FACULTY OF ECONOMICS AND
APPLIED ECONOMIC SCIENCES
CENTER FOR ECONOMIC STUDIES
ENERGY, TRANSPORT & ENVIRONMENT

KATHOLIEKE
UNIVERSITEIT
LEUVEN

WORKING PAPER SERIES
n° 2005-03

Urban Transport Pricing Reform With Two Levels Of Government [1]

S. Proost (K.U.Leuven – CES ; UCL - CORE)
Ahksaya Sen (India)

March 2005

secretariat:
Isabelle Benoit
KULeuven-CES
Naamsestraat 69, B-3000 Leuven (Belgium)
tel: +32 (0) 16 32.66.33
fax: +32 (0) 16 32.69.10
e-mail: Isabelle.Benoit@econ.kuleuven.ac.be
http://www.kuleuven.be/ete

URBAN TRANSPORT PRICING REFORM WITH TWO LEVELS OF GOVERNMENT [1]

Stef Proost[2] , Ahksaya Sen
CES-KULeuven

Abstract

This paper analyses two challenges in the reform of urban transport pricing. The first challenge is the construction of an optimal package of urban transport pricing instruments assuming one benevolent government level that maximizes overall welfare. We examine the welfare gains from implementing in succession better parking prices, improved public transport prices and time varying tolling. It is found that parking and tolling are the most important elements of the optimal package and that the alternative policy instruments are sub-additive in their benefits. The second problem studied is the use of these pricing instruments by different government levels. We examine a case where an urban government controls parking fees and the regional government controls the tolling. Although both government levels have different objective functions, we find that the overall efficiency losses in the Nash and Stackelberg equilibria are limited.

JEL codes : R48, H71, H21

---

[1] The research summarised in this paper was carried out as part of the EU Fifth Framework research project MC-ICAM (DG TREN, Financial support from the European Commission is gratefully acknowledged. The opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the European Commission. The authors are indebted to Sara Ochelen for her help in preparing a forerunner to this paper in 1996 (Ochelen and Proost, 1996), to Kurt Van Dender and Edward Calthrop for their help with the TRENEN model and to Bruno De Borger, André de Palma and Robin Lindsey for detailed comments on a previous version of this paper.

[2] Stef Proost, CES-KULeuven and CORE, Ahksaha Sen, CES-KULeuven

1.Introduction

There is a growing interest in the use of transport pricing and taxation to solve transport problems. Often a combination of pricing instruments is used, varying from gasoline taxes to tolls and parking charges. In many instances the authority over the different instruments is spread over different government levels. Gasoline taxes are usually determined at the federal level while parking fees are typically fixed at the urban levels. This leads us to the two topics we will study in this paper. The first is the construction of an optimal package of pricing instruments. We examine the role of parking fees, public transport pricing and time varying road tolling, what each instrument can achieve on its own and what is its value added if instruments are combined. This exercise conveys important information for an implementation plan of better urban transport pricing.

The second topic we study are the possible efficiency losses when the different pricing instruments are controlled by different levels of governments. As the different government levels are elected by different sets of voters they will in general pursue different objectives. How important is this problem when there is no coordination between the different governments?

As analytical results are difficult to derive we devote most of our attention to a modelling case study for the city of Brussels. With the model we first compare the performance of alternative sets of policy instruments when there is only one welfare maximizing government. Next we introduce two government levels: we let the city government choose the parking fees and the regional government choose the level of the cordon toll to enter the city. Comparison of the non-cooperative equilibrium where power is shared between two government levels and the equilibrium where there is only one government level allows us to estimate the potential efficiency losses.

Section 2 presents briefly the transport model that will be used and the current transport pricing inefficiencies in Brussels. Section 3 examines the contribution of different types of pricing instruments to an optimal implementation plan. Section 4 is devoted to a detailed description of the policy setting and the differences in objectives of an urban and a regional government. In Section 5 we explore numerically the case where the urban government controls parking fees and where the regional government controls a cordon toll around the city. Section 6 concludes.

2. The transport model used for the case study of Brussels

Introduction

The case study concerns the city of Brussels. It is the capital of Belgium and has 1 million inhabitants. The presence of the federal government, of the offices of the European Community together with the service industry (banking, insurance etc.) entails a lot of commuting: some 0.6 million people commute daily into Brussels. The city has a fairly well developed public transit system with a metro system, busses and

some regional trains. Public transport accounts for 28% of the urban passenger transport market. There are no detailed plans yet for a cordon toll but this cordon could very well be placed outside the city borders near the ring.
We will use the strategic model TRENEN-II URBAN[3]. The strategic model simplifies the urban network to one link but has the advantage that it can look for optimal combinations of price and regulatory policies. Urban and regional government policy choices can then be simulated by optimising their objective functions.
The TRENEN-II model structure is explained in more detail in the next subsection. In the final subsection we discuss the calibration and the properties of the reference equilibrium.

The structure of the transport model

The main idea of TRENEN-II URBAN is to model urban transport during a representative day as a one-link road network plus a one-link rail network with fixed capacity. Two periods of fixed length are distinguished: peak and off peak.
In each period, the road link is used by different types of users: inhabitants and commuters, private cars and busses, cars paying for parking and cars having free parking, gasoline and diesel cars, small and large cars, solo drivers or car-poolers. The rail link represents metro and rail public transport that can be used in the peak and off peak.

The generalised user cost of these different transport options is determined by the congestion level and the money price charged to the users. This money price contains all the resource costs and all charges paid, as well as the subsidies received. For given taxes, subsidies and regulations, travel time costs serve as the equilibrating mechanism to reach user equilibrium.

Figure 1 shows the main components of TRENEN-II: a demand module, a supply module and an equilibrium price module in between. In addition there are two types of policy controls (shown as ellipses): transport taxes and technology regulation on vehicles.

[3] There are several versions of the TRENEN model. The one used here is TRENEN II URBAN. The model description is based on Proost and Van Dender (2001). TRENEN –I and II were acronyms for European research consortia and stood for TRansport ENergy and ENvironment.

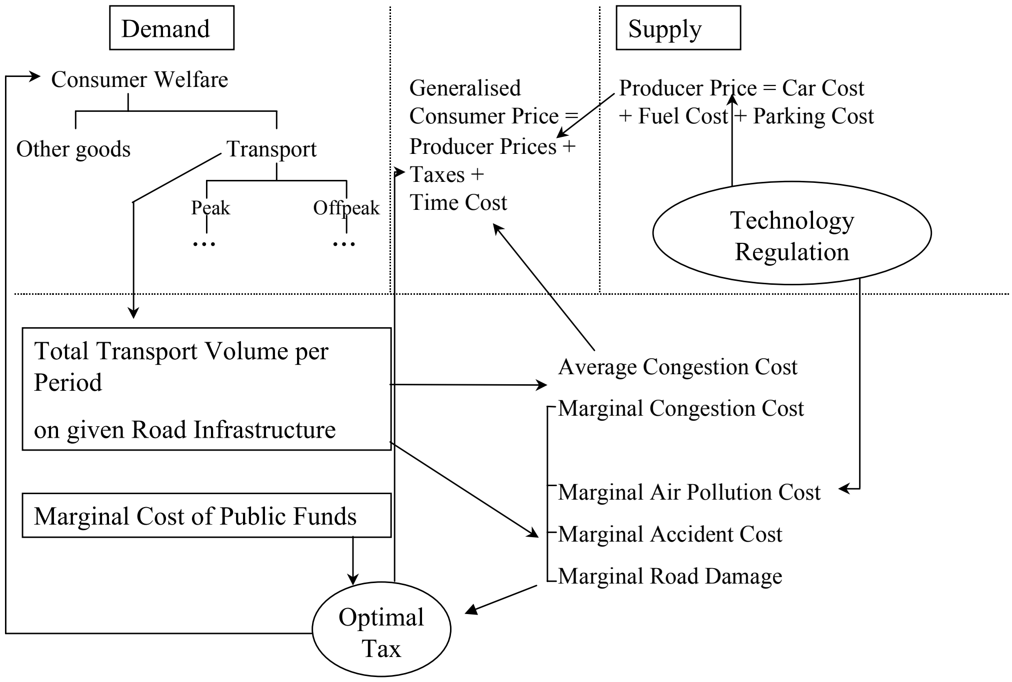

Figure 1 Main components of the TRENEN-II model

The demand part

The model used in this case study only contains passenger transport[4]. We model total transport demand via the behaviour of four representative individuals. There are two types of inhabitants; those who pay for parking and those who do not pay for parking. There are also two types of commuters; those who pay and those who do not pay for parking. Commuters will, compared to inhabitants, make longer trips to an urban destination (their urban trip is only part of the global trip) and will have to pay a cordon toll if there is one.

The transport choices of a representative household are modelled via a nested CES utility function whose structure is given by Figure 2. The choice possibilities are represented in detail for transport consumption, but not for other consumption; only the peak branch is shown in detail in Figure 2. In particular, a household can:

- Vary overall demand for transport, that is it can choose between transport and other goods;
- Choose the time of day for its travel (peak or off-peak);
- Choose between motorised and non motorised transport (that includes the small motorcycle as it is a good substitute for a bike)
- Choose between private and public transport modes;

[4] One can easily add urban freight by using nested CES cost functions (see De Borger & Proost, 2001).

- For private transport there is a further choice between solo driving and shared driving (car pool), and for public transport there is a choice between metro or tram and bus;
- If the car mode is chosen, different sizes of vehicles are available;
- Finally there is a choice between diesel and petrol fuel.

Car-pooling is considered as a separate mode. By doing so the overall occupancy rate for cars becomes endogenous. Non-motorised modes are aggregated into one mode because the case study focuses on congestion and air pollution problems, which originate mostly from motorised transport[5].

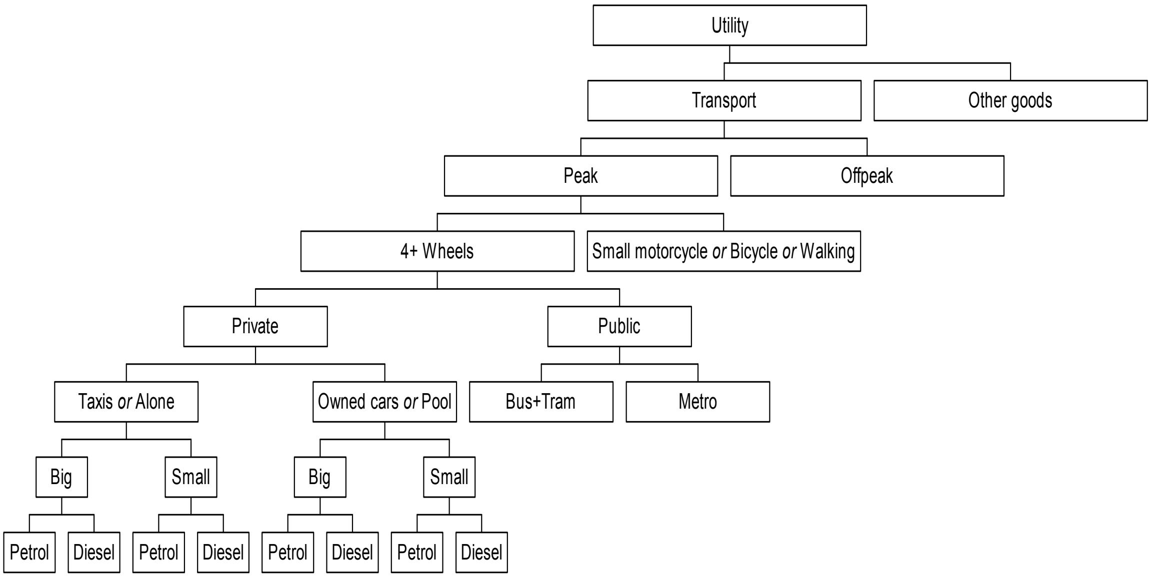

Figure 2 Utility tree of a representative individual[6]

This leads to a total of 11 options in the peak (8 car options, 2 public transport options and 1 option to use slow mode), 11 options in the off peak and one non-transport option. Consumption of transport goods is measured in units of passenger kilometres for a specific type of vehicle in a given period. Demand functions depend on the generalised price of transport: the cost of transport consists of a money cost (the public transport fare or the expenditures for the use of a car) and a time cost (the time necessary for the trip multiplied by the value of time). The time requirement may depend on the mode of transport (car or public transport) and on the discomfort of the users (a minute lost when driving to work in the morning peak has a higher subjective value than a minute lost during a shopping trip in the afternoon). Trip distances are fixed by assuming fixed locations for all activities. The use of generalised prices is a shortcut for a more elaborate model with endogenous values of time. The shortcut is justified as long as values of time do not change between two equilibria.

[5] Small motorcycles also contribute to noise and air pollution.
[6] "Owned cars or Pool" stands for cars with 2 or more occupants.

The supply part

The supply part of the model (right hand side of Figure 1) represents the activities and choices made by the producers of cars and public transport. Assuming perfect competition among the suppliers of cars, supply will deliver at marginal resource costs plus producer taxes. The producer can be forced by regulation to offer a particular emissions technology.

Two types of modes are distinguished: public and private transport modes. Each is considered in turn.

For the **private passenger transport** modes resource costs are taken as constant per vehicle kilometre[7]. The costs of ownership and of car use are not explicitly distinguished. This is acceptable for a static implementation of a model that represents a long-run adjustment of the stock of cars. Six inputs are combined to produce a car km. There is no substitution possible between these inputs. To obtain one km in period *X* by individual of type *Y* with car type *Z*, a fixed amount of fuel and parking space and time is required. The other costs are vehicle depreciation costs, insurance costs, maintenance costs and (possibly) road toll costs. The relevant costs are the marginal resource costs per vehicle km. Money prices will then equal the sum of the marginal resource costs plus the sum of the taxes on each of the components. As regards *vehicle costs*, since fixed and variable cost components are not distinguished, the cost of the vehicle is expressed as a cost per vehicle km (assuming a certain amount of km driven during the lifetime of an average vehicle). A constant cost for each vehicle type (size and fuel type) is used. The *parking cost* consists of two components: the resource cost per hour of parking and the average parking time per trip. The cost of an hour of parking can differ according to time of day and vehicle size. Parking time may depend on time of day as well, and it can differ between residents and non-residents of the city. However, for the Brussels case study, parking costs are taken constant – on a per trip basis – over all these categories.

It is assumed that **public transport** is completely controlled by the government. There are two types of public transport: busses and trams, and metro. Busses and trams are assumed to use the same road network, and both contribute to the overall road congestion while metro does not.

All public transport modes are represented by a linear cost function that contains a fixed cost and a proportional variable cost that differs by period: capacity costs are fully allocated to the peak period as extra vehicles are only needed in this period.
Walking times to the public transport stops and waiting times at stops are included in the generalised cost of public transport. Waiting times depend on public transport volumes according to the optimality rule for bus frequencies derived by Mohring (1972). It is assumed that frequency can be increased or decreased at constant marginal costs. Average bus occupancy rate is further assumed to be constant in each period. For Brussels it amounts to 40 persons/vehicle in the peak, and 9 persons/vehicle in the off-peak.

---

[7] We neglect differences in fuel consumption due to congestion.

Equilibrium module

For given values of the two sets of policy variables (taxes and technology regulations), the supply part (the right hand upper part of Figure 1) determines the generalised cost functions for each of the 22 transport options and for each of the 4 representative households that are active on these markets. The generalised cost function is a function of the total car and bus kilometres on the urban link in that period. When the generalised cost functions are plugged into the 4 sets of 23 demand functions (22 transport options and 1 non transport consumption option) one can solve for equilibrium[8].

One can also select any objective function and any set of policy instruments and compute an optimum solution that is a users' equilibrium. We use this feature to describe the transport policy choices of the two government levels.

Calibration and Reference equilibrium

The model is calibrated by using observed taxes and money prices, observed quantities, existing regulations, a speed flow function for the urban road link and assumptions on the cost of public transportation. This generates reference market equilibrium. Adding elasticities of substitution generates the demand functions and the utility functions for the 4 representative households. The elasticities of substitution are chosen such that the generated price elasticities conform to estimates that are available from the literature (see Proost and Van Dender, 2001). Table 1 gives the price elasticities for the TRENEN model, averaged over all consumer groups and computed in the reference equilibrium.

Table 1 Price elasticities in reference equilibrium (Brussels, 2005)

	Car peak	Car off-peak	Public peak	Public off-peak
Car peak	-0.36	0.025	0.12	0.0002
Car off-peak	0.025	-0.54	0.001	0.65
Public peak	0.025	0.0007	-0.19	0.0051
Public off-peak	0.003	0.05	0.0054	-0.35

Transport markets and traffic flows

The geographical area for the case study is the zone within the outer ring road of Brussels. This area was chosen for two reasons: (a) an analysis of available data on transport flows shows that magnitude of flows and average speed clearly differs within and outside the ring; (b) the area within the ring is serviced by one urban public transport operator. The geographical scope also closely relates to the

[8] Technically, the equilibrium is computed via maximisation of a welfare function with as constraints the demand equations and exogenous values of the policy parameters. The Nash and Stackelberg equilibria are computed by constructing many points on the reaction functions and looking for the intersection (Nash) or the highest utility for the leader on the reaction function of the follower.

administrative boundaries of the Brussels Capital Region. Data on traffic flows are derived from the projection for 2005, from IRIS (1993). This is the only detailed study available at present. The traffic flows are measured for a representative day. A day is the most relevant time scale for an analysis of urban transport problems. All prices, costs and taxes are for 2005, on the assumption that there is no change in policy with respect to 1995.

We have four types of representative households; their number is given and is reported in Table 2. As can be seen there are more inhabitants than commuters and only a minority pays for parking.

Table 2 Number of individuals of each type (Brussels, 2005)

In 1000	**Pay for parking**	**Don't pay for parking**
Inhabitants	281	655
Commuters	194	454

Since a price difference exists between payers and non-payers, and price differences have an impact on demand, the impact of parking charges on the level and the modal split of transport demand by the 4 types of households is taken into account. Travellers who have to pay for parking consume less transport services, and the share of public transport in their total transport demand is higher than the share for those who do not pay for parking. It should be noted that parking demand at the trip origin, mostly residential on-street or off-street parking, is not included in the model.

Reference Situation 2005 and initial pricing inefficiencies

The upper part of Table 3 presents the cost structure for a number of transport markets in Brussels in 2005. Markets have been selected to reveal the most important pricing inefficiencies. The first row shows the price per passenger kilometre of a small petrol car driven alone, during peak hours, by an inhabitant who does not have to pay for parking at the trip destination. The time cost (€ 0.334 per vehicle kilometre) which is the difference, in the first line of Table 3, between generalised price (0.614) and money price(0.28), equals 54 per cent of the total trip cost. In the off-peak, for an otherwise identical trip, this share is only 35 per cent. Other price components differ between peak and off-peak only because of differences in speed that affect slightly fuel consumption.

The money price in row 1 is lower than the resource cost because this inhabitant does not pay for parking. Since the parking cost per vehicle kilometre is € 0.17, the money price minus the taxes (0.280 - 0.089 = 0.191) is € 0.17 below the resource cost (0.191 + 0.17 = 0.361). Commuters who do not pay for parking pay a money price of € 0.280, while the resource cost is € 0.261. This difference does not exist for drivers who do pay for parking (cfr. row 3 for inhabitants and row 4 for commuters).
The resource cost per kilometre of an inhabitant is higher than for a commuter. This is because parking costs are converted from a per trip basis to a per kilometre basis, and average total trip distances are higher for commuters than for inhabitants (cfr supra). As a consequence, the parking cost per kilometre is € 0.17 for inhabitants and € 0.07 for commuters. The difference in per kilometre costs between payers and non-payers for parking is large. For inhabitants, the generalised price of a kilometre is 28 per cent

higher if they have to pay for parking. For commuters, the difference is 11 per cent. A different way to illustrate the importance of parking costs is their share in the resource cost: 47 per cent for inhabitants, and 27 per cent for commuters. The importance of parking costs is an essential difference between an urban and an interregional transport situation.

The cost of a kilometre by diesel car is lower than the cost for a petrol car. This is due to lower taxes on diesel vehicles and the lower resource costs per kilometre of diesel vehicles (due to higher average mileage). The high share of diesel cars in the vehicle stock in Belgium is due to this tax regime.

The tax column reports the average tax paid per passenger-kilometre for the different categories. The level of tax needs to be compared with the marginal external cost and with the unpaid resource cost of parking. Taxes are far below marginal external costs in the peak period, while the situation is reversed in the off-peak. This suggests that the present tax structure is badly suited for the internalisation of external congestion costs that are particularly high in the peak period. This is a more general phenomenon as demonstrated by a wider set of European case studies with the TRENEN-II model (Proost et al.,2002).

As for public transport, it is noted that the money price is equal in peak and off-peak. Resource costs differ strongly on a per passenger kilometre basis, however, because of differences in occupancy rates. As a consequence, peak period bus driving more than covers the marginal resource cost of the bus (including the capacity cost of the bus that is allocated fully to the peak), whereas in the off-peak the net taxes are strongly negative so off-peak bus transport is heavily subsidised. For public transport, the share of time costs in the total travel costs is higher than for private transport (80 per cent in peak hours). The reason is that walking times to bus (or tram, or metro) stops, and waiting times at bus stops are included in the travel time.

In the lower part of Table 3, the level and the composition of traffic has been summarised. Peak period traffic accounts for 62 per cent of total traffic, expressed in passenger kilometres. Public transport accounts for 28 per cent of all passenger kilometres. Within the peak period, 32 per cent of all passenger kilometres is produced by public transport. In the off-peak period, this share is 22 per cent. The explanation is that commuting trips, which are concentrated in peak hours, make more frequent use of public transport modes. The share of carpooling in the total number of passenger kilometres is also slightly higher during peak hours, because carpooling is more frequent in work trips than for trips with other motives. Given the expected traffic volumes, average speeds are expected to be about 23 km/h for passenger cars during peak hours, and about 50 km/h during the off-peak. Public transport travels more slowly than private transport. The share of passenger kilometres by diesel car in the total demand for passenger km by passenger car is 38 per cent. This share is higher than in most European cities, because, in Belgium, the tax structure on passenger cars used to be more favourable to diesel cars.

Finally, Table 3 shows that aggregate tax revenues from private transport are positive, while those of public transport are slightly negative. The total value of the external costs of accidents, air pollution and noise (i.e. exclusive of congestion costs) is € 0.432 million per day. The reference situation described here is inefficient, because of three reasons directly related to the transport sector. First the resource cost of parking is not charged to all the drivers. Second the external congestion cost, particularly high in the peak period, is not internalised. Third public transport prices are in general also smaller than their marginal social cost.

Table 3: Characteristics of the Reference Situation (Brussels, 2005)

Prices and costs (€/pkm)	Resource cost	Tax	Money price	Marginal external cost per vehicle kilometre	Generalised price
Peak					
Car, solo, small, petrol, free parking					
Inhabitants	0.361	0.089	0.280	1.834	0.614
Commuters	0.261	0.089	0.280	1.834	0.614
Car, solo, small, petrol, paid parking					
Inhabitants	0.361	0.089	0.450	1.834	0.784
Commuters	0.261	0.089	0.350	1.834	0.684
Car, solo, small, diesel, free parking					
Inhabitants	0.326	0.083	0.271	1.863	0.547
Bus/tram (inhabitants)	0.080	0.039	0.12	0.092	0.587
Off-peak					
Car, solo, small, petrol, free parking (inhabitants)	0.359	0.083	0.271	0.047	0.419
Bus/tram (inhabitants)	0.271	-0.151	0.12	0.014	0.521
Volume and composition of traffic	mio pkm	Share (per cent)	per cent carpool	Speed (km/h)	
Peak, private	3.846	41.6	29.6	23.1	
Peak, public	1.839	19.9		20.6	
Off-peak, private	2.839	30.7	25.4	49.7	
Off-peak, public	0.727	7.9		44.2	
Tax revenue (mio €/year)					
Private	152,4				
Public	-30,0				
External costs other than congestion (mio €/year)	129,6				

3. What is the added value of different pricing instruments?

Constructing a package of pricing instruments is an important component of the selection of a succesful implementation plan for marginal social cost pricing. Here we start with the easiest instrument to implement (parking), add public transport pricing, and complete the policy package with electronic road pricing. We analyze the value added of each of the instruments. Table 4 sets out the order in which we combine instruments and describes each of them in more detail.

Table 4: Implementation plan for Brussels

Key features & second-best constraints Phases	Composition and level of pricing measures	Coverage or scope of the pricing system	Degree of differentiation of pricing measures	Rules and principles governing revenue use	Use of supplementary non-price measures
Parking only	Set parking fees at resource cost	Urban area Parking pricing to cover resource cost	Parking fees are not differentiated spatially or over time	Revenues are returned to all inhabitants + commuters and MCF=0	None
Parking + optimal bus pricing	Parking fees=resource cost Public transport prices set at second-best optimal levels.	Urban area Parking Public transport	Parking fees are not differentiated spatially or over time Public transport prices are differentiated over time	Revenues are returned to all inhabitants + commuters and MCF=0 No budget constraint on Public transport	None
Parking + optimal bus pricing + time differentiated electronic toll	Parking fees=resource cost Public transport prices set at second-best optimal levels. Optimal time differentiated electronic toll	Urban area Parking Public transport Road congestion	Parking fees are not differentiated spatially or over time Public transport pricesare differentiated over time Electronic toll is time differentiated	Revenues are returned to all inhabitants + commuters and MCF=0 No budget constraint on public transport	None

We are interested in three questions:

a) What is the added value of the different pricing instruments?
b) How do the optimal values for the different policy instruments change when more policy instruments are added?
c) How does the most efficient equilibrium compare with the reference equilibrium?

A property of a successful implementation path is that it transmits correct and plausible pricing signals to the public. Take as an example public bus prices. Our analysis shows that optimal public transport pricing, as long as peak car use is not priced correctly, requires very low public transport prices in the peak period. Table 5 lists the peak bus prices and the welfare gains for the three different combinations of instruments that we study. The low public transport prices obtained in the absence of other instruments may be rather misleading as, once optimal road pricing is introduced, peak public transport prices have to increase strongly again. This conflict between short and long term signals has to be traded off with the welfare gain that can be achieved by using very low public transport prices in the peak in the transition to the full implementation of the other policies. This short term welfare gain of very low public transport prices is, all in all, rather small.

From our results we see also that there are decreasing returns or subadditivity when we add more pricing instruments. When public transport pricing is the only instrument we achieve a 0.18%[9] welfare gain but when public transport pricing is added to the parking instrument, this gain is reduced to 0.12% (0.54%-0.42%).

Table 5: Comparing the four sets of instruments (Brussels, 2005)

	Peak bus price (€ per pkm)	**Welfare gain (compared to reference)**
Parking only	0.039	0.42 %
Public transport only	-0.080	0.18%
Parking + Public transport	-0.074	0.54 %
Parking + public transport + time differentiated electronic road pricing	0.025	1.15%

The pricing of parking is a more direct instrument. Making all car users pay the resource cost of parking is always an important component of the best pricing strategy and generates an important welfare gain. We conclude from this overview that a parking fee and a time-varying electronic toll are the principal pricing instruments to be used to reform urban transport pricing. This does not mean that public transport pricing need not be corrected, we only point out that it is far less important than the other two instruments in order to reach the most efficient urban transport equilibrium.

It is of interest to examine the most efficient equilibrium, in which all three instruments are deployed, somewhat more closely in Tables 6 and 7. The first two lines in Table 6 show the charges to be paid by inhabitants and commuters in the peak period by a small gasoline car that has a single occupant. These two lines can be compared with the reference prices in Table 3. Now that the resource cost of parking is paid by every user, the net tax (including the time varying electronic toll) should approximate the marginal external cost[10]. This is indeed the case: the taxes (0.466 and 0.447 €/pkm) are indeed very close to the MEC (0.471 €/ pkm). The same holds for the public transport prices: the tax on the peak bus use (0.025 €/pkm) is close to the marginal external cost (0.023 €/pkm). This implies a very strong increase in the money price for car use in the peak. Inhabitants pay now 0.827 €/pkm while those not having to pay for parking only paid 0.280 €/pkm, the difference is a parking fee of 0.17 €/pkm and a tax increase of 0.377 €/pkm[11] The generalised price for inhabitants

[9] The welfare gains are defined as a percentage of total generalised income.

[10] The reader may wonder why tolls do not perfectly match the MEC's. The reason is that, there are more than 20 different transport alternatives that have each their own MEC. With 3 instruments one can match most of the MEC's but not all.

[11] 0.377 €/pkm = (0.466 €/pkm of first line of table 6 – 0.089 €/pkm of first line of table 3)

at the optimum is 1.023 €/pkm instead of 0.614 €/pkm. The difference (0.409 €/pkm) is smaller than the increase in parking fees and other taxes (0.17+0.377=0.547 €/pkm) because there is a reduction in transport time costs of 0.138 €/pkm. This corresponds to an increase in transport speed in the peak of 70%.

There are three important sources of efficiency gains here: gains in road transport time costs, gains in the parking market (where everybody has to pay resource cost of parking), and gains in the public transport market.

Table 6: Prices in most efficient urban transport equilibrium using as instruments parking fees at resource cost, time varying public transport prices and time varying cordon tolls (Brussels, 2005)

Price/cost	Resource cost (including parking)	Tax	Parking Fees	Money Price	MEC (per vehicle kilometre)	Generalised Price
Small gasoline car in peak	(€/pkm)					
Inhabitants	0.361	0.466	0.17	0.827	0.471	1.023
Commuters	0.261	0.447	0.07	0.708	0.471	0.904
peak. bus	0.080	0.025	--	0.106	0.023	0.446
TAX REVENUE (mio €/year)						
Private	523.8					
Public	4.2					
WELFARE (million €/day)	Welfare gain over reference equilibrium: 1.15%					

It is interesting to see that the most efficient urban transport equilibrium does not entail a strong reduction of overall mobility. In Table 7 we see that overall volume of transport activity (pkm) is reduced by 4% compared to the reference. There is a stronger reduction in the off peak than in the peak because for off peak trips, the increase in parking fees is relatively more important and they have a higher own price elasticity (cfr. Table 1) , in addition also the large public transport subsidies (pricing below marginal social cost) are abolished. In the peak period, the market share of public transport is increased by 50% from 19.9% (bottom of Table 3) to 28.9% (Table 7). In the off peak period, the share of public transport does not increase.

In terms of overall tax revenues, the new equilibrium generates an increase in tax revenues from private transport of more than 300% (compare 152 million €/year in Table 3 with 523.8 Mio € in Table 6) while the public transport operations no longer incur a deficit on their operations[12]

[12] We include investment or leasing of vehicles in the operating costs.

Table 7 Volumes in the most efficient urban transport equilibrium (Brussels, 2005)

Modal Share	Peak	Off-peak	Total
Private Transport (%)	34.1	29.3	63.5
Public Transport (%)	28.9	7.7	36.5
Index Total Volume (reference=100)	98.5	92.3	96.1
Index Average Speed car (reference=100)	171	100	

4 Sharing pricing instruments between two governments in a broader context.

Transport pricing with multiple governments and externalities is complicated because different types of externalities occur simultaneously. There are the spillovers of congestion and environmental externalities but there also tax externalities. This combination of problems has not been studied in great detail up to now.[13] In Table 8 we summarize the most important externality problems that are relevant in urban transport policy. The three first externality problems are typical tax externality problems that are well known in the fiscal federalism literature.

In the fiscal federalism literature one usually distinguishes between two types of tax externalities: horizontal fiscal externalities and vertical fiscal externalities. A typical horizontal fiscal externality is tax exporting: each local government (city) tries to shift the tax mainly upon the foreigners (see, e.g., Arnott and Grieson (1981) or Dahlby (1996)). This will lead to higher taxes on goods that are typically consumed more heavily by commuters or tourists. A second type of horizontal tax externality is the competition between local governments for the same tax base. If capital is the mobile factor, many papers (see the survey in Wilson (1999)) suggest that tax competition puts downward pressure on tax rates and yields too low a level of public good supply. In transportation, the taxation of motor fuel is a nice illustration of this.
A common vertical fiscal externality is the taxation by both local and central government of the same tax base. This is an externality because whenever a local government decides to raise taxes it will not take into account fully the losses of tax revenues for the central government because only part of the centrally collected taxes will be returned to the local governments in grants. This may lead to too high tax levels.

When a local government sets transport charges and taxes, it will also take into account the traditional transport externalities but will do this in a different way than a central government. Consider congestion on urban roads. A local government will be mainly concerned with the time delays of its citizens and not by the delays experienced by commuters and tourists as long as these delays do not affect the local tax base. The same holds for air pollution or accident externalities that affect mainly non residents.In Table 8 the ultimate effect of the different types of externality taxes

[13] See De Borger & Proost (forthcoming) for a survey on which we draw here.

on the tax rates is not clear and will depend on the problem structure. Our short discussion shows that simply relying on local governments to set optimal transport taxes does not guarantee welfare optimal pricing. Over the years many instruments have been developed to overcome the tax externality problems. States may agree on minimum fuel taxes to avoid downward pressure on fuel taxes. Most countries have tax sharing agreements and use transfers of tax revenues from central to regional authorities to overcome horizontal and vertical tax externalities.

The study of the role of local governments in the use of new pricing instruments to deal with congestion is somewhat lagging behind. This problem has two dimensions: the tax exporting dimension that is mainly of interest for urban problems and the tax competition dimension that is more relevant for interregional transport. In this paper we concentrate on the potential tax exporting problems in urban transport pricing. Some preliminary results on the second problem are found in De Borger et. al. (2005).

Table 8: Tax externalities and other externalities with two government levels

Type	**Source**	**Transport example**	**Potential implications**
horizontal tax externality	**Tax exporting**: desire of governments to shift the tax burden to foreigners	High taxes on local transport infrastructure used by tourists and commuters	Too much reliance on taxes borne by foreigners
	Tax competition for a mobile tax base	Low taxes on fuel or low tolls to attract more transit and generate revenues (e.g., Luxemburg)	Downward pressure on tax rates
Vertical tax externality	Overlapping tax bases: potential for higher and lower government to tax the same base	Federal and regional fuel taxes	Excessive taxes on the shared tax base
Congestion externality	Local governments are only concerned by delays experienced by locals	Too low taxes on local traffic users when transit can not be taxed	Too low congestion taxes
Environmental externality	Local governments only take into account damage to locals	No attention to greenhouse gas emissions in local transport policy	Too low environmental taxes

4. The urban pricing problem with two government levels studied in more detail

A complete problem description requires four elements: (1) a representation of the urban transport problem, (2) a specification of the objective functions of urban and regional governments, (3) an allocation of transport pricing instruments over the two types of government, and (4) an assumption on the type of equilibrium.

Before we can enter into more detail we need **two important assumptions**. The first is that we analyse only two government levels: an urban government and a regional government where the latter overlaps the urban area and has authority over a much wider area and a larger population. In reality there are often more than two overlapping government levels and there may be specific government institutions to deal with transport problems.

The second important assumption is that the behaviour of each of the two government levels consists of maximising the welfare of the representative citizens in its constituency. We work with representative urban households and representative commuter households that live outside the city. This means that the urban government maximises the welfare of the inhabitants only[14]. The regional government maximises a weighted sum of the welfare of its urban citizens and its non-urban citizens, where the weights correspond to their relative numbers in the population. This assumption implies that we do not study the two political processes in detail. This can be an important source of conflicts between government levels as the two levels may aggregate the preferences of the different groups of representative urban citizens in a different way. Moreover this assumption rules out all bureaucratic and political rent seeking.

Table 9 describes the structure of the problem. The table contains two columns that describe two regulatory problems: the problem faced by the urban government and the problem faced by the regional government. In each case the corresponding objective function to be maximised, the externalities taken into account, and the set of relevant policy instruments are presented. The table presents but one of the many possibilities. We have selected a problem structure that applies to our case study of Brussels.

We distinguish between three types of pricing **instruments** (cfr. upper part of Table 9): parking charges inside the city, public transport pricing and a cordon toll around the city. The urban government receives the net profit or loss of the urban public transport operations and receives all of the parking charge revenues but none or only part of the cordon toll revenues. The urban government redistributes the net revenues to its inhabitants. The regional government controls only the cordon toll and redistributes the cordon revenues to the commuters.

Compared to the packages of instruments that we studied in Section 3 we make two simplifications. First we eliminate public transport pricing as an instrument. Second we replace the electronic time varying toll by a much simpler cordon toll that can not be

[14] One observes sometimes low taxes for commuters and visitors. This can be explained by higher indirect tax margins on other consumption categories or by high urban payroll or profit taxes on these two groups. We do not consider this complication in this paper.

varied over time and only applies to the commuters. These simplifications are made to reduce the dimension of the problem we study: now each level has only one pricing instrument that it controls: parking fees (urban government) and time-invariant cordon toll (regional government).

The **urban government** is concerned about the welfare of its residents and not about the welfare of the commuters. The total welfare considered by the urban government consists of three components. The first element is the utility or consumer surplus of the residents, the second component are the tax revenues that are returned to the citizens and the third element are the external costs other than congestion.

The consumer surplus depends, among other things, on the generalized prices of passenger transport, which include all monetary expenses as well as the relevant time costs. It is via the time costs of travel that the external congestion costs are taken into account.

The last elements in the objective function of the urban government are the external costs that affect its population. They include the external noise cost, the external accident costs and the urban air pollution costs. A rational urban government cannot be expected to take the non-urban impacts of air pollution into account if it is not forced to do so, moreover it only pays attention to the congestion externality that affects its own citizens as only the consumer surplus of the urban citizens matter for the urban government.

The **regional government** is assumed to take into account the utility of the inhabitants and the commuters with equal weights. It values all tax revenues collected, the losses of all public transport firms and all externalities. The regional government can use a time invariant cordon toll as instrument to address congestion. It is levied only on commuters when they enter the urban area. The toll revenue is redistributed by the regional government to the commuters only, and in a lump sum way.

We neglect interactions of the transport taxes with other taxes in the economy (profit taxes, payroll taxes, income taxes). It is well known that there may be important interactions and that this affects the optimal level of congestion and environmental taxes as well as the optimal use of the tax revenues (Mayeres & Proost (1997)). This assumption implies that 1 € of urban or regional tax revenue has the same value as 1 € of user benefits for a representative citizen. We also neglect freight transport and its effect on product prices.

Of course this set up is only but one of the many **specific institutional structures** that can exist. In order to specify the equilibrium of the game between the two government levels we need two more assumptions on the institutions. Firstly, the regional government can tailor its instruments specifically to the problems of one urban region - normally the regional government has to use the same instrument to address problems in many different localities. Secondly, we assume that the regional government has full information on local preferences and costs.

Table 9 Problem structure with two active government levels

	Urban Government	Regional Government
INSTRUMENTS		
Parking charges	Full control	No control
Public transport pricing	Urban public transport prices	No control
Time invariant Cordon toll	No control	Full control
OBJECTIVE FUNCTION		
Consumer surplus	Utility of residents Utility is a function of all passenger transport prices and of congestion	Utility of residents and commuters receive the same weight Utility is a function of all passenger transport prices and of congestion
Net Tax revenue	Net public transport deficit, revenues from urban parking taxes and shares in regional tax revenue	net public transport deficit, all regional tax revenue, revenue of cordon toll
External accident costs	Yes	Yes
Air pollution with urban impact	Yes	Yes
Regional and global air pollution	No	To a larger extent
noise	Yes	Yes

We study in this section five alternative equilibria for the game between the two governments (cfr. Table 10). When the regional government controls both the cordon toll and the parking charge, the outcome will be equal to the cooperative solution because the regional government maximizes the sum of the welfare of the urban and the non-urban citizens and controls all the instruments. In the Nash equilibrium, each of the government levels controls only one instrument and takes the behaviour of the other as given. This results in a mutual best reply equilibrium. In the Stackelberg equilibrium, the regional government announces its policy first knowing how the urban government will react. A Stackelberg equilibrium where the regional government is the leader is more plausible than the reverse because the regional government may very well need to announce a harmonised policy guideline for several urban areas at the same time.

In the last two equilibria we give the urban government a share in the total cordon toll revenues.

Table 10 Different equilibria considered

Type of equilibrium	Urban government	Regional government
Cooperative solution [15]	No active role	Regional government controls parking charges and cordon toll
Nash equilibrium without urban government sharing of toll revenues	Controls parking charges and takes as given the level of the cordon toll	Controls cordon toll and takes as given the level of the parking charge
Stackelberg equilibrium without urban government sharing of toll revenues	Controls parking charges and takes as given the cordon toll	Controls cordon toll and takes into account, as Stackelberg leader, how the urban government reacts via the parking charge
Nash equilibrium with urban government sharing of toll revenues	As above but takes into account its share in cordon toll revenues	As above
Stackelberg equilibrium with urban government sharing of toll revenues	As above but takes into account its share in cordon toll revenues	As above

5. Simulating transport pricing policies with two government levels: results

The centralised or cooperative solution

In the centralised solution the regional government controls all the policy instruments and has perfect information. As the welfare function of the regional government includes the welfare of the urban citizens and of the commuters, this solution can be interpreted as a cooperative equilibrium between the two levels of government.

[15] The cooperative solution corresponds to the case where the regional government has all the power because the objective function of the urban government is one of the elements of the objective function of the regional government and the latter uses the same welfare weights for the urban citizens as the urban government.

The optimal or “centralised” policy is shown in the second row of Table 11. It involves a toll and an increase in parking fees beyond the resource costs that were resp. 0.07 €/veh-km for commuters and 0.17 €/veh-km for inhabitants. The drawbacks of the toll are that it is uniform over time, and that it only affects commuting traffic coming into the city and not the traffic of inhabitants. As most commuting traffic is peak traffic, the uniform cordon toll is however still relatively efficient to discourage commuting peak traffic. In order to discourage the peak traffic of the inhabitants, the optimal policy is to supplement the cordon toll with a parking charge that covers more than the resource cost. This is the only instrument available in our set up to achieve this. Welfare is increased by € 170 per capita per year.

Table 11: Performance of the different equilibria (Brussels, 2005)

	Optimal parking fee (€/vehicle km) In / Out *	**Optimal cordon toll (€/vehicle km)**	**Gain in regional welfare as % of gain in centralised solution**
Reference equilibrium			—
Centralised solution	0.246/ 0.101	0.301	100%
Nash equilibrium	0.27/ 0.11	0.29	89%
Stackelberg equilibrium	0.22 / 0.09	0.44	92%

* In: inhabitants of city area, Out: outsiders or commuters

The non-cooperative Nash equilibrium

In the Nash equilibrium, each government level optimizes its own objective function using the instruments it controls and taking the policy chosen by the other government as given. The optimal policy of each level of government becomes a function of the control chosen by the other government level. This function is called a reaction function. Equilibrium of the game is then reached when both reaction functions cross, this is a mutual best reply.

Figure 3 shows the reaction functions of the urban and regional governments. The flatter reaction function is the reaction function of the urban government that chooses its preferred parking fee while taking the cordon toll as given. The steeper reaction function represents the optimal cordon toll chosen by the regional government for a given parking fee. The latter reaction function also contains the centralised solution and shows that parking fees and cordon tolls are to some extent substitutes.

The urban government’s reaction function reflects its interest in taxing commuters via high parking fees since the revenue is redistributed exclusively to urban citizens. Compared to the centralised solution, the Nash equilibrium (parking = 0.27, cordon toll = 0.29) has a higher parking fee and a lower cordon toll. Parking fees act here as a tax export mechanism (cfr. first line of Table 8). Nevertheless, the welfare gain achieved by the non-coordinated solution is only 11% below the fully coordinated solution (row 3 of Table 11).

There are three reasons why the welfare loss of the non-coordinated solution is limited. First, the objective functions of the two governments are not that different: the urban government is concerned about the urban residents in the same way as the regional government In models that include several groups of urban voters instead of a representative citizen, the instabilities and path dependence of the political aggregation process itself could produce different political outcomes at urban and regional level, even in the absence of non-urban (McKelvey, 1979).. Second the ability of the city government to extract revenues from commuters by charging inefficiently high parking fees is limited as parking fees are also to be paid by city inhabitants. The two instruments are to be considered as close substitutes. Once parking charges become very high, the inefficiency losses to the urban citizens outweighs the tax revenue gains and the speed increase enjoyed by commuters. The pricing inefficiency caused by the tax exporting motive would have been larger if the city government could control the cordon toll, which is paid by commuters only. The third reason is that greater efficiency losses would probably also result if either level of government did not act in the interests of its citizens. This could be due to bureaucratic behaviour or lobbying by special interest groups.

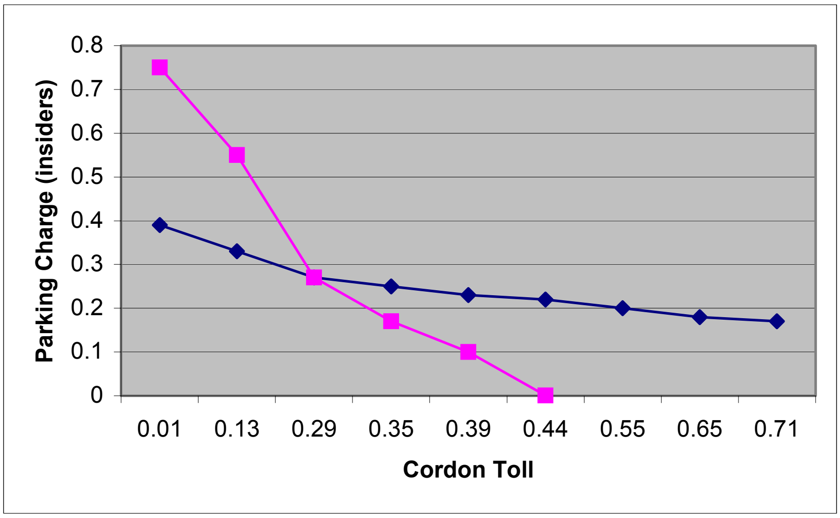

Figure 3: Reaction functions of the urban and regional government (Brussels, 2005)[16]

16 The flatter curve represents the parking fee setting of urban government – the steeper curve represents the cordon toll set by the regional government.

The Stackelberg solution

In the Stackelberg solution the regional government takes into account the tendency of the urban government to charge too high parking fees and announces therefore a relatively high cordon toll (0.44 rather than 0.29). This is the best strategy to limit the appetite of the city government for very high parking fees and revenues. Indeed, given this high toll the city government limits the parking fee to 0.22 (compared to 0.27 in the Nash equilibrium) because the commuters have already been taxed by the regional government. As a result, the Stackelberg equilibrium does better than the Nash equilibrium, with the welfare gain falling short of that in the centralised solution by only 8%. The welfare gain is logical when we know that the Stackelberg leader is a regional government that optimizes an objective function that contains an unweighted sum of the welfare of inhabitants and commuters.

Sensitivity analysis

It has been assumed that the urban government does not receive any share in the cordon toll revenue, and this results in a high parking fee to extract revenue from commuters. One way to mitigate the city government's tendency to overcharge for parking is to give it a share in the cordon toll revenues. To investigate this we now assume that the urban government receives a share equal to half its share of the total population of inhabitants and commuters. This causes the city government's reaction function to shift down relative to its previous positions; compare Figure 4 with Figure 3.

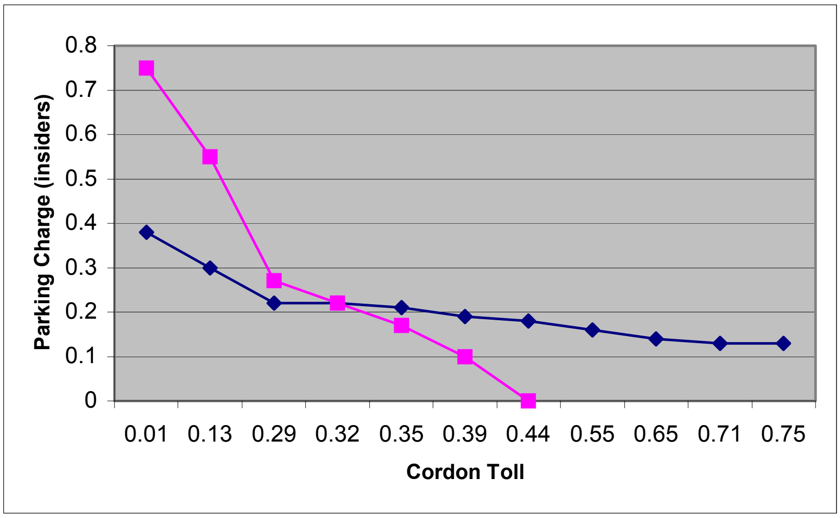

Figure 4: Reaction functions when the urban government receives a 50% share in the cordon toll revenue (Brussels, 2005)[17]

Comparison of Table 11 with Table 12 reveals that in the resulting Nash equilibrium parking charges are lower, the cordon toll is higher, and the efficiency loss relative to

[17] **The flatter curve represents the parking fee setting of urban government – the steeper curve represents the cordon toll set by the regional government**

the centralised solution is only 6.5% instead of 11%. The Stackelberg equilibrium is also improved, with an efficiency loss of only 3% rather than 8%. The greater efficiency in either equilibrium comes at a price in equity, however, because the commuters receive an even smaller share of the toll revenue they pay.

Table 12: Performance of the different equilibria when the urban government receives a 50% share in the cordon toll revenue (Brussels, 2005)

	Optimal parking fee (€/vehicle km) In / Out *	Optimal cordon toll (€/vehicle km)	Gain in regional welfare as % of gain in centralised solution
Reference equilibrium			—
Centralised solution	0.246/ 0.101	0.301	100%
Nash equilibrium	0.22/ 0.09	0.32	93.5%
Stackelberg equilibrium	0.24/0.10	0.34	97%

* In: inhabitants of city area, Out: outsiders or commuters

6 Conclusions

In this paper we analyzed the interaction between two overlapping government levels who each control one of the transport pricing instruments. As there are many interactions and many externalities between the two levels of government, a division of roles between the two government levels does not guarantee an efficient pricing outcome. Different tax externalities and the incomplete consideration of transport externalities may lead to over or undercharging by urban government levels. The precise result will depend on the institutional set-up and on the correspondence between the objective functions of the two government levels.

To explore this problem we limited our attention to parking fees and a cordon toll as policy instruments and focussed on one city: Brussels. The city government was assumed to choose the level of parking fees, while power to set the cordon toll resides with the regional government which has authority over a wider group of the population including the city's. Both levels of government were assumed to behave benevolently on behalf of their constituents. The city government seeks to maximise welfare of the city inhabitants, and the regional government to maximise the welfare of both inhabitants and commuters.

In this setting an efficiency loss occurs because the city government overcharges for parking in order to export taxes to commuters that are outside its jurisdiction. The regional government is forced to respond by setting a cordon toll that is lower than the first-best optimal level in order not to discourage commuting too much. However, this incentive is constrained by the fact that city inhabitants also pay the fees. As a result, the non-cooperative Nash and Stackelberg equilibria achieve most of the welfare improvements that can be obtained in the fully coordinated centralised solution. The main reasons are (a) both governments are assumed to be welfare maximisers rather than revenue maximisers, and (b) parking fees and cordon tolls are substitutes. Further improvements can be achieved by changing the sharing rules for tax revenue in favour of the city inhabitants, although this comes at a cost of greater inequity to commuters.

Our analysis has to be considered as a first exploration. The results depend on the precise institutional set up: what type of instruments can be used and what is the division of responsibilities between the two government levels. Furthermore we paid no attention to such factors as asymmetric information, and the political process itself that are at the heart of the decentralisation of transport policies to lower government levels.

REFERENCES:

Arnott, R. and R. Grieson (1981), Optimal fiscal policy for a state and local government, *Journal of Urban Economics 9*, 23-48.

Dahlby, B. (1996), Fiscal externalities and the design of intergovernmental grants, *International Tax and Public Finance* 3, 397-412.

De Borger B., Proost S. (eds.), *Reforming Transport Pricing in the European Union – A Modelling Approach*, Edward Elgar Publishing Ltd

De Borger, B., S.Proost, (2004), Vertical and horizontal tax competition in the transport sector, Reflets et Perspectives de la Vie Economique, Vol XLIII,n°4, pp 54-64

De Borger, B., S.Proost, K.Van Dender (2005), Congestion and tax competition in a parallel network, European Economic Review, forthcoming

IRIS –Region de Bruxelles-Capitale (1993). Plan regional des déplacements, Plan IRIS, Constat et Scenario Tendanciel

Mayeres, I., S. Proost (1997) "Optimal Tax and Investment Rules for Congestion Type of Externalities", Scandinavian Journal of Economics, 99 (2), 261-279

McKelvey, R.D. (1979), General conditions for Global intransitivities in Formal Voting Models, *Econometrica*, Sept, p1085-1112

Mohring, H. (1972). Optimisation and scale economies in urban bus transport, *American Economic Review*, 591–604.

Ochelen S., S. Proost (1996). Internalisation of Transport Externalities by a Local Government, paper presented at the European Meeting of Environmental economists, Lisbon, June.

Proost. S., K. Van Dender (2001a). Methodology and structure of the urban model. Chap. 4 in De Borger B., Proost S. (eds.), *Reforming Transport Pricing in the European Union – A Modelling Approach*, Edward Elgar Publishing Ltd. [Move reference down one spot.]

Proost S., .K.Van Dender,,C Courcelle, B. De Borger et al. (2002). How large is the gap between present and efficient transport prices in Europe?. *Transport Policy*

Proost S., K. Van Dender (2001b). Welfare impacts of alternative policies to address atmospheric pollution in urban road transport. *Regional Science and Urban Economics* 31, 383-411.

Van Dender, K (2001). Testing alternative pricing policies for Brussels, Chap. 11 in De Borger B., Proost S. (eds.), *Reforming Transport Pricing in the European Union – A Modelling Approach*, Edward Elgar Publishing Ltd

Wilson, J. (1999), Theories of tax competition, *National Tax Journal* 52, 269-304.

The Center for Economic Studies (CES) is the research division of the Department of Economics of the Katholieke Universiteit Leuven. The CES research department employs some 100 people. The division Energy, Transport & Environment (ETE) currently consists of about 15 full time researchers. The general aim of ETE is to apply state of the art economic theory to current policy issues at the Flemish, Belgian and European level. An important asset of ETE is its extensive portfolio of numerical partial and general equilibrium models for the assessment of transport, energy and environmental policies.

ETE WORKING PAPER SERIES 2005

N°2005-03 Proost S., Sen A. (2005), URBAN Transport pricing reform with TWO levels of government

N°2005-02 Moons E., Saveyn B., Proost S., Hermy M. (2005), Optimal location of new forests in a suburban area

N°2005-01 Pepermans G., Willems B. (2005), The potential impact of cross-ownership in transmission: An application to the Belgian electricity market

ETE WORKING PAPER SERIES 2004

N°2004-16 Franckx L, D'Amato A., Brose I. (2004), Multi Pollutant Yardstick Schemes as Environmental Policy Tools

N°2004-15 Rousseau S., Proost S. (2004), The Relative Efficiency of Market-based Environmental Policy Instruments with Imperfect Compliance

N°2004-14 Eyckmans J., Finus M. (2004), An Almost Ideal Sharing Scheme for Coalition Games with Externalities

N°2004-13 De Borger B., Mayeres I. (2004), Taxation of car ownership, car use and public transport: insights derived from a discrete choice numerical optimisation model

N°2004-12 De Borger B., Proost S. (2004), Vertical and horizontal tax competition in the transport sector

N°2004-11 de Palma A., Dunkerley F., Proost S. (2004), Imperfect Competition and Congestion in a City with asymmetric subcenters

N°2004-10 Calthrop E., Proost S. (2004), Regulating on-street parking

N°2004-09 de Palma A., Proost S. (2004) Imperfect competition and congestion in the City

N°2004-08 Pepermans G., Willems B. (2004), Ramsey Pricing in a Congested Network with Market Power in Generation: A Numerical Illustration for Belgium