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The Political Economy of Cordon Tolls

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THE POLITICAL ECONOMY OF CORDON TOLLS¹

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Abstract. Political acceptability is the primary obstacle to implementation of road pricing in many cities. This paper studies the political economy of urban road pricing in its most common incarnation: cordon tolling. We relate voters' preferences for the road toll to its impact on the city's land market. We consider a monocentric city inhabited by pure renters and resident landowners. The price of land within (resp. outside) the cordon increases (decreases) with the toll. Hence, tolling redistributes welfare not only from renters to landowners, but also within landowners. We show that the majority voting equilibrium depends both on the extent to which land is owned by residents and on which part of the city the majority owns land in. The equilibrium toll can be equal or higher than the socially optimal level only if the majority of city residents own land within the cordon. Otherwise, the majority always votes for a toll smaller than the optimal level or even no toll at all. If residents have heterogeneous wages, the above results are confirmed as long as the median individual has a smaller wage than the average.

JEL CLASSIFICATION: R41, D78, H23

KEYWORDS: cordon tolls, road pricing, voting, monocentric city

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1 Introduction

Road congestion is one of the major problems city governments throughout the world are confronted with. In light of this, economists routinely make the case for adoption of road pricing. The rationale behind the idea is simple: having drivers pay for using roads internalizes the external costs of automobile traffic, including congestion and pollution. Yet, governments often appear unable or unwilling to act accordingly: road pricing has been implemented by only a handful of cities (including Oslo, London, Stockholm, Milan and Singapore). Political acceptability is still the main challenge faced by policymakers seeking to introduce this policy (Small and Verhoef, 2007).

In principle, there are several forms of road pricing that a city can implement. Since the external cost of a car trip is a function of kilometers traveled, drivers should ideally be charged according to the distance they cover. However, distance-based pricing is technically challenging, as each car’s path would have to be monitored in order to compute tariffs. Indeed, a much simpler form is usually considered in practice: *cordon tolling*. In a nutshell, this consists in charging drivers that enter a given area (usually including the central business/commercial district), irrespectively of distance traveled. Though potentially less effective, this policy has the advantage of being simple to implement (from a technical point of view).² In fact, most road pricing schemes currently existing in cities are essentially cordon tolls. Two well-known examples are the congestion charges in London and Stockholm (Figure 1).

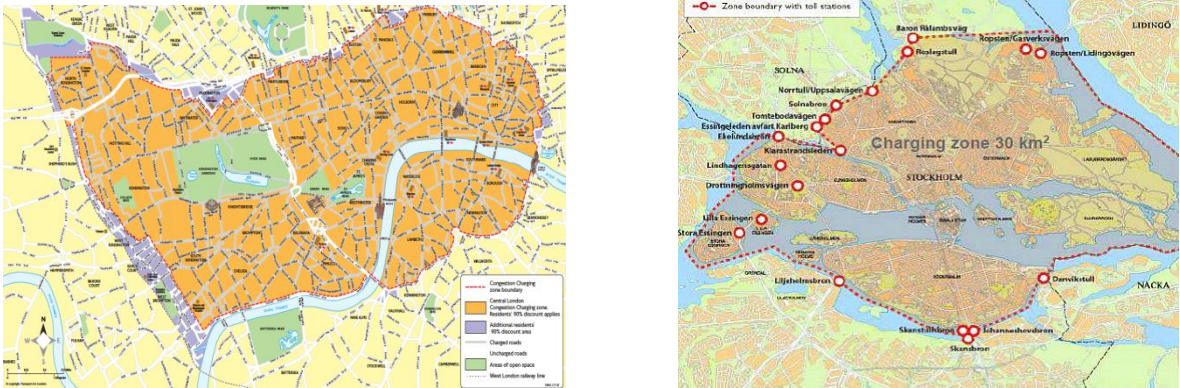


Figure 1: Map of road pricing schemes in central London (left) and Stockholm (right).

² Cordon tolling is sometimes referred to as “second best” road pricing, the first best being distance-based pricing. The literature has found that cordon tolling can achieve a large fraction of the welfare gains attainable with first best pricing (see, e.g., Verhoef (2005)).

Urban economists have extensively studied road pricing and its impact on the city's land market (Brueckner, 2011). However, relatively few studies have accounted for the specific features of cordon tolls.³ Furthermore, despite acceptability being a key obstacle to implementation, these studies have ignored the fact that governments have to respond to voters when choosing whether and how to introduce a toll. In our view, there is a need for better understanding of how democratically elected policymakers use such instrument.

The aim of this work is to study the political economy of cordon tolls, accounting for its effect on the urban land market. We build on the framework recently developed by Brueckner (2014), who studies tolling in a monocentric city consisting of three islands linked by congestible bridges. We extend his model by considering majority voting on the cordon toll and look at the implications of landownership arrangements on the policy adopted. In equilibrium, land rents (and population density) within the cordon increase with the toll, and decrease outside of it. As a result, the extent to which city residents support the toll depends not only on whether they own land, but also on where the land they own is located.⁴ We find that the equilibrium toll can be equal or higher than the socially optimal level only if the majority of city residents own land within the cordon. Otherwise, the government always implements a toll smaller than the optimal level, or even no toll at all.

The intuition for the above result is as follows. On top of correcting the congestion externality, the toll changes commuting costs and, thus, land rents within the city. It therefore redistributes welfare between renters and landowners. Furthermore, since the toll increases the value of land only inside the cordon, it also redistributes *within* landowners. The socially optimal toll is determined by taking into account the welfare of landowners in the entire city. However, a voter forms her policy preferences considering only the effect of the toll on the value of the parcel of land she owns (if any). Individuals who do not own any land (simply renting the lot they live on) prefer a toll lower than optimal, as long as total land rents go up with it. The same goes for individuals who own land outside the cordon, since the toll reduces the value of their asset. The only individuals who may prefer a toll higher or equal than the socially optimal one are those who own land within the cordon. Thus, unless these are a majority, the government adopts a toll below the optimal level.

Simple as it is, the above result can help explain the low political support road pricing finds in reality. Indeed, cordon tolls are generally designed to include a small fraction of the city, usually including its center. Thus, land within the cordon tends to be scarce and expensive. It is therefore unlikely that the majority of residents own land there. This reasoning applies quite naturally in

³ See Brueckner (2014), Anas and Hiramatsu (2013), De Lara *et al.* (2013), Verhoef (2005), Mun *et al.* (2003).

⁴ Bento *et al.* (2006) study anti-sprawl policies in the monocentric model, distinguishing landowners according to where they own land.

presence of the typical income-location pattern of European cities, where income tends to decrease with distance from the city center. In such setting, we can expect land within the tolled area to be owned predominantly by high income residents, while the low income (majority) own land outside (if at all).⁵ This scenario is explicitly considered in an extension. We also consider the opposite polar case, where high income individuals only live in the suburbs (the typical income-location pattern of most American cities). The baseline results still hold, as long as a high-income individual owns a larger share of land in the central island than a low-income one. In fact, it might be even harder to obtain a majority for the optimal toll, since, all else equal, the share of high income commuter to the central city is larger. Hence, the external cost of car trips is greater (due to the rich's larger value of time), but the poor majority's willingness to pay to reduce congestion is smaller than that of rich individuals.

There exist only few papers studying the political economy of urban transport systems in presence of a land market (see Brueckner and Selod (2006), Borck and Wrede (2005, 2008)). The closest paper to ours is Borck and Wrede (2005). They study majority voting on commuting subsidies in a monocentric city. Considering two types of individuals (rich and poor), they describe conditions under which support for subsidies can be expected. Our work differs in two main respects. First, we model traffic congestion, which is the primary reason for implementing road pricing. Second, we focus on cordon tolling. Borck and Wrede consider a linear (i.e. proportional to distance) commuting tax/subsidy. This is important since the effect of cordon tolling on commuting costs is not the same as that of a distance-based tax and so is the impact on the city's land market.⁶

2 The basic model

2.1 Setup

We adopt the basic structure of the model developed by Brueckner (2014). Specifically, the city consists of three 'islands': a Central island C, where the employment center (CBD) is located, a Midcity island M and a Suburban one S, where the city boundary is placed. Island C has a size

⁵ In many countries, the majority of city residents either does not own land (i.e. are pure renters) or only owns the land their home is built upon. Data from the US Census Bureau suggests that in most major US cities homeownership rates are above 50% (US Census, 2012). Similar figures apply to most EU countries (Eurostat, 2011).

⁶ Furthermore, the absence of congestion in Borck and Wrede's framework implies that, by assumption, residents can never unanimously vote in favor of even a small commuting tax. In presence of a congestion externality, a positive (but small) toll is always Pareto-enhancing. However, under plausible conditions, we obtain that there is no majority in favor of any positive toll.

normalized to one. We denote by Q the size of island M. Land is elastically supplied in island S at a constant rental price, which we normalize to zero. That is, there is no space constraint in S. We provide an illustration of the spatial structure in Figure 2.

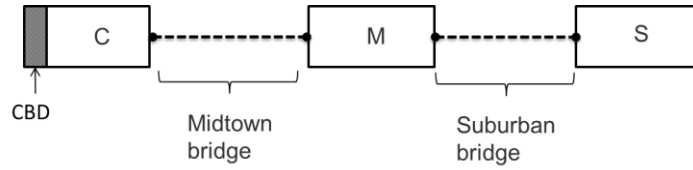


Figure 2: Spatial setup

A midcity bridge connects islands C and M and a suburban bridge connects M to S. Both are congestible. We assume the time cost functions of crossing the two bridges are given by

$$t_m(n_m + n_s) \text{ and } t_s(n_s), \text{ with } t'_m(\cdot) > 0, t'_s(\cdot) > 0.$$

Here $n_m + n_s$ is the total number of commuters crossing the midtown bridge, and n_s is the number of commuters crossing the suburban bridge. The total population is denoted N , where

$$N = n_c + n_m + n_s$$

N is exogenous, but the quantity of individuals n_c, n_m, n_s residing, respectively, in C, M and S are endogenous. We assume all individuals are commuters to the CBD which is located on island C. All travel takes place by car.⁷ We denote by q_l consumption of residential land by an individual living in $l = c, m, s$. Individual utility is defined on consumption of land and of a composite consumption good e_l , the numeraire. Preferences are specified by the quasi-linear utility function

$$u(q_l, e_l) = e_l + v(q_l) \quad l = c, m, s$$

where $v(\cdot)$ is increasing and concave. We assume that all residents have the same exogenous labor income y (this assumption will be relaxed below).

2.2 Voting on a midcity (cordon) toll

Given the positive approach of this paper, we concentrate on the policy which is most often observed in reality, i.e. a cordon established only around the city center. We assume therefore that a

⁷ This assumption will be relaxed in the complete version of the paper. We briefly discuss the presence of alternative commuting modes, e.g. public transportation, in section 4 below.

toll τ is imposed on users of the midcity bridge. There is no toll on the suburban bridge. The individual budget constraints for a person living in C, M and S is given by, respectively:

$$y + R_i + L = e_c + r_c \cdot q_c$$

$$y + R_i - \tau - t_m (n_s + n_m) + L = e_m + r_m \cdot q_m$$

$$y + R_i - \tau - t_m (n_s + n_m) - t_s (n_s) + L = e_s + \bar{r} \cdot q_s$$

In these expressions, the R_i represents income from land-ownership, i.e. what the individual receives in terms of land rents. This will be specified below. r_m and r_c are the rental price of land in M and C, respectively. Revenues from the cordon toll are redistributed lump sum and uniformly to the whole population, so

$$L = \tau \left(\frac{n_s + n_m}{N} \right).$$

There are no other taxes or government expenditures. Substituting the budget constraint in the utility function and maximizing utility, we find the optimal land consumption conditional on location:

$$q_c \text{ such that } v'(q_c) = r_c$$

$$q_m \text{ such that } v'(q_m) = r_m$$

$$q_s \text{ such that } v'(q_s) = 0.$$

Quasi-linearity implies that, in equilibrium, land consumption only depends on the rental price of land on each island. Since the size of islands C and M is limited; we assume the following normalizing constraints hold

$$n_c q_c = 1 \text{ and } n_m q_m = Q.$$

Residents only differ with respect to whether and where they own land. We will consider three groups:

- Resident landowners in C. The size of this group is N_c . We denote by $\beta_c \in \left[0; \frac{1}{N_c}\right]$ the share of total land rent r_c in C that accrues to one such individual. Hence, her income from land-ownership is $R_c = \beta_c r_c$
- Resident landowners in M. The size of this group is N_m . We denote by $\beta_m \in \left[0; \frac{Q}{N_m}\right]$ the share of total land rent r_m in M that accrues to one such individual. Hence, her income from land-ownership is $R_m = \beta_m r_m$
- Pure Renters. The size of this group is N_p . They do not own any land. Hence $R_p = 0$.⁸

We will index groups by $i = c, m, p$. N_i and β_i are exogenous and $\sum_{i=c,m,p} N_i = N$.

The effect of the toll on land rents

Intuition suggests that imposing a cordon toll on the midtown bridge will affect land rents in C and M. To find out how land rents change, first note that in equilibrium a resident must have the same utility, irrespective of where she lives. We denote by U_l^i the indirect utility of an individual of type i conditionally on residing in area l , i.e.

$$U_l^i = y + R_i - r_c q_c + \frac{\tau(n_s + n_m)}{N}$$

$$U_l^i = y + R_i - r_m q_m - \tau - t_m(n_s + n_m) + \frac{\tau(n_s + n_m)}{N}$$

$$U_l^i = y + R_i - \tau - t_m(n_s + n_m) - t_s(n_s) + \frac{\tau(n_s + n_m)}{N}.$$

Since individuals can freely choose where to live within the city, the following equalities have to be satisfied in equilibrium

$$U_c^i = U_m^i = U_s^i, i = c, m, p, \quad (1)$$

⁸ Land in S is elastically supplied and the land rent is exogenous and equal to opportunity cost of agricultural land. We normalize this cost to zero. Thus, any individual owning land in S would have the same policy preferences as pure renters.

which, after simplification, give

$$v(q_c) - r_c q_c = v(q_s) - \tau - t_m (n_s + n_m) - t_s (n_s) \quad (2)$$

$$v(q_m) - r_m q_m = v(q_s) - t_s (n_s) \quad (3)$$

Before proceeding, note the following results

$$\frac{dn_s}{d\tau} = -\frac{dn_c}{d\tau} - \frac{dn_m}{d\tau} = \frac{1}{q_c^2 v_c''} \frac{dr_c}{d\tau} + \frac{Q}{q_m^2 v_m''} \frac{dr_m}{d\tau}$$

$$\frac{d(n_s + n_m)}{d\tau} = -\frac{dn_c}{d\tau} = \frac{1}{q_c^2 v_c''} \frac{dr_c}{d\tau}$$

Note that v_c'' is the second derivative of $v(q_c)$ computed in q_c and v_m'' is the second derivative of $v(q_m)$ computed in q_m . These expressions are in turn obtained using $N = n_c + n_m + n_s$, $n_c q_c = 1$, $n_m q_m = Q$ and the first order conditions $v'(q_c) = r_c$ and $v'(q_m) = r_m$. Differentiating (2) and (3) and using these results we find

$$\left[-q_c + (t'_m + t'_s)(Z_c)\right] \frac{dr_c}{d\tau} + \left[(t'_s)(Z_m)\right] \frac{dr_m}{d\tau} + 1 = 0 \quad (4)$$

$$\left[-q_m + (t'_s)(Z_m)\right] \frac{dr_m}{d\tau} + \left[(t'_s)(Z_c)\right] \frac{dr_c}{d\tau} = 0, \quad (5)$$

where $Z_c = \frac{1}{q_c^2 v_c''} < 0$, $Z_m = \frac{Q}{q_m^2 v_m''} < 0$.

Solving system (4)-(5) we obtain

$$\frac{dr_c}{d\tau} = \frac{1}{\Delta} \left[q_m - (t'_s)(Z_m) \right] \quad \frac{dr_m}{d\tau} = \frac{1}{\Delta} \left[(t'_s)(Z_c) \right] \quad (6)$$

where

$$\Delta = \left[q_c - (t'_s)(Z_c) \right] \left[q_m - (t'_s)(Z_m) \right] - q_m (t'_s)(Z_c) > 0$$

This is strictly positive, so that $\frac{dr_c}{d\tau} > 0$ and $\frac{dr_m}{d\tau} < 0$: a higher toll on the midtown bridge raises land rents in C but reduces them in M. The reason is that the toll can be avoided only by residing on island

C. Thus, individuals in both M and S have an incentive to move there following a marginal increase in the toll. However, individuals in S have no incentive to move to M, as this would not avoid the toll. Hence, population increases in C but decreases in both M and S. Furthermore, land rents increase in C and decrease in M. Recall that land rents in S are constant by assumption.

The welfare optimal (second best) cordon toll

We first determine the second best toll (it is “second best” as there is no toll on the congested suburban bridge by assumption). Social welfare consists of residents’ utility plus total land rents. Using (1), we have

$$SW = N \left(v(q_c) + y - r_c q_c + \frac{\tau(n_s + n_m)}{N} \right) + r_c + r_m Q .$$

Maximizing this with respect to the toll, we have the first-order condition

$$\frac{dSW}{d\tau} = 0 \Leftrightarrow N \left[-q_c \frac{dr_c}{d\tau} + \frac{n_m + n_s}{N} + \frac{\tau}{N} \left(Z_c \frac{dr_c}{d\tau} \right) \right] + \frac{dr_c}{d\tau} + \frac{dr_m}{d\tau} Q = 0$$

Solving for the toll we find⁹

$$\tau^{SB} = t'_m \cdot (n_m + n_s) + \frac{t'_s (q_m n_s)}{q_m - t'_s (Z_m)} \quad (7)$$

The optimal (second best) toll exceeds the marginal external cost on the midcity bridge. This is because there is no toll on the suburban bridge, but congestion develops there as well. Since the toll on the midtown bridge increases commuting costs also for commuters using the suburban bridge, it is optimal to set it above the MEC on the midtown bridge. This is one of the results in Brueckner (2014), arrived at using a different solution approach.¹⁰

The most preferred toll by individuals owning land in the different areas

⁹ We assume throughout the paper that second order conditions are satisfied.

¹⁰ We ignore the first-best policy, i.e. tolls on both bridges; as shown by Brueckner (2014) this simply consists of Pigouvian tolls on each bridge. Derivation of first best tolls is in the Appendix.

We will now compute the most preferred toll rates for each group $i = c, m, p$ (that is, those who own land in C and M and pure renters). Consider first pure renters. Using (1), we can write their utility as

$$U^p = V + y - r_c q_c + \frac{\tau(n_s + n_m)}{N}.$$

The first-order condition reads

$$\frac{dU^p}{d\tau} = 0 \Leftrightarrow -q_c \frac{dr_c}{d\tau} + \frac{n_m + n_s}{N} + \frac{\tau}{N} (Z_c) \frac{dr_c}{d\tau} = 0$$

Solving for the toll we get, after rearranging

$$\tau^p = t'_m \cdot (n_m + n_s) + \frac{q_m t'_s(n_s)}{q_m - t'_s(Z_m)} + \frac{t'_s(q_m n_m)}{q_m - t'_s(Z_m)} + q_c^2 v_c'' \quad (8)$$

It is useful to inspect the expression for the pure renter's most preferred toll τ^p . The first two terms are the "second best terms" we also find in the expression for τ^{SB} (see (7)). The last two terms account for the effect of the road toll on total expenditures for land within the city. Indeed, using (6), it can be shown that

$$\frac{t'_s(q_m n_m)}{q_m - t'_s(Z_m)} + q_c^2 v_c'' < 0 \Leftrightarrow \frac{dr_c}{d\tau} > \left| \frac{dr_m}{d\tau} \right| Q.$$

The intuition is that there is an important redistributive channel opened by the cordon toll: as commuting costs change, so do land rents. Hence, there is some redistribution of welfare between landowners and renters. If total expenditures for land increase with the toll, this goes in favor of landowners. We will come back on this point shortly below.

Let us now turn to resident landowners. The equalities in (1) imply that

$$\frac{dU^c}{d\tau} = \frac{dU^p}{d\tau} + \beta_c \frac{dr_c}{d\tau} \quad \frac{dU^m}{d\tau} = \frac{dU^p}{d\tau} + \beta_m \frac{dr_m}{d\tau}.$$

Indeed, recall that resident landowners only differ from pure renters to the extent that they own some of the land within the city. Using the above, we easily find:

$$\tau_c = t'_m \cdot (n_m + n_s) + \frac{q_m t'_s(n_s)}{q_m - t'_s(Z_m)} + \frac{t'_s(q_m n_m)}{q_m - t'_s(Z_m)} + q_c^2 v_c'' - \beta_c N q_c^2 v_c''$$

$$\tau_m = t'_m \cdot (n_m + n_s) + \frac{q_m t'_s(n_s)}{q_m - t'_s(Z_m)} + \frac{t'_s(q_m n_m - \beta_m N)}{q_m - t'_s(Z_m)} + q_c^2 v_c''.$$

One should be careful when interpreting the expressions for τ^p , τ^c and τ^m , since toll rules are evaluated at different values for the endogenous variables.¹¹ Bearing this caveat in mind, comparison of the rules suggests

$$\tau_c \geq \tau_p \geq \tau_m. \quad (9)$$

That is, the most preferred toll is highest (lowest) for individuals owning land in C (M). The intuition is straightforward: since the effect of the toll is to raise land rents in C and to reduce them in M, it not only redistributes welfare between renters and landowners, but also within the group of landowners itself. Those who own land within the cordon prefer a larger toll than those who own land outside of it. Finally, pure renters, who do not own any land, prefer an intermediate toll between τ_c and τ_m .

Majority voting equilibrium

We assume the road toll is decided by a majority voting procedure. Of course, if one of the groups $i = c, m, p$ has a size larger than half the total population, the voting equilibrium coincides with that group's most-preferred toll. Consider now the more interesting case in which no group constitutes a majority on its own. To establish existence of a voting equilibrium, we use the results of Gans and Smart (1996). Define the marginal rate of substitution

$$M_i \equiv \frac{\frac{dU^i}{d\tau}}{\frac{dU^i}{dL}} \quad i = c, m, p,$$

where $L \equiv \frac{\tau(n_s + n_m)}{N}$. Gans and Smart (1996) prove that the Single Crossing Property is satisfied if the change in M_i with respect to type i is monotonic (when evaluated at any τ). This condition holds in our model, since

- (i) for any τ we have

¹¹ Indeed, the right hand side of each rule of course depends on the toll itself. Hence, we cannot immediately conclude that the relation between rules translates into the same relation between toll levels.

$$\frac{dU^p}{d\tau} = \frac{dU^c}{d\tau} - \beta_c \frac{dr_c}{d\tau} = \frac{dU^m}{d\tau} - \beta_m \frac{dr_m}{d\tau} \Rightarrow \frac{dU^m}{d\tau} \leq \frac{dU^p}{d\tau} \leq \frac{dU^c}{d\tau}$$

$$(ii) \quad \frac{dU^i}{dL} = 1 \text{ for any } \tau \text{ and } i = c, m, p.$$

The fact that preferences satisfy Single Crossing implies that a majority voting equilibrium exists. Moreover, the equilibrium coincides with the most preferred toll by the group that wants the median toll, namely, pure renters (except if one group has a size exceeding half the total population). Hence, we can state

LEMMA 1: the majority voting equilibrium is

- τ^i if $N^i > \frac{N}{2}$ where $i = c, m, p$
- τ^p otherwise

Comparison of second best toll and the voting equilibrium

We now proceed comparing the second best toll with the voting equilibrium. Given Lemma 1, it is important to establish whether pure renters will support a toll equal (or higher) than the optimal one. Subject to the same caveat as before (i.e., we compare toll rules, not values), comparing τ^{SB} and τ^p and using (6), we have

$$\frac{dr_c}{d\tau} > \left| \frac{dr_m}{d\tau} \right| Q \Leftrightarrow \frac{t'_s(q_m n_m)}{q_m - t'_s(Z_m)} + q_c^2 v_c'' < 0 \Leftrightarrow t'_s Q \left(\frac{q_c^2 v_c''}{q_m^2 v_m''} - 1 \right) > q_c^2 v_c'' q_m \Leftrightarrow \tau^{SB} > \tau^p \quad (10)$$

In words, the most preferred toll by pure renters is below the second best one if and only if total land rents within the city increase with the toll. In that case, raising it redistributes welfare from renters to landowners. Hence, pure renters (not owning any land) want a toll below the optimal level.

Unfortunately, the middle inequalities in (10) are ambiguous. The right hand side of the third one is strictly negative. As for the left hand side, the sign depends the congestibility of the suburban bridge t_s , but also on the function $v(q)$. For instance, for $v(q) = \log(q)$ the left hand side is zero.

Hence, in that case, $\frac{dr_c}{d\tau} > \left| \frac{dr_m}{d\tau} \right| Q$ and $\tau^{SB} > \tau^p$ hold unambiguously. However, with other

(concave) functional forms the left hand side might be negative, making the comparison a priori undetermined. Therefore, we do not have a clear prediction on whether total land rents increase with the toll. Nevertheless, we have so far been unable generate examples where the inequalities in (10) are reversed.

Using (9) and (10) and recalling Lemma 1, we can conclude the following:

PROPOSITION 1: Assume the road toll raises total land rents throughout the city, i.e. (10) holds. The toll resulting from majority voting is equal or higher than the optimal level only if resident landowners in C are a majority and own a sufficiently large share of land. Otherwise, the toll is strictly below the optimal level.

The intuition for Proposition 1 is simple. As mentioned above, if the toll raises land rents overall in the city, it redistributes welfare from renters to landowners. Furthermore, because land rents increase only within the cordon, the toll redistributes welfare from those who own land outside the cordon to those who own land inside. As a result, only resident landowners within the cordon can support a toll higher than optimal. All other groups want a suboptimal toll, possibly even equal to zero (this will be illustrated in our numerical example below).

Proposition 1 outlines conditions such that a city government, responding to the will of voters, tends to underprice road congestion. Can it help us explain why cities rarely manage (or even try) to implement road pricing in reality? By nature, cordon tolls cover an area which is relatively small in size and includes the very center of the city. Land within the cordon is therefore scarce and highly expensive. Indeed, it seems unlikely that the majority of the population owns land within the area potentially covered by a cordon. According to the proposition, the lack of such a majority will lead to a voting equilibrium where the city government tends to set the toll too low with respect to the optimal level. We have therefore identified a force that discourages local governments from pricing congestion. In fact, as the numerical example below will illustrate, voters who do not own land within the cordon may easily want no toll implemented at all.

A comparison of this result with Borck and Wrede (2005) is worthwhile. In our model, land rents increase with the toll only within the cordon and decline outside. If the toll makes total expenditures for land increase, pure renters want a below-optimal toll. This prediction is similar to that of Borck and Wrede. However, in their model the commuting tax increases land rents everywhere within the city. Hence, it redistributes welfare only between renters and landowners.

Consequently, the greater the extent to which land is owned by city residents, the stronger support for such tax. In our model the effect of the toll on land prices depends, both in sign and in magnitude, on location. Thus, the toll also redistributes welfare *within* landowners, as only those who own land inside the cordon gain. As a result, not only how much but also where city residents own land is crucial for the voting equilibrium.

Finally, it should be noted that in this simple model some voters are at the same time renters and landowners. However, the outcome we described in Proposition 1 (toll below second best) could also be obtained under different assumptions. For instance, we could assume all voters in the city are purely renters. In that case, they would all vote for a toll equal to τ^P . Even if they do not vote, landowners could influence the political equilibrium by lobbying the government, and we could expect those who own land in C to lobby in favor of the toll, while those who own land in M to lobby against it.¹²

2.3 A numerical example

An numerical example may illustrate the results. We use the following specification for the utility function: $U = v(q_i) + e_i = \ln(q_i) + e_i$. Note that this implies $v'(q_i) = \frac{1}{q_i}$; $v''(q_i) = -\frac{1}{(q_i)^2}$. The congestion functions are linear, both on the mid-city and the suburban bridge:

$$\begin{aligned} t_m(n_m + n_s) &= \alpha_m + \delta_m \cdot (n_m + n_s) \\ t_s(n_s) &= \alpha_s + \delta_s \cdot n_s \end{aligned}$$

Parameter values used in the example were the following:

$$\beta_m = \beta_c = \frac{1}{3}; \alpha_m = \alpha_s = 0; \delta_m = \delta_s = 0.1; Q = 1..$$

The first-order condition for land consumption and the normalizations $n_c q_c = n_m q_m = 1$ imply that $r_i = n_i$ ($i = c, m$). In the no-congestion (in essence, setting $\delta_m = \delta_s = 0$) and no-toll ($\tau = 0$) equilibrium we have that:

$$q_i = n_i = r_i = 1 \quad (i = c, m, s).$$

The results are summarized in Table 1. The case without toll ($\tau = 0$) but allowing for congestion ($\delta_m = \delta_s = 0.1$) raises land prices in the central city quite substantially. Note that land prices in the

¹² See Bento *et al.* (2006) for a study of land regulation policy adopting a related approach. Another alternative could be to explicitly consider homeownership. We are currently working on an extension of the model that considers homeowners.

mid-city also moderately rise. The reason is that congestion makes the central city more attractive relative to the mid-city and suburban areas but, as more people move to the central city housing consumption declines and this reduces utility. The trade-off between housing consumption and time losses due to congestion limits the increase in central city population, and population in M also rises. Consumption of land in areas M and C declines, and the population in the suburban area s is strongly reduced. The second-best toll is positive; it amounts to 0.195 per cordon crossing. The toll further raises the central city population at the expense of areas M and S.

	r_c	r_m	n_c	n_m	n_s	q_c	q_m	Toll
No congestion	1	1	1	1	1	1	1	0
Congestion, $\tau = 0$	1,213	1,073	1,213	1,073	0,714	0,825	0,932	0
τ^{SB}	1,477	1,049	1,477	1,049	0,474	0,677	0,953	0,195
τ^c	1,564	1,040	1,564	1,040	0,396	0,639	0,961	0,275
τ^m								<0
τ^p								<0

Table 1: Numerical example

Now consider the desired tolls by the three population groups. The toll wanted by people owning land in the central city exceeds the second best toll: the central city becomes a more attractive place to live, raising its population, and land owners benefit from increasing land rents. Land consumption per household declines.

Interestingly, both the toll wanted by the mid-city landowners and pure renters are negative. In practice they want a zero toll (restricting the toll at zero produces the solution of the second row of the table). For a positive toll, the mid-city people would see their land rents slightly decline and they would face the toll on the mid-city bridge; hence, they prefer no such toll. The pure renters also prefer not to pay the toll at all, as they have no benefits from such a toll except lower congestion, but this is out-weighted by the toll payments. In sum, the political equilibrium would be a zero toll, despite a substantial second-best optimal toll.

3. Extending the model: two income classes

We have so far assumed that all individuals have the same labor income. We now extend the model assuming heterogeneity of wages. There are two types of individuals: high income and low income. They will be indexed by $w = h, l$. Denoting by N_w the size of each group, we have $N = N_h + N_l$. We assume $N_h < N_l$: low income individuals are the majority of the population. We denote by Y the time endowment (assumed equal for all types) and by x_w the hourly wage, assuming that $x_l < x_h$. High income types earn a larger wage than low income types, which also implies that they have a higher opportunity cost of commuting time. The individual budget constraints for a high and a low income individual $w = h, l$ are given by

$$x_w(Y - t_s(n_s)) - t_m(n_s + n_m) - \tau + R_w + L = e_w$$

$$x_w(Y - t_m(n_s + n_m)) - \tau + R_w + L = e_w + r_m \cdot q_{w,m}$$

$$x_w(Y) + R_w + L = e_w + r_c \cdot q_{w,c},$$

depending on whether the individual lives in S, M or C respectively and where $q_{w,c}$ is housing consumption of an individual of type $w = h, l$ when living in island C (and so on). Note that travel time costs $t_m(n_s + n_m)$ and $t_s(n_s)$ are assumed to directly reduce labor time. Hence, they are valued at the wage rate. Recall that land rent in S is zero and only the midtown bridge can be tolled. r_i denotes land rents in island $i = s, m, c$ while R_w denotes the land rent accruing to an individual of type $w = h, l$ (more on this below).

We assume all individuals have the same utility function (up to a preference for location) $u(q, e)$ introduced above. Note that, because of the assumption of quasi-linear preferences, we have

$$q_{w,i} = q_i \quad w = h, l; i = c, m, s \quad (11)$$

that is, land consumption is not differential with income, conditionally on location.

As in the baseline model, we divide high and low income individuals in three subgroups:

- Resident-landowners in C. The size of this sub-group is denoted N_{wc} , $w = h, l$. We denote by β_{wc} the share of total land rent in C that accrues to one such individual. Hence, $R_{wc} = \beta_{wc} r_c$ and $\beta_{lc} N_{lc} + \beta_{hc} N_{hc} = 1$.

- Resident-landowners in M. The size of this sub-group is denoted N_{wm} , $w = h, l$. We denote by β_{wm} the share of total land rent r_m in M that accrues to one such individual. Hence, $R_{lm} = \beta_{lm} r_m$ and $\beta_{lm} N_{lm} + \beta_{hm} N_{hm} = Q$.
- Pure renters. They do not own any land. The size of this group is denoted N_{wp} , $w = h, l$. Hence $R_{wp} = 0$.

We have of course $N_w = N_{wc} + N_{wm} + N_{wp}$, $w = h, l$. To simplify the presentation below, we will assume that the share of land on the central island owned by a low income individual is never greater than that owned by a high-income individual, i.e. $\beta_{lc} \leq \beta_{hc}$.

The presence of several income classes implies that we need to make assumptions concerning the city's income-location pattern (see, e.g., Borck and Wrede 2005, 2008). We will consider two alternative scenarios. In the first, high-income types live in the city's most central locations, while the low-income types live farther away. This is representative of the income/location pattern in European cities, where income tends to decrease with distance from the CBD. In the second, high-income individuals reside in the suburbs (a stylized representation of most US cities).

3.1 Scenario Rich in center (the "European" city)

In this scenario, the high-income individuals have a larger willingness-to-pay to live in proximity of the CBD than low-income types. This is due to the higher value of time. Hence, they always outbid the low income types for land in the central island.¹³ Whether high-income types occupy entirely island C or share it with low income ones in equilibrium depends on parameter values. Intuitively, if the high income types are sufficiently numerous, they will occupy all island C and also some of island M. We assume the size of the rich population N_h is small enough that they do not occupy the entire C. That is, we assume that $N_h q_c < 1$, where q_c is equilibrium land consumption on the central island. As a result, some low income individuals live in C and islands M and S are entirely inhabited by low income types.¹⁴ This assumption is made purely for ease of exposition: except for one

¹³ In general, a necessary condition for this equilibrium to arise is that the elasticity of land consumption with respect to income is small enough. However, we are assuming that the latter is zero. Note from (11) that land consumption is not differential across types.

¹⁴ The equilibrium land rent in C is the value of r_C that makes a low-income type indifferent between living in S consuming q_s units of land and living in C consuming q_c units of land. Anything lower would imply excess demand of land in C: the low income types would be willing to pay more to live in C than r_C . A higher price

difference we discuss below, little would change under the assumption that island C is entirely occupied by high-income individuals and some of them also live on island M.

Given these assumptions, in equilibrium all high-income individuals live in C and get utility

$$U^{hi} = v(q_c) + x_h Y - r_c q_c + R_{hi} + L, \quad i = c, m, p \quad (12)$$

where R_{hi} is the land rent accruing to a high-income individual, conditionally on the subgroup he belongs to. We assume high-income types are either pure renters or own land only on the island where they live, i.e. C. Hence, $N_{hm} = 0$. Consider now low-income types. We have

$$\begin{aligned} U_c^{li} &= v(q_c) - r_c q_c + x_l Y + R_{li} + L, \\ U_m^{li} &= v(q_m) - r_m q_m + x_l (Y - t_m(n_s + n_m)) + R_{li} + L - \tau, \\ U_s^{li} &= v(q_s) + x_l (Y - t_m(n_s + n_m) - t_s(n_s)) + R_{li} + L - \tau, \end{aligned} \quad (13)$$

where $i = c, m, p$ denotes the subgroup the low income individual belongs to. In equilibrium, free mobility implies that

$$U_c^{li} = U_m^{li} = U_s^{li} \quad i = c, m, p. \quad (14)$$

In addition, space on both the central and midcity island has to be fully occupied. So the following conditions hold

$$n_c q_c = (N_h + n_{lc}) q_c = 1, \quad n_m q_m = Q,$$

where $n_{lc} = n_c - N_h$ is the quantity of low income residents in C and n_m that of residents in M (all of low income by assumption).

As before, we first compute the change in equilibrium land rents with respect to a marginal increase in τ . Using the equilibrium conditions (14) we have

$$v(q_c) - r_c q_c = v(q_s) - \tau - x_l (t_m(n_s + n_m) - t_s(n_s)) \quad (15)$$

$$v(q_m) - r_m q_m = v(q_s) - x_l t_s(n_s) \quad (16)$$

would mean that no poor individual lives in C. Since, by assumption, $N_h q_c < 1$, some land would remain vacant in C, which cannot hold in equilibrium.

Observe that these equations are the same as (2) and (3) except that the cost of crossing bridges is multiplied by the value of time for low income individuals x_l : they are the only group that uses the city's bridges. One can therefore follow the same procedure as in Section 2.2 to obtain

$$\frac{dr_c}{d\tau} = \frac{1}{\Delta} [q_m - (x_l t'_s)(Z_m)] > 0 \quad \frac{dr_m}{d\tau} = \frac{1}{\Delta} [x_l (t'_s)(Z_c)] < 0, \quad (17)$$

where

$$\Delta = [q_c - (x_l t'_s)(Z_c)][q_m - (x_l t'_s)(Z_m)] - q_m (x_l t'_s)(Z_c) > 0$$

$$\text{and } Z_c = \frac{1}{q_c^2 v_c} < 0, \quad Z_m = \frac{Q}{q_m^2 v_m} < 0.$$

Second best toll

To determine the second best toll, note that -- using (12), (13) and (14) -- we can write the social welfare function as

$$(N_l + N_h) \left\{ v(q_c) - r_c \cdot q_c + \frac{\tau(n_m + n_s)}{N} \right\} + Y(N_l x_l + N_h x_h) + r_m Q + r_c$$

Maximizing this objective function with respect to τ , making use of (17), we get

$$\tau^{SB} = t'_m x_l \cdot (n_m + n_s) + \frac{t'_s x_l (q_m n_s)}{q_m - t'_s x_l (Z_m)} \quad (18)$$

This is almost identical to the second best toll in the baseline model, except that time costs are multiplied by the value of time for low income commuters (the only type to use the city's bridges).

Most preferred tolls by low and high income individuals

We now compute the most preferred tolls for each group, starting from high-income individuals. We maximize (12) with respect to τ , obtaining

$$\tau^{hc} = t'_m x_l \cdot (n_m + n_s) + \frac{t'_s x_l (q_m n_s)}{q_m - t'_s x_l (Z_m)} + \frac{t'_s x_l Q}{q_m - t'_s x_l (Z_m)} + q_c^2 v_c (1 - \beta_{hc} N) \quad (19)$$

$$\tau^{hp} = t'_m x_l \cdot (n_m + n_s) + \frac{t'_s x_l (q_m n_s)}{q_m - t'_s x_l (Z_m)} + \frac{t'_s x_l Q}{q_m - t'_s x_l (Z_m)} + q_c^2 v_c'' \quad (20)$$

The formulae for τ^{hc} and τ^{hp} have a similar structure to (8). The difference between τ^{hc} and τ^{hp} is due to the increase in the value of land owned within the cordon. We have indeed $\tau^{hc} > \tau^{hp}$.

Turn now to low-income individuals. Maximizing (13) with respect to τ and following the usual steps, we get

$$\tau^{lc} = t'_m x_l \cdot (n_m + n_s) + \frac{t'_s x_l (q_m n_s)}{q_m - t'_s x_l (Z_m)} + \frac{t'_s x_l Q}{q_m - t'_s x_l (Z_m)} + q_c^2 v_c'' (1 - \beta_{lc} N) \quad (21)$$

$$\tau^{lm} = t'_m x_l \cdot (n_m + n_s) + \frac{t'_s x_l (q_m n_s)}{q_m - t'_s x_l (Z_m)} + \frac{t'_s x_l Q - \beta_{lm} t'_s x_l N}{q_m - t'_s x_l (Z_m)} + q_c^2 v_c'' \quad (22)$$

$$\tau^{lp} = t'_m x_l \cdot (n_m + n_s) + \frac{t'_s x_l (q_m n_s)}{q_m - t'_s x_l (Z_m)} + \frac{t'_s x_l Q}{q_m - t'_s x_l (Z_m)} + q_c^2 v_c'' \quad (23)$$

Comparison of the toll rules in (19) - (23) suggests that

$$\tau^{lm} < \tau^{lp} = \tau^{hp} < \tau^{lc} \leq \tau^{hc} \quad (24)$$

It is interesting to note that pure renters want the same toll, irrespectively of labor income. This might be somewhat surprising: one could expect the effect of the toll to vary according to individual income. However, it is not the case. By assumption, high-income pure renters do not use the city bridges (they all live on island C). Hence, there are only two redistributive channels through which the toll affects their welfare. First, it produces extra revenue, generated by commuters that cross the midtown bridge. Second, it produces a change in the rent on island C. These two channels affect a low income pure renter in exactly the same way, regardless of where he resides. First, revenues from the toll are redistributed uniformly. Furthermore, in equilibrium, the change in r_c has the same effect on a low and a high income pure renter living in C (recall that, by quasi-linearity, they consume the same quantity of land). In turn, the effect of a marginal increase in the toll on a pure renter living in C must necessarily be the same as that on a pure renter in M and S, after accounting for the change in land rents and commuting costs.¹⁵

¹⁵ Two assumptions underpin for this outcome: quasilinear preferences (so land consumption is invariant with income) and the assumption that all high income types live in C. Suppose some of them lived also on island M. The most preferred toll of a high income pure renter would be strictly higher than that of a low income one. The reason is that, on top of the redistributive channels mentioned above, there would be the fact that both

Turning now to resident landowners, as should by now be clear only individuals who own land in C see their gross income increase with the toll. Recall that, by assumption, a high income type owns a greater share of land in C than a low income one (recall that $\beta_{lc} \leq \beta_{hc}$). Finally, those who own land in M suffer a loss when the toll goes up. As a result, they want the lowest toll among all groups.

Majority voting and comparison with second best toll

As in the baseline model, we can prove that individual policy preferences satisfy the single crossing property. Hence, a majority voting equilibrium exists and coincides with the most-preferred toll by the median voter. Given (24) and $N_h < N_l$, the median is necessarily a low income individual. Using (24), we have:

LEMMA 2: In the rich in center scenario, the majority voting equilibrium is

- τ^{lm} **if** $N_{lm} > \frac{N}{2}$
- τ^{lp} **if** $N_{lm} + N_{lp} > \frac{N}{2} > N_{lm}$
- τ^{lc} **otherwise**

The comparison with τ^{SB} follows the same steps as in the baseline model. We have

$$\frac{dr_c}{d\tau} > \left| \frac{dr_m}{d\tau} \right| Q \Leftrightarrow x_l t_s ' Q \left(\frac{q_c^2 v_c''}{q_m^2 v_m''} - 1 \right) > q_c^2 v_c'' q_m \Leftrightarrow \tau^{SB} > \tau^{lp} . \quad (25)$$

The middle and right inequalities are simply the counterpart of (10) for the scenario we consider here. Assuming total land rents increase with the toll, the most-preferred toll by pure renters is strictly below the second best. The same intuition underlying (10) applies, and we refer the reader to the discussion provided there. Using (24) and Lemma 2, we can therefore conclude the following

low and high income individuals use the midtown bridge for commuting, but the latter have a higher value of time.

PROPOSITION 2: Consider the “Rich in center” case. Assume the road toll raises total land rents throughout the city, i.e. (25) holds. The toll resulting from majority voting is equal or higher than the optimal level only if resident landowners in C are a majority, i.e. $N_{ic} + N_{hc} > \frac{N}{2}$, and the share of land they own is large enough. Otherwise, the toll is strictly below the optimal level.

3.2 Scenario “Poor in center” (the “American” city)

Consider now the case in which high-income types live far from the center. This income-location pattern is interesting since it characterizes many North American cities. We assume the low-income individuals live on all three islands, while the high-income ones only live in S. To obtain this in equilibrium, we need to make an additional assumption: since the rich have a higher value of time than the poor, one would expect them to outbid them in C. However, the rich have a “taste for location” that induces them to reside in S.¹⁶ Observe that there is no space constraint in S, so both rich and poor live there as long as the quantity of poor people is large enough that both the central and the midcity islands are fully occupied.

The indirect utility of a high-income individual is

$$U_h = v(q_s) + x_h(Y - t_m(n_s + n_m) - t_s(n_s)) + R_h + L - \tau + \gamma \quad (26)$$

where γ is the rich individual’s extra utility from living in S (assumed large), i.e. the “taste for location” mentioned above. R_h is the income from the land rents accruing to a rich individual. We assume that a high income individual owns some land on island C and denote by β_{hc} the share of land owned in C by one such individual.¹⁷

The utility of a poor individual is as described as in (13) and, in equilibrium,

$$U_c^{li} = U_m^{li} = U_s^{li} \quad i = c, m, p. \quad (27)$$

Furthermore, space on both the central and midcity island is fully occupied. So

$$n_c q_c = 1, \quad n_m q_m = Q,$$

¹⁶ See Brueckner and Selod (2006) for further justification on this assumption.

¹⁷ It would also be natural to assume high income types own some land on the suburban island S. However, since land rents are constant there by assumption, this would not change the analysis below..

where n_c is the quantity of residents in C and n_m the quantity of residents in M. Recall that both are entirely composed of low income individuals by assumption. Following the usual steps, we have in equilibrium

$$\frac{dr_c}{d\tau} = \frac{1}{\Delta} [q_m - (x_l t'_s)(Z_m)] > 0 \quad \frac{dr_m}{d\tau} = \frac{1}{\Delta} [x_l (t'_s)(Z_c)] < 0. \quad (28)$$

Second best toll

Using (13) and (26) we can write the social welfare function as

$$\begin{aligned} & N_l \left\{ v(q_s) + x_l (Y - t_m(n_s + n_m) - t_s(n_s)) + \frac{\tau(n_m + n_s)}{N} - \tau \right\} + \\ & + N_h \left\{ v(q_s) + x_h (Y - t_m(n_s + n_m) - t_s(n_s)) + \frac{\tau(n_m + n_s)}{N} - \tau + \gamma \right\} \\ & + Y(N_l x_l + N_h x_h) + r_m Q + r_c \end{aligned}$$

Maximizing this with respect to τ , making use of (28), we obtain

$$\tau^{SB} = t'_m (x_h \cdot N_h + x_l \cdot (n_m + n_s - N_h)) + \frac{t'_s q_m (x_l (n_s - N_h) + x_h N_h)}{q_m - t'_s x_l (Z_m)} \quad (29)$$

This differs from the “rich in city” scenario only because now both rich and poor use the midcity and suburban bridges. Hence, the marginal external cost of a car trip accounts for the fact that value of time of commuters using the midtown bridge is not homogeneous.

Most preferred tolls

Let us now compute the most preferred toll for each group. Start from high-income individuals. Maximizing (26) with respect to τ , making use of (28), we get, after some rearrangements,

$$\begin{aligned} \tau^h &= t'_m (x_h \cdot N_h + x_l \cdot (n_m + n_s - N_h)) + \\ & + t'_m (x_h - x_l) N_l + \frac{t'_s q_m (x_l (n_s - N_h) + x_h N_h + (x_h - x_l) N_l)}{q_m - t'_s x_l (Z_m)} \\ & + \frac{t'_s q_m (x_l (n_m))}{q_m - t'_s x_l (Z_m)} + q_c^2 v_c'' (1 - \beta_{hc} N) \end{aligned} \quad (30)$$

This expression contains the “second best” terms, plus additional (positive) ones that account for the difference $x_h - x_l$ between value of time of high- and low-income types: the latter have larger value of time than the average commuter. The terms on the last line account for the effect of the toll on the land market. The first two capture the effect of the toll on total land rents in the city (see below). The last one accounts for the increase in the value of land owned by high income types for a high type when the toll goes up (note that v_c'' is negative).

Consider now a low income pure renter. We maximize (13) with respect to τ and consider $i = p$. We obtain:

$$\begin{aligned} \tau^{lp} = & t'_m (x_h \cdot N_h + x_l \cdot (n_m + n_s - N_h)) + \\ & + t'_m (x_l - x_h) N_h + \frac{t'_s q_m (x_l (n_s - N_h) + x_h N_h + (x_l - x_h) N_h)}{q_m - t'_s x_l (Z_m)} \\ & + q_c^2 v_c'' + \frac{t'_s q_m (x_l (n_m))}{q_m - t'_s x_l (Z_m)} \end{aligned} \quad (31)$$

This formula contains the second best terms, plus negative terms that account for the fact that low income types have a lower value of time than the average commuter. Hence, they are less willing to pay to reduce congestion. Finally, we have terms that account for the effect of the toll on the land market, as in (30). The difference is that a pure renter does not earn any income from landownership. Finally, the most-preferred tolls for a low income type owning land in M and C are respectively

$$\begin{aligned} \tau^{lm} = & t'_m (x_h \cdot N_h + x_l \cdot (n_m + n_s - N_h)) + \\ & + t'_m (x_l - x_h) N_h + \frac{t'_s q_m (x_l (n_s - N_h) + x_h N_h + (x_l - x_h) N_h)}{q_m - t'_s x_l (Z_m)} \\ & + q_c^2 v_c'' + \frac{t'_s x_l (q_m n_m - \beta_{lm} N)}{q_m - t'_s x_l (Z_m)} \end{aligned} \quad (32)$$

and

$$\begin{aligned} \tau^{lc} = & t'_m (x_h \cdot N_h + x_l \cdot (n_m + n_s - N_h)) + \\ & + t'_m (x_l - x_h) N_h + \frac{t'_s q_m (x_l (n_s - N_h) + x_h N_h + (x_l - x_h) N_h)}{q_m - t'_s x_l (Z_m)} \\ & + q_c^2 v_c'' (1 - \beta_{lc} N) + \frac{t'_s x_l (q_m n_m - \beta_{lm} N)}{q_m - t'_s x_l (Z_m)} \end{aligned} \quad (33)$$

Comparison of toll rules in (30) - (33) suggests the following

$$\tau^{lm} < \tau^{lp} < \tau^{lc} < \tau^h. \quad (34)$$

Majority voting and comparison with second best toll

Using similar arguments to the “rich in center” scenario, we have

LEMMA 3: In the poor in center scenario, the majority voting equilibrium is

- τ^{lm} **if** $N_{lm} > \frac{N}{2}$
- τ^{lp} **if** $N_{lm} + N_{lp} > \frac{N}{2} > N_{lm}$
- τ^{lc} **otherwise**

The comparison of τ^{lp} and τ^{SB} resembles that of the “rich in city” scenario. The main difference is that low income individuals have a smaller value of time than the average commuter. Hence, their willingness to pay to reduce congestion is below average. In other words, there is an additional redistributive channel that comes with introduction of the toll. By assumption, all individuals pay the same toll, but the high-income types receive a larger benefit from reducing congestion. As a result, a low-income individual is even more likely, all else equal, to want a toll below the optimal toll τ^{SB} . Indeed, in this scenario, the fact that the road toll increases land rents within the entire city is sufficient, but not necessary, to have that a low income pure renter wants a sub-optimal toll

$$\frac{dr_c}{d\tau} > \left| \frac{dr_m}{d\tau} \right| Q \Leftrightarrow x_l t_s ' Q \left(\frac{q_c^2 v_c''}{q_m^2 v_m''} - 1 \right) > q_c^2 v_c'' q_m \Rightarrow \tau^{SB} > \tau^{lp} \quad (35)$$

We can therefore state the following

PROPOSITION 3: Consider the “Poor in center” case. Assume the road toll raises total land rents throughout the city, i.e. (35) holds. The majority voting equilibrium is such that the toll is higher or

equal than the socially optimal level only if the majority of landowners in C are a majority and the difference between the value of time of high and low income commuters is small.

4. Alternative travel modes and non-commuters

We have so far assumed that all residents in the city commute to the CBD and only use cars. Of course, both of these assumptions are unrealistic. The purpose of this section is to provide an informal discussion of how our results might change if they were relaxed.

Suppose city residents could also use an alternative travel mode, e.g. public transportation. Suppose also that commuting costs by public transport increase with distance more rapidly than commuting costs by car, but that there is a fixed cost of ownership for the car. This is a rather crude assumption, but it is not unrealistic.¹⁸ We would obtain that, in equilibrium, residents living close enough to the CBD use public transport, while the others use cars. The results of the model would then hinge on how fast the cost of using public transport system increases with distance from the CBD. Suppose the increase is quite steep, so that only residents in the central island use public transport. Hence, only by residing within the cordon area would individuals be able to avoid the toll. Thus, the results presented so far would be essentially unchanged. In a different scenario, suppose residents of both C and M use only public transport and individuals use cars only if they live in S. In that case, the population of both C and M would increase in equilibrium with the toll, while that in S would decline. Hence, land rents throughout the city would unambiguously increase throughout the city, and all landowners would benefit from the toll as a result. This should not be very surprising since, in our simple model, if only people in S use cars, tolling only the midtown bridge is equivalent to tolling only the suburban bridge. In a more general model, one would expect that, even if the share of people using public transport does not decline very steeply outside of the cordon area, the toll would increase density and land prices relatively close to the CBD (possibly also outside the cordon), but decrease them farther away. As a result, the implications for the voting outcome would not differ substantially from those of our basic model.

It should perhaps be pointed out that, as shown in Borck and Wrede (2008), given that the a commuting tax on cars (in our case, the cordon toll) affects the price of land in equilibrium, it is not necessarily the case that individuals who do not commute by car support it. On the other hand, evidence (CITATION) suggests that public transport users tend to be among the main supporters of road pricing. To the extent that individuals who use public transport (or other alternative modes to

¹⁸ See, e.g., Borck and Wrede (2008), Su and De Salvo (2007)...

the car) also own some land (for instance because they are homeowners) in the part of the city where density and land rents tend to increase, this is in line with the predictions of our model.

5. Concluding remarks

We have studied majority voting on a cordon toll in a model that explicitly considers the city's land market. Of course, the analysis of this paper can be extended in several interesting directions. We have assumed that only the midcity bridge can be tolled. A natural question is if and how the outcome of the political process would change if tolls on both bridges were set. Moreover, in principle the model allows also to study the acceptability of a cordon of larger size than the one we considered, i.e. a toll on the suburban bridge only. The question would then be whether such larger cordon would have higher or smaller chances of being accepted. Finally, one may want to explicitly model homeowners. It seems nevertheless fair to say that very few models incorporating homeownership in a political economy framework exist. The only model we are aware of that treats the issue in a purely static framework is Brueckner and Lai, 1996. Hilber and Robert-Nicoud (2007) and Ortalo-Magné and Prat (2014) propose dynamic models that are too complex to be embedded in our framework (their focus is not on transportation policy). A more realistic modeling of homeowners would nevertheless be desirable.

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APPENDIX: derivation of first-best tolls

We first determine how land rents in C and M change with respect to the road tolls. The following equilibrium conditions must now hold

$$v(q_c) - r_c q_c = v(q_s) - \tau_m - \tau_s - t_m(n_s + n_m) - t_s(n_s)$$

$$v(q_m) - r_m q_m = v(q_s) - \tau_s - t_s(n_s)$$

Totally differentiating these equations with respect to τ_m , and noting the first-order condition for optimal housing consumption we obtain, using similar derivations as in the one toll case

$$\left[-q_c + (t'_m + t'_s)Z_c\right] \frac{dr_c}{d\tau_m} + \left[(t'_s)Z_m\right] \frac{dr_m}{d\tau_m} + 1 = 0$$

$$\left[-q_m + (t'_s)Z_m\right] \frac{dr_m}{d\tau_m} + \left[(t'_s)Z_c\right] \frac{dr_c}{d\tau_m} = 0$$

Solving the system (8)-(9) gives obviously the same effect of the midcity bridge toll on land rents we had before:

$$\frac{dr_c}{d\tau_m} = \frac{1}{\Delta}(q_m - t'_s Z_m) > 0; \quad \frac{dr_m}{d\tau_m} = \frac{1}{\Delta}(t'_s Z_c) < 0$$

A similar procedure yields after analogous simplifications:

$$\frac{dr_c}{d\tau_s} = \frac{1}{\Delta}(q_m) > 0; \quad \frac{dr_m}{d\tau_s} = \frac{1}{\Delta}(q_c - t'_m Z_c) > 0$$

Let us determine the (first-best) outcome where both bridges can be tolled. The solution is obtained by solving the following problem:

$$\text{Max}_{\tau_m, \tau_s} N \left\{ v(q_c) - r_c \cdot q_c + \frac{\tau_m \cdot (n_m + n_s)}{N} + \frac{\tau_s \cdot (n_s)}{N} \right\} + r_m + r_c$$

The first order conditions can be written as

$$\tau_m \left[(Z_c) \frac{dr_c}{d\tau_m} \right] + \tau_s \left[(Z_c) \frac{dr_c}{d\tau_m} + (Z_m) \frac{dr_m}{d\tau_m} \right] = (Nq_c - 1) \frac{dr_c}{d\tau_m} - \frac{dr_m}{d\tau_m} - (n_m + n_s)$$

$$\tau_m \left[(Z_c) \frac{dr_c}{d\tau_s} \right] + \tau_s \left[(Z_c) \frac{dr_c}{d\tau_s} + (Z_m) \frac{dr_m}{d\tau_s} \right] = (Nq_c - 1) \frac{dr_c}{d\tau_s} - \frac{dr_m}{d\tau_s} - n_s$$

Substituting earlier results for the effect of tolls on land rents, multiplying both sides by Δ , noting that $N \cdot q_c - 1 = (n_m + n_s) q_c$ and working out, we easily show that

$$\tau_m = t_m' \cdot (n_m + n_s)$$

$$\tau_s = t_s' \cdot n_s$$