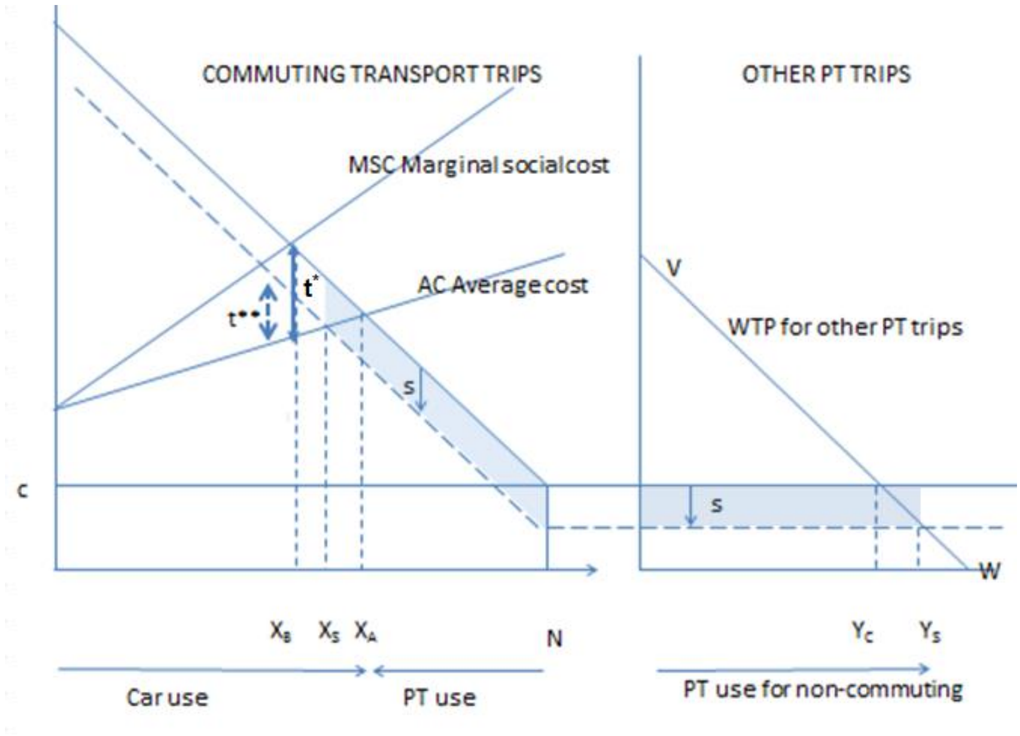
Costs and benefits of road pricing and of public transport reforms

We now extend the model to include the market of individuals that only use PT, and use it for non-commuting purposes. The total demand for commuting trips was assumed to be fixed but for the non-commuting public transport users this no longer holds. We represent the market for PT users in the right-hand part of Figure 3. The left part is a copy of Figure 2 and represents the market for commuting trips. The individuals who want to make a trip have a willingness to pay for a PT trip ranging from V to W. When PT is priced at its marginal social cost *c*[4], there is a non-commuting demand for PT equal to Y_C. In this initial situation, as long as PT is priced at *c*, the introduction of road pricing will extend the use of PT for commuting but will not affect the non-commuting use of PT.

The existence of individuals that are non-commuters will enlarge the majority in favour of road pricing as they are not directly affected but share in the redistribution of toll revenues. The existence of other PT users is not a problem for the introduction of road pricing.

Consider now a starting point for the reform where the use of low PT prices is used as a second best strategy. This means that we start in Figure 3 with a subsidy s. In the right figure this increases PT use to Y_S. In the left figure that represents the commuting market, this means that the switching cost to PT has been reduced and now N-X_S commuters use PT, so that there is some congestion relief on the road market before the introduction of road pricing.

Figure 3. **Subsidies for PT as second best strategy**



Source: Based on De Borger and Proost (2010)

If only commuters used PT, one could obtain the same result as with road pricing by using a subsidy equal to t*, in as far as public revenues are not costly. This would reduce the number of car users to X_B. But when a subsidy for PT also attracts public transport users that are not former car users (a diversion ratio smaller than 1), this ideal scenario is no longer possible. The more the PT subsidy attracts non-car drivers and the more difficult the substitution from car to PT, the larger is the PT subsidy needed for car drivers to switch, and the less efficient a subsidy becomes for PT to address road congestion.

The total PT subsidy needed can easily be seen on the Figure 3 by summing the shared areas:

$$s^*\left[N-X_S\right]+s^*Y_S.$$

When we take this subsidised equilibrium as a starting point, what are the chances of obtaining a majority in favour of the introduction of road pricing?

First keeping the "second best" subsidy *s* as given, the existing subsidy may make it slightly easier to obtain a majority. The reason is that, in the presence of a subsidy for PT, one needs a smaller road toll to address congestion. A toll *t*** would be sufficient. There are two drawbacks. First the reform is not fully efficient, as only the private transport market price has been corrected and not the inefficiency on the public transport market. There remain too many non-commuting public transport trips. Second, the net revenues to be expected from the road toll will be much smaller: the toll itself is smaller and the former car users X_S-X_B increase the total subsidy that is needed for PT and this absorbs part of the toll revenues.

Next consider a complete reform of private and public transport pricing. This requires a larger toll t* plus the abolishment of the second best subsidy (*s*). This will be a more difficult reform: all users of peak transport, private as well as public, will have to pay more for their trip. This generates more public revenues but when this needs to be shared with passengers that are not travelling in the peak, all peak travellers will fear that they lose with the reform.

Finally, one can consider a reform of public transport prices only. This can consist of moving away from subsidies for PT that are too high or moving away from season cards to differentiated peak and off peak electronic cards. There are clear efficiency gains and the net spillback to an increased use of cars will be limited. In addition, it reduces the ability of the PT deficit to be covered. Of course, when the users of PT already have a majority, they can block this type of reform. But when those that do not travel and the car drivers can form a majority, this reform may succeed.

In conclusion, although a reform of private transport prices is best complemented by a reform of public transport prices, this reform looks more difficult to implement. Building a majority when all transport users have to pay higher prices is a challenge and we did not yet see this type of grand reform.

Spatial impacts of road pricing

Up to now we have considered the urban area as a homogeneous zone where we distinguished three groups: car users, public transport users and those individuals that do not travel in the peak. A metropolitan area is not homogenous and has a central business district (CBD) surrounded by zones with different population density. De Borger and Russo (2018) study the political economy of a zonal toll around the inner city but dropped the asymmetric information assumption for the drivers used in the De Borger and Proost model. In their model, there is no uncertainty on the modal shift costs. The population is differentiated according to three axes: high income vs low income, using cars or public transport and (according to location (within the cordon)), in a surrounding zone with PT and in a more distant zone with only car access to the city. In the short run, the population is immobile and the rents are fixed. When the majority of the population is living outside the cordon, they will vote for a toll that is too low when the revenues are redistributed uniformly over the population. The difference with the optimal toll becomes smaller when the toll revenues can be used to decrease the price of PT. The latter result is in line with our findings in the simple non-spatial model.

In the longer run, people can change residence and the introduction of road pricing will affect land rents. A toll will increase the land rent within the tolled zone but the impact on the land rent will be mitigated when the toll revenues are used to decrease public transport prices. The majority will opt for a toll that is too low when the majority lives outside the cordon and does not own most of the land in the cordon zone.

This model explains stylised facts on road pricing: the difficult political support for cordon pricing from suburb citizens, the rather small cordon zone as well as the preference to use the revenues for PT support.

Should we decentralise transport pricing to the metropolitan level?

Most transport pricing is still decided at the national level using fuel taxes and car ownership taxes. Many public transport companies are also national or receive a large subsidy from the national government. Why not decentralise the pricing of private and public transport to the level of the metropolitan areas? The decentralised alternative for national uniform car pricing is to have a lower fuel tax[5] that covers the specific externalities of fuel use like climate damage and complement it with a local congestion tax. For public transport, one would have a locally decentralised public transport company fare that varies over peak and off peak.

According to Fung and Proost (2017) local transport pricing has two major advantages. The first is a *simple efficiency advantage*: fuel taxes can, because of tax competition, only be uniform. Replacing a uniform tax by regional differentiation means that the transport prices can be better aligned with the local transport problems.

The second advantage is that there may be an *accountability advantage*. Politicians can be more or less rent seeking and they are more or less lobbied by all kind of stakeholders (PT unions, PT equipment suppliers, etc.). When the transport performance of different city agencies can be compared, there is more room for identifying promising innovations and making politicians or PT managers accountable. There is not much systematic evidence for these comparisons. In Sweden, Goteborg followed the example of Stockholm but in the UK, other cities proposed tolls but they were not able to get a majority.

The major disadvantage of local decision making is the *risk of tax exporting* when there are spill-overs. Spill overs exist when the local transport infrastructure is also used by non-inhabitants.

De Borger and Proost (2015 and 2016) use a formal political economy model to compare centralised and decentralised pricing. In their model, there are two regions that each have individuals that are either car and PT users or PT-only users and use the infrastructure in their own region and in the other region. Regions decide using majority voting. At the level of the federation, regionally elected representatives decide using a minimum winning coalition system. With only two regions, this means that each region has a 50% chance of winning.

They offer three results. Firstly, they show that decentralised transport pricing is always better than centralised pricing whenever spill-overs are not too large as then tax exporting steps in and fares and tolls become too high. Secondly, the share of outside users always improves the cost recovery of PT, this is again driven by the tax exporting motive.

Thirdly, imposing a zero deficit constraint on regional public transport operators or on the city road administration implements the second-best welfare optimum. The zero surplus constraint implies that toll revenues or fare revenues have to be used for road capacity extension or increased PT frequency. The zero surplus constraint, together with a non-price discrimination clause, implies that the local authority cannot exploit the incoming commuters and will only charge higher prices when there is a real need for extra capacity.

Conclusions

We studied the optimal level of public transport (PT) prices when road pricing is introduced. Very low public transport prices and large public transport investments have been used as second-best measure in most congested cities where road pricing was not implemented. This paper discussed several public and private transport pricing topics.

The first topic is about the usefulness of optimising PT prices even in the absence of road pricing when the majority of urban trips in the peak are using PT. We found that the need to also reform public transport prices cannot be underestimated as in the peak period more than half of the trips are PT trips in metropolitan areas.

The second topic is about how we should optimally adapt public transport prices, frequencies and public transport subsidies when road pricing is implemented. The theoretical principles are clear: in the absence of road pricing, pricing public transport below its marginal cost is a sensible second-best strategy. But when road pricing is introduced, it is optimal to also charge the full marginal social cost for public transport.

In addition, we also discussed whether public transport prices should be higher or lower from an efficiency point of view, what public transport pricing strategy helps to make road pricing socially acceptable and whether there is a need to commit part of the revenues of road pricing to public transport subsidies.

Numerical simulations for Stockholm, where road pricing is in place, show improvements to welfare by differentiating PT prices between peak and off-peak and to have higher PT prices in the peak period. Paris has no road pricing yet but simulations also show that there is a welfare gain of differentiating public transport prices and one should charge much higher prices in the peak period. It was also shown that an introduction of zonal road pricing is best accompanied by higher PT prices.

The introduction of road pricing is often sold to the voters by letting the public transport users share in the revenues via extra investments and or lower prices. But when the public transport prices are already too low, this is not an efficient strategy, it leads to an excessive use of public transport. Proposing to package the introduction of road pricing with higher PT prices in the peak, even if this is more efficient, will not make the reform easier to digest politically.

When one faces difficult policy reforms, decentralisation of decision making and local experimentation may help to move things forward. Decentralisation of transport pricing in the presence of non-resident users tends to generate higher public transport fares and increases the probability that road pricing is introduced. Possible tax exporting problems may appear when central cities exploit the incoming commuters but this problem can be contained by imposing federal restrictions on the use of the net revenues of road pricing and of public transport pricing.

Notes

1 Initially, most attention was paid to the negative external cost that consists in waiting times savings when additional passengers allowed to increase the frequency (Mohring, 1982). Nowadays, the crowding effects in the peak period are better recognized (See Tirachini, Henscher, Rose, (2013) and de Palma, Monchambert and Lindsey (2017) for the history of ideas).

2 In a study for Paris, we found that the diversion ratio was between 0 and 10% (Kilani, Proost, Van der Loo (2014), for a Stockholm corridor we found a diversion ratio of 19% (Borjesson , Fung, Proost (2017), synthesizing the results of studies relevant for the UK, Dunkerley, Wardman, Rohr and Fearnley (2018) found values in the range 0.24 to 0.30

3 See Borjesson (2017) contribution to this round table for a detailed description of the Stockholm experience.

4 We assume here that there are no crowding externalities in PT. This simplifies the graphical exposition but does not invalidate our conclusions.

5 Based on the Oil Bulletin of DG Energy (http://ec.europa.eu/energy/en/data-analysis/weekly-oil-bulletin), the weighted average excise in the EU on Eurosuper 95 was about 623 EUR/1000 litre and that on automotive diesel was about 497 EUR/1000 litre. This corresponds with an implicit CO2 tax of approximately 270 EUR/ton CO2 in the case of eurosuper 95 and 187 EUR/ton CO2 for automotive diesel. Most climate damage estimates are rather in the range 30 to 100 EUR/ ton of CO2. So the fuel taxes on gasoline should be only 30% of the current level in the EU.

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International Transport Forum

Reforming Private and Public Urban Transport Pricing

This paper examines the optimal level of public transport pricing in metropolitan areas, using Stockholm and Paris as case studies. It shows that overall welfare improves if public transport prices are increased during peak hours to balance demand and fund additional services in the peak. This report considers the sources of welfare improvements and compares the effect of such pricing policy on cities with and without road pricing.

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