Parking Policy under Strategic Interaction

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Abstract:

I examine the effect on parking policy of strategic interaction between jurisdictions. To do this I use an inventory scheme and an analytical model based on Hotelling's linear city model. I conclude that the procedure for setting supply has a downward effect on prices, that resource flow competition implies that the competitive prices are higher than the efficient prices (but that the effect of the supply procedures makes this effect incongruous), that road investments lowers parking prices and that municipality' park-and-ride policies often leads to the full benefits of public transport investments not being attained.

Keywords: Parking, spillover, resource flow, efficiency, strategic interaction, linear city

INTRODUCTION

Although parking is partly provided by private actors, municipalities are important actors in the parking market through providing both on- and off-street parking themselves, through being responsible for zoning and through deciding parking norms that specify how much parking is required for new construction. Transportation takes place in a system that stretches outside of a given municipality's borders. Thus, parking policy decisions taken in one municipality affect other municipalities and vice versa. This creates an element of strategic interaction; parking policies must be decided upon taking other municipalities´ policies into account. There is also an interrelationship between municipal transport policy and transport policy decided upon by regional or national governments. Furthermore, these higher-level policies will influence the outcome of the strategic interaction between local governments. A large literature focuses on parking policy issues within a municipality. In this article I instead study parking policy as a tool for strategic competition. This has, as far as I know, not been done before.

In many countries, transport policy mainly lies in the hands of the national government which typically decides on taxes and subsidies as well as on large infrastructure projects. Except for parking charges local pricing instruments such as road pricing, taxes or user fees are seldom used, neither to finance regional infrastructure nor to correct externalities. Since parking policy is most often the only pricing instrument municipalities' use it is an important policy measure to study. Strategic interaction is probably most intense in city districts were the border between jurisdictions goes through densely populated areas. One example is the Stockholm/Solna/Sundbyberg-area in Sweden shown in the map below:

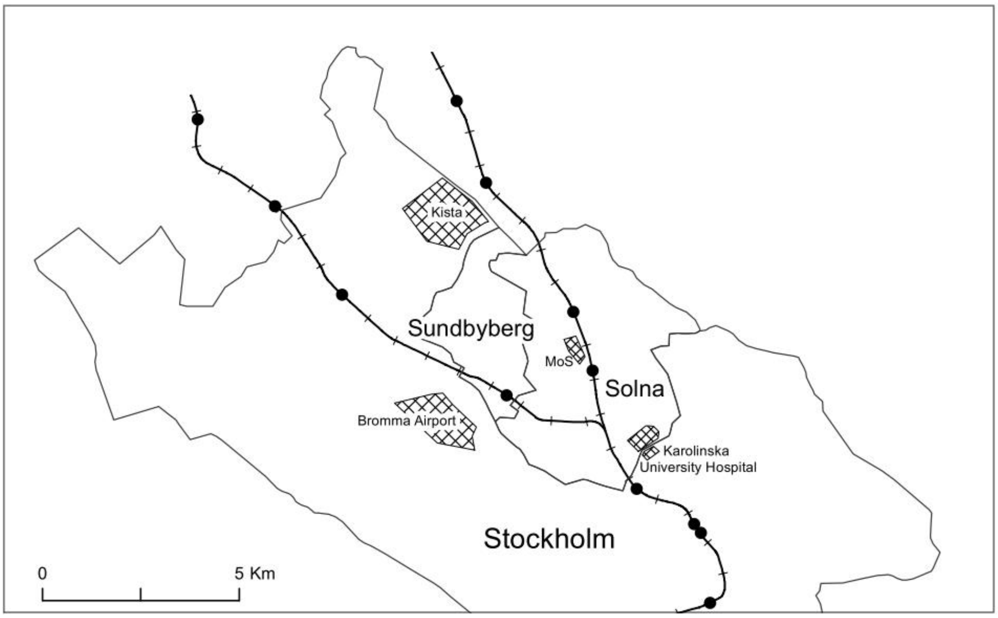

Figure 1. Map over Stockholm/Solna/Sundbyberg.

Strategic interaction might come through destinations lying close or on both sides of the border. The destinations marked out in the map are Kista ("Swedens silicon valley"), Mall of Scandinavia, Bromma Airport and Karolinska University hospital. Strategic interaction might also come from park-and-ride (the dots on the lines going through all jurisdictions are commuter train stations that might be used to avoid the congested Stockholm City area). The strategic interaction is probably more intensive in larger city districts like the Ruhr-area in Germany.

My focus is strategic competition between municipalities, but I also study the interaction between the municipalities' policies and national/regional policies. This means that I study horizontal interaction, how this horizontal interaction can be influenced by actors higher in the hierarchy and vertical interaction. Strategic competition within the transport sector might also exist between other levels of governance, for example between countries, see e.g. Mandell & Proost (2016), but these dimensions are not that relevant to parking policy.

The two main forces affecting the interaction between jurisdictions are in the literature usually referred to as resource flow and spillover. In the spillover models each individual municipality chooses the level of a policy measure, but is also affected by the outcome in nearby municipalities. In resource flow models the municipality is affected by how much of a certain mobile resource - the typical example would be some kind of tax base - which is within the municipal borders. In the case of parking policy, tax exporting might also be an important factor. Tax exporting refers to when governments try to shift the tax burden to users from other jurisdictions (without trying to make the individuals who make up the tax base move, as in resource flow).

The basis for the analysis in this article is an analytical model. The model builds on Hotelling´s linear city model originally developed in Hotelling (1929).

The remaining paper is structured as follows. Section 2 is a literature review, briefly describing the parking literature and the literature on strategic competition. In Section 3, I develop the model and use it to draw some conclusions. In Section 4, I inventory and analyze the different types of strategic interaction. Section 5 concludes.

LITERATURE REVIEW

The parking literature is concerned with parking policy within the same jurisdiction, most often a city. Mainly due to lack of data, the literature is generally theoretical. There is little written about supply of parking spaces, but there is more on pricing of parking at a given supply. The early literature (Roth, 1965) assumed that parking is generally a private good and that the market for parking as well as the markets for substitute and complementary goods is mostly free from distortions. This leads to the first best-conclusion that parking should be priced at its marginal opportunity cost. An obvious second best argument is that road congestion indicates that road traffic in cities are underpriced, meaning that parking fees should be set higher to compensate for this (Glazer and Niskanen, 1992; Verhof et al, 1995; Arnott and Inci, 2006 and 2010; Bonsall and Young 2010). Another argument for setting prices above direct marginal cost is the external effects of searching for a parking space. A common conclusion (Arnott and Rowse, 1999; Arnott and Inci, 2006) is that the price should be raised until search traffic almost ceases. Arnott and Inci (2006) show that, with reasonable assumptions about search traffic, parking fees could be raised with zero burden for the travelers (since it is exactly offset by a decrease in travel costs).

Strategic interaction between different jurisdictions when deciding on parking policy is, as far as I know, not examined before. In doing this we therefore have to turn our focus to a different strand of literature. The reasons and consequences of strategic competition between regional policy makers is often discussed in the public economics literature. An early seminal paper is Oates (1972). The theoretical models underlying most of the empirical studies can be separated into spillover models and resource-flow models (see Brueckner (2003) and Genschel & Schwarz (2011) for reviews). Below is a description of these two model types.

In the spillover models, each individual municipality chooses the level of an instrument (for example a tax) in order to influence an outcome (for example traffic emissions). The individual municipality is not only affected by the outcome in their own municipality, but also by the outcome in other nearby municipalities. Similarly, other municipalities are affected by the outcome (the traffic emissions in our example) that occurs in the municipality under study. Because each individual community only cares about the welfare of its own residents, the level of the instrument (the tax in our example) will differ compared to what would be required to maximize total welfare. In our example total welfare is maximized given an instrument that sets the cost of further emissions (the marginal cost) equal to the marginal utility - for everyone, not just residents in a given neighborhood. However, since a portion of the benefit accrues to those who are not local residents but only local residents bear the cost, the individual municipality will set the instruments at too low a level.

Resource flow models focus on an indirect relationship. In these models, the municipality is affected by how much of a certain mobile resource - the typical example would be some kind of tax base – there is within the municipal borders. By their choice of policy instrument, the individual municipalities may affect how the mobile resources choose to allocate themselves. A simple example is the choice of municipal income tax level. The municipality uses the revenue from income taxes to finance public goods. The optimal tax level is then represented by a trade-off between the willingness to pay for the public good and the cost of providing it. If the tax base is mobile, then a higher tax results in individuals reallocating. Some individuals choose to move to avoid the higher tax - they will instead contribute to the tax base of the municipality where they chose to reside. The result is thus similar to that of the spillover models; since the municipalities take the reallocation effects into account and compete for the mobile tax base the optimum tax is too low (from a total welfare perspective).

The two types of models can be described in more formal terms as follows (this description is based on Brueckner (2003)). In spillover models each jurisdiction´s objective function consists of the level of the decision variable z_i (where i is the jurisdiction), the level of the variable in other jurisdictions z_{-i} and a vector of characteristics of i X_i: $V(z_i; z_{-i};X_i)$. Maximizing the objective function by setting its derivative w.r.t. z_i to zero gives the reaction function $z_i=R(z_{-i}; X_i)$. The sign of the reaction function's slope is not given by theory except for that it will be zero if spillovers are absent. Hence, a test of the null hypothesis that the reaction function's slope is zero is effectively a test for the existence of spillovers. In resource flow models a jurisdiction is not affected directly by the z levels in other jurisdictions, but by the amount of a particular resource that resides within its borders. Because the distribution of this resource among jurisdictions is affected by the z choices of all jurisdictions, jurisdiction i is indirectly affected by z_{-i}. Jurisdiction i's objective function can be written as $V(z_i, s_i; X_i)$, where s_i is the resource level enjoyed by jurisdiction i. The distribution of resources depends on the entire z vector as well as on jurisdiction characteristics: $s_i = H(z_i, z_{-i} ; X_i)$. To derive the reduced form of the resource flow model, substitute this equation into the objective function: $V[z_i, H(zi, z_{-i}; X_i); X_i] \equiv V(z_i, z_{-i}; X_i)$. This objective function has the same form as the spillover models implying that the empirical testing is similar.

The theoretical literature on strategic competition in the transport sector is primarily based on network models. In order to derive useful economic insights without having to engage in the complexity of real-world networks, it mainly focuses on three prototypes: parallel, serial and mixed networks (De Borger and Proost, 2012). Since these types of model deals with flows on links, they are not applicable to analysis of strategic competition in the parking sector (hence my need to develop a new model).

MODEL AND ANALYSIS

Consider two adjacent municipalities, M1 and M2, who each has a number of municipally owned parking spaces. Each municipality has a given number of inhabitants that all have a preferred place to park. Parking is associated with a parking fee that is set by each municipality and is uniform throughout that municipality. Let us denote these P_{M1} and P_{M2}. For an individual *i*, there is a travel cost (not including search costs), t, associated with not parking at one's preferred place to park. I assume that the line has length 1, that M1 and M2 are at the respective ends of the line and that the preferred places to park are uniformly distributed along the line with density 1. This means that demand (the preferred places to park) is uniformly distributed along the line, but that supply (the actual places of parking) are at the ends of the line. The preferred places of parking being uniformly distributed is an unrealistic assumption, but it makes the algebra simpler without altering the conclusions. The parking spaces are homogenous; differentiation (so far) only comes from transport costs. If the preferred place to park come from work, leisure or residential parking is inconsequential for my analysis. Figure 2 below illustrates the setup.

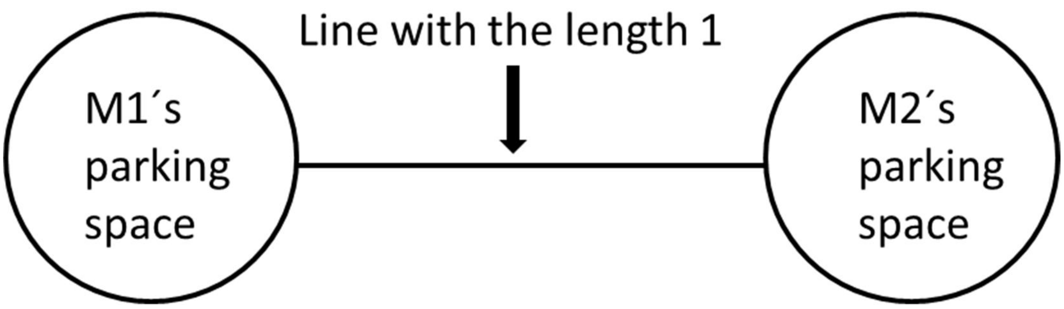

Figure 2. The basic setup

Since the length is 1, a person with a preferred parking space x has the cost tx to go to M1's parking and t(1-x) to go to M2's parking. A person who is indifferent between parking at M1 or M2, given P_{M1} and P_{M2}, is located at x = $D_1(P_{M1}, P_{M2})$. If $|P_{M1} - P_{M2}|<t$ (so that both M1 and M2 have parking customers) and the market is covered, then x is given by equating generalized costs:

$$P_{M1} + tx = P_{M2} + t(1 - x) \quad (1)$$

Demand is then given by solving for x:

$$D_1(P_{M1}, P_{M2}) = x = \frac{P_{M2} - P_{M1} + t}{2t} \quad (2)$$

$$D_2(P_{M1}, P_{M2}) = 1 - x = \frac{P_{M1} - P_{M2} + t}{2t} \quad (3)$$

The demand functions are illustrated diagrammatically in Figure 3 below.

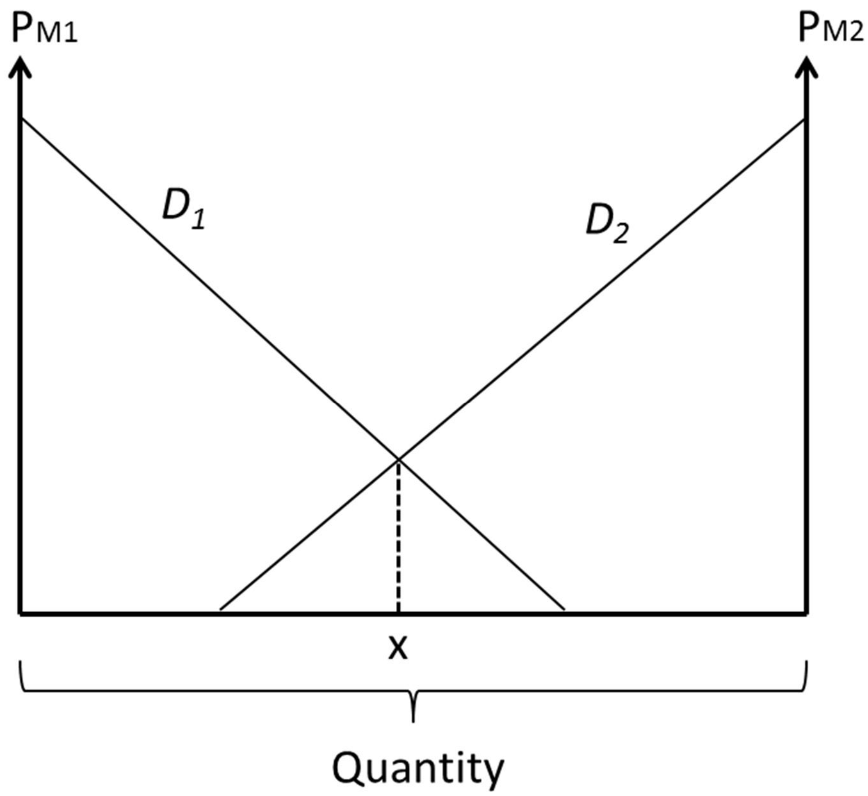

Figure 3. Illustration of demand functions

The profit for M1 is:

$$\pi_1(P_{M1}, P_{M2}) = (P_{M1} - c)(\frac{P_{M2}-P_{M1}+t}{2t}) \quad (4)$$

Where c is the unit cost (production, opportunity and maintenance) for a parking space.

Since the game is symmetrical, the profit for M2 is:

$$\pi_2(P_{M1}, P_{M2}) = (P_{M2} - c)(\frac{P_{M1}-P_{M2}+t}{2t}) \quad (5)$$

Maximizing Mi's profit given P_{Mj} gives the first order condition:

$$\pi_1 = \left(P_{M1} * P_{M2} - {P_{M1}}^2 + P_{M1} * t - c * P_{M2} + c * P_{M1} - c * t\right)/2t$$

$$\rightarrow \frac{d\pi_1}{dP_{M1}} = (P_{M2} + c + t - 2P_{M1})/2t = 0$$

$$\rightarrow P_{M2} + c + t - 2P_{M1} = 0 \qquad (6)$$

The second order conditions are satisfied (second order derivatives are negative). Using the symmetry again, we obtain the following competitive prices:

$$P_{M1} = P_{M2} = c + \mathrm{t} \qquad (7)$$

As can be seen from Equation 7 the competitive prices are above marginal cost (which is the expected result from a model that assumes imperfect competition).

My model is so far almost analogous to the schoolbook version of Hotelling's (1929) linear city model; see for example Tirole (1988). An obvious difference is that instead of customers located at different places, we have the individuals preferred parking located at different places. Another difference is that my model is linear, not quadratic.[1] To make the model suitable for parking analysis, I will now introduce three more characteristics: search traffic, elastic total demand and pollution.

[1] Hotelling's linear city model can also be used for modelling choice of location. Since I am not analyzing location (for reasons I will discuss in the next section), I am not deriving with respect to x. This enabled me to simplify by making the transport cost functions linear instead of quadratic (the resulting competitive prices in Equation 7 would have been the same with quadratic transport cost functions since the quadratic terms cancel one another out).

Since search traffic is included in the travelers' generalized costs, but appears in the parking area (not when traveling between the municipalities), we can treat it in the same way as price in our demand function. Modelling search traffic (str) in this way the formula for equating generalized costs (Equation 1) becomes:

$$P_{M1} + tx + str_1 = P_{M2} + t(1 - x) + str_2 \tag{8}$$

Solving for x means that the demand function becomes:

$$D_1(P_{M1}, P_{M2}) = x = \frac{P_{M2} - P_{M1} - str_1 + str_2 + t}{2t} \tag{9}$$

$$D_2(P_{M1}, P_{M2}) = 1 - x = \frac{P_{M1} - P_{M2} - str_2 + str_1 + t}{2t} \tag{10}$$

This means that the profit functions become:

$$\pi_1(P_{M1}, P_{M2}) = (P_{M1} - c)(\frac{P_{M2} - P_{M1} - str_1 + str_2 + t}{2t}) \tag{11}$$

$$\pi_2(P_{M1}, P_{M2}) = (P_{M2} - c)(\frac{P_{M1} - P_{M2} - str_2 + str_1 + t}{2t}) \tag{12}$$

Maximizing Mi's profit given P_{Mj} gives the new first order condition:

$$P_{Mj} + c + t - str_1 + str_2 - 2P_{Mi} = 0 \tag{13}$$

Since str_1 is not necessarily equal to str_2, the difference creates a wedge between competitive prices:

$$P_{M1} = c + t - str_1 + str_2 \tag{14}$$

$$P_{M2} = c + t - str_2 + str_1 \tag{15}$$

Equations 14 and 15 imply that prices are high where search traffic is low. The conclusion is that all else equal lower search traffic enables higher prices. In reality, parking is often more expensive in the central business district (where search traffic costs are usually high) than in the suburbs. This means that the assumption that the preferred place to park are uniformly distributed along the line is often violated. Regardless, the basic conclusion still stands: lowering search traffic means that one can charge higher prices.

Realistically, search traffic is dependent on demand, which in turn is dependent on prices:

$$str_i = f\big(D_i(P_{Mi})\big) \tag{16}$$

This means that changing prices has two effects on generalized costs: the direct effect (equal to 1, if you raise the price by one dollar, generalized cost goes up by one dollar) and the (counteracting) indirect effect through search traffic:

$$\frac{dGC_i}{dP_{Mi}} = 1 + \frac{dstr_i}{dD_i} * \frac{dD_i}{dP_{Mi}} \tag{17}$$

Depending on the situation, $\frac{dGC_i}{dP_i}$ varies between 0 and 1. $\frac{dGC_i}{dP_i}$ close to 0 is not as unrealistic as it may seem (as mentioned in Section 2 Arnott and Inci (2006) showed that it could be 0 under realistic circumstances).

So far we have assumed that the market is covered. To be able to analyze pollution spillovers we need to relax this assumption. Hence we still assume that the market is covered in the sense that all cars are parked within municipality 1 or 2, but that the amount of cars is a function of price. This means that the preferred place to park for a person who is indifferent between parking at M1 or M2, given P_{M1} and P_{M2}, is still located at x and that the length of the line is still 1. The difference is that the density is now a function of generalized cost (price, search traffic costs and transport costs). This gives:

$$D = D_1 + D_2 = f(P_{M1}, P_{M2}, str_1, str_2, t) \tag{18}$$

The partial derivative with respect to price must then be:

$$\frac{dD}{dP_{Mi}} = \frac{dD_i}{dP_{Mi}} + \frac{dP_{Mj}}{dP_{Mi}} * \frac{dD_j}{dP_{Mj}} \tag{19}$$

Equation 19 says that if one municipality raises its prices the effect on total demand consists of two parts: the direct effect and the counteracting effect that comes from the responding price raise in the other municipality. Before I had introduced elastic total demand $\frac{dD_i}{dP_{Mi}}$ plus $\frac{dD_j}{dP_{Mi}}$ added to zero ($-\frac{P_{Mi}}{2t} + \frac{P_{Mi}}{2t} = 0$, see Equations 9 and 10). Now we have that $\frac{dD_i}{dP_{Mi}} > \frac{dD_j}{dP_{Mi}}$. Higher price elasticities imply steeper demand curves and lower competitive prices. A conclusion from this is that investment in non-car modes affects parking prices, since it affects the slope of the demand curve. An investment in public transport, for example, flattens the demand curve for parking and lowers parking fees.

The size of the car park affects the amount of traffic, which affects pollution. For my purposes, it is enough to assume that pollution is a constant times D. For simplicity, I assume that the amount of pollution caused by D that burdens municipality 1 and 2 are fixed. Total pollution burden is then $Poll_1$ (the amount that burdens municipality 1) + $Poll_2$ (the amount that burdens municipality 2) + $Poll_{other}$ (the amount that burdens other municipalities, i.e. the rest of the world). $Poll_{other}$ mainly represents greenhouse gases. $Poll_1$ and $Poll_2$ represents local pollution as particles and acidification. It is important to remember that it is not the parking in itself that cause pollution, cars are (almost) not polluting when they are turned off, but the trip to the parking spot. Hence the division between $Poll_1$ $Poll_2$ is logical, even though the impact area of local pollution is often very local.

To be able to speak about how including pollution affects efficiency, one has to include how increased traffic affects tax revenue. This can be done in two ways. The first is to model the tax revenue effects, preferably also modelling the marginal cost of public funds effect (the revenues makes it possible to lower other taxes), and the pollution burden effect separately. The second way is to only put in not internalized pollution in the equation. To keep it as simple as possible I have chosen the latter, which means that pollution burden in our case refers to un-internalized pollution.

We now take the modified demand functions (9 and 10) and treat pollution the same way as production costs. This means that the profit functions become:

$$\pi_1(P_{M1}, P_{M2}) = (P_{M1} - c - \ poll_1)(\frac{P_{M2}-P_{M1}-str_1+str_2+t}{2t}) \tag{20}$$

$$\pi_2(P_{M1}, P_{M2}) = (P_{M2} - c - poll_2)(\frac{P_{M1}-P_{M2}-str_2+str_1+t}{2t}) \tag{21}$$

Note that the assumption that the amount of cars is a function of price does not change the profit functions since the demand functions are derived by solving for x (and x is still in the same place).

Including pollution means that I have extended the profit functions with welfare aspects, although they are not ‘full’ normative welfare functions since I do not include consumer surplus (including consumer surplus would mean that the model drifts too far from my purpose, i.e. to model competition between municipalities).

Maximizing M1’s profit given P_{M2} gives the new first order condition:

$$P_{M2} + c + t + poll_1 - str_1 + str_2 - 2P_{M1} = 0 \tag{22}$$

The new competitive prices are:

$$P_{M1} \ = c + t + poll_1 - str_1 + str_2 \tag{23}$$

$$P_{M2} \ = c + t + poll_2 - str_2 + str_1 \tag{24}$$

From Equations 23 and 24 we see the competitive prices now include the pollution effect, but only the part that burdens the own municipality. This means that parking is underpriced since (un-internalized) pollution spillovers are not priced.

The analysis so far has concerned pricing, for which the extended version of Hotelling's model turned out to work well. Hotelling's model can also be used for modelling choice of location for the supplier and competition based on supply. My conclusion though is that this is not appropriate for parking since supply does not behave like in Hotelling's model (where it is increased or decreased based on demand). Below, I discuss how parking supply is set and draw conclusions about the effect on prices.

Shoup (1997) shows that parking supply in the USA is set to cover demand without regarding prices. Andersson et al (2016) found support for this in Sweden as well; Swedish municipalities seem to set parking norms so that all residential parking is covered. An overview of parking norms and other parking issues in Europe is given in Cost (2005). Although there are exceptions and the juridical status of parking norms differ, the view that parking supply is set to meet the demanded quantity at a low price to meet is generally supported. Therefore, that is not a new conclusion in this article. The new conclusion is that this also implies the contrary: that prices are set disregarding opportunity costs.

The main conditions is that supply is set by the urban planning offices based on parking norms and that the norms are not set based on the cost/demand relation but on demanded quantity at a low price. This means that the costs for building parking spaces are taken by the construction firms and are embedded in the total construction costs.

Since the costs are not taken by the city, and are even hard to see for the city, the city might treat parking costs as if they are sunk with no opportunity cost. This is amplified by supply and pricing most often being handled by different parts of the cities' administrations (the urban planning department and the traffic department). Both cognitive limits and self-interest are likely to play a role. The self-interest for the traffic department is for example often to cover maintenance costs, not opportunity costs. Since administrative structures are often partly the product of evolutionary processes (Willamson, 2000), the explanation for this division must not be rational in all aspects. Hence, it is not unexpected that the outcome fails to meet neo-classical efficiency criteria'.

The implications of c being a sunk cost is easy to see in the model. If c is a sunk cost and equals zero in the profit functions (Equations 4 and 5) it also disappears from the competitive prices in 7. This means that the disconnection of supply and demand implies that competitive prices are lower than the socio economic efficient prices: as I describe in the literature review the first best parking price is equal to marginal cost, and all second best argument point at higher prices. Instead of c + t from Equation 7, where the inclusion of t means that the prices are higher than what is efficient from a socio economic perspective, we are left with only t. This might be a too radical conclusion, but it seems clear that the procedures for setting parking supply being at most vaguely connected to prices have a strong downward effect on competitive prices and that this is an explanation to why parking prices are generally much lower than the socio-economic optimal prices.

It should be noted that the basic result is the same if we instead do our analysis based on Equations 23 and 24; including both pollution and (the relative amount of) search traffic does not alter the conclusion that prices are below the efficient level (since c is still equal to zero).

Two comments should be made about my conclusion that the vague relationship between demand and supply is an explanation of the gap between actual and optimal prices that is often pointed out in the literature.

The first is that the conclusion is robust for changes in the model: it is not even necessary to model competition between municipalities to come to the conclusion that deleting opportunity costs by treating them as sunk costs lowers prices (it follows from level 1 micro economic textbooks).

The second is that public acceptance is most likely another explanation of why parking charges are so low. The early view on public acceptance was that only self-interested motives are important for acceptance, see for example Stern et al. (1993). More recent literature has lifted other aspects. One aspect is time; the acceptance of parking measures goes up after implementation (Cost, 2005), which is in line with other policy measures. Kallbekken et al. (2013) finds that public acceptance is dependent on perceived effectiveness of the tax in diminishing pollution and congestion, expected distributional effects and expected impact on out-of-pocket costs. This is in line with most recent findings; see Dresner et al (2006), Eriksson et al (2008), and Fujii et al (2004). Gaining public acceptance is a substantial challenge for parking policy instruments. Surveys in Sweden show that parking is considered by many to be a right, in contrast to a more technical view of efficient steering (Hamilton et al, 2013). Introducing prices on something that used to be free could then be perceived as losing a right. There are also indications that fuel taxes are perceived as much more effective than road pricing and parking charges in reducing both local air pollution and congestion (Kallbekken et al., 2013). Since the public debate on externalities in most countries focus on fuel tax (and possibly congestion charges), it can also be questioned whether parking fees are perceived as corrective taxes at all.

To sum up the supply discussion, I contribute with one reason for parking prices being so low, while the acceptance literature contributes with another reason.

DISCUSSION ABOUT DIFFERENT TYPES OF STRATEGIC INTERACTION

To make sure all types of strategic interacting are covered, I inventoried them using a matrix the dimensions' effect type and hierarchal level.

	Spillover effects	Resource flow effects
Municipality	*A1*	*B1*
Regional government	*A2*	*B2*
National government	*A3*	*B3*

Figure 1. Structure of the inventory scheme

In the first row we find the pure spillover and resource-flow cases that concern interaction between two agents on the same hierarchical level. In the bottom two rows we find cases where a municipality's parking policies are influenced by - and influence - policy on areas that are controlled by agents on a higher hierarchical level. The box in which a case is placed does not say anything about the direction of the effect, only which parts are affected. I have found that separating national and regional governments is purposeful for the inventory process, but that presenting the analysis in that way is confusing for some since the division differs between countries. Hence national and regional are combined below. The results of the inventory and the analysis for each type of strategic interaction is given below.

Municipality/municipality spillover effects (A1)

A common quest in the strategic competition literature is to analyze the effect of one jurisdiction paying for infrastructure that others also use, but since parking spaces are priced (in my model even competitively priced) these benefit spillovers are not relevant. On the other hand, pollution spillovers might be important.

From Equations 23 and 24 we have that the competitive price only includes $Poll_1$ (the part of the pollution from municipality 1 that burdens municipality 1). Hence we reach the classical conclusion that not caring about the pollution spillovers to other municipalities leads to inefficiently low prices. The effect is partially dependent on total demand being a function of price (Equation 18), if not the effect would be smaller since the non-priced effect would have only been the pollution that burdens the other municipality.

The socio-economic damage of this spillover effect is highest in densely populated areas, since traffic is generally more underpriced there. In the absence of congestion charges, traffic in urban and rural areas is priced the same, even though the disutility of pollution is much higher in urban areas since more people are affected.

Municipality/municipality resource flow effects (B1)

There is a resource flow effect in that municipalities compete for parking revenue. It could be argued that this is more tax exporting than resource flow since the municipalities are not trying to make the travelers move, but I will stick with resource flow since the competition is about parking fees (not income taxes). Tax exporting in parking occurs when residents and non-residents are charged different fees, for example using residential parking discounts.

The result of the resource flow competition is that the competitive prices are higher than the socio economic efficient prices since the inclusion of transport costs means that prices exceed marginal cost (see Equation 7). However, the reasoning in Section 5 about marginal cost not being included in prices makes this effect incongruous.

Resource flow competition also means that lowering transport costs has the positive side effect that parking prices approaches first best optimum. This holds as long as transport costs do not reach zero and we reach the Bertrand solution where the price is zero (Bertrand, 1883), but that seems unrealistic.

Tax exporting by differentiating prices through residential parking discounts is very common. This behavior has harmful welfare effects, which can be shown by a normative welfare model. The high frequency of residential parking discounts can be explained in two ways: by political economic models where the decision makers only care about voters from their own jurisdiction and by public acceptance studies where parking is considered to be a right.

From earlier literature, e.g., Mintz & Tulkens (1986), we know that the tax setting behavior of governments depends on the relative sizes of the countries. Smaller countries gain more by undercutting their neighbors than larger countries. The reason is that the small country may capture a large foreign tax base while the domestic inefficiency (due to an inefficiently low tax level) is relatively small. If we apply this insight on the case of municipalities' parking policies it means that large municipalities are less likely to engage in competitive behavior resulting in inefficient parking fees, as they have less to gain and also have a large base of residents that would suffer from such behavior, as compared to smaller municipalities.

Municipality/regional and national government spillover effects (A2, A3)

The connection here is public transport and national infrastructure. Regional investments in public transport influence both the travel costs and the demand for parking, and vice versa the supply of park and ride influences the demand for public transport and national infrastructure. Tax exporting is common for park and ride (people from other municipalities are often charged more), which may affect the benefits achieved due to national infrastructure.

Investments in public transport lowers both transport costs (t) and parking demand (D). Lowering transport costs lowers parking prices in the same way as in 6.2 above, but the effect on demand is specific for non-car modes. With two effects pointing in the same direction, the effect is clear-cut. The situation is the opposite for national road investments where one must use a network model and car ownership model since there are two counteracting effects (t down, D up).

Since park and ride primarily benefits travelers from other municipalities the providing municipality has low incentives to provide. Parkhurst and Meek (2014) find that only a portion of park and ride users car trips are shortened. My conclusion from this is that the main problem with under-provision of park and ride is not environmental but that the full benefits of the public transport investments are not attained. Park and ride is also an important example of tax exporting through diversification, which, as discussed above, lowers welfare. Danderyd, a wealthy municipality just north of Stockholm, is a good example. There, several park-and-ride areas are reserved for Danderyd's residents only. Even if this policy makes good sense from the point of view of the politicians and voters in Danderyd, the total welfare effects of this practice seems to be substantially negative.

Municipality/regional and national government resource flow effects (B2, B3)

There is resource flow competition between parking fees and congestion charges/fuel tax since parking fees provide revenue to the municipality while congestion charges and fuel tax provide revenue to the regional/national government. In some cases the revenues from congestion charges goes directly to the municipality. That would mean that congestion charges affect municipality-municipality resource flow competition (Box B1), but I have chosen to focus on the case where the revenue goes to national or regional governments.

A reason for resource flow competition between parking fees and congestion charges/fuel tax since parking fees provide revenues to the municipality while congestion charges and fuel tax provide revenues to the regional/national government. The congestion charges/parking fees competition is most likely higher than fuel tax/parking fees since the fuel tax cannot be geographically differentiated.

However, raising congestion charges has two effects on parking revenues: they lower demand (which decreases parking revenue) and raise transport costs (which increases parking revenues, see Equations 23 and 24). Hence, as with national road investments, the effect needs to be calculated empirically. A reasonable conclusion is that the resource flow connection is not as clear-cut as it might seem at first (i.e. two governmental bodies competing for a tax base).

I introduced search traffic in the model to make it more realistic and to show the connection between supply and generalized travel costs. The inclusion of search traffic did not alter our earlier conclusions, which is comforting from a model perspective, but it does not really help us explain the resource flow connection between congestion charges and parking fees. To explain this one needs to incorporate congestion in the profit function (not only the search traffic part) and make the profit function normative or political economic. Assuming that there is congestion and that the policymaker perceives this as a problem one can raise/implement either congestion charges or parking fees. Congestion charges has been given more attention in the literature, but Calthrop et al (2000) showed in a numerical simulation that second-best pricing of all parking spaces produces higher welfare gains than the use of a single-ring cordoning scheme. When the relative effectiveness is discussed in the literature, the perspective is often that one has to choose (in which case the impact on which governmental body gets the money is obvious), but even if both are implemented the socially efficient parking fees are not as high as without congestion charges (which means that the impact on the municipalities' revenues is still clear-cut).

CONCLUSIONS

Parking is most often the only local pricing instrument that is used. Since the transport system crosses municipal borders the municipalities parking decisions must take other municipalities policies into account. Since regional and national governments also impose policy measures there is also vertical interaction. The main aim of this paper is to study these horizontal and vertical interactions. To do this I first use a matrix to inventory relevant spillover and resource flow effects. I then developed a model based one Hotelling's linear city model to analyze them. As far as I know both the inventory matrix-approach and the linear city based approach are new for parking. The inventory matrix could be used in lots of other contexts, while the linear city model on the contrary is already used in lots of other contexts but not in parking. The reason it, as far as I know, has not been used in parking before is that the parking literature focuses on issues within the same jurisdiction.

I find that the supply side is not feasible to study with a linear city model. The procedures for setting supply has been examined in for example Andersson et al (2016) and Shoup (1997). In this paper, I examine its effect on prices and conclude that the procedure for setting supply in most municipalities is likely to have a strong downward effect on prices. The reason is that the process is likely to make them sunk, which eliminates marginal cost from the pricing equation. The effect is that parking prices are lower than what the literature suggests is optimal (first best parking price is equal to marginal cost, all second best arguments point at higher prices). This means that the effect on prices constitutes a further disadvantage of parking norms. One of the main theoretical arguments for parking norms is that street parking is underpriced, implying that constructors (if not forced to build parking spaces) will want their resident to park on the streets causing excess demand. That parking norms in itself contributes to underpricing implies that this argument suffers from circularity.

Resource flow competition between municipalities implies that the competitive prices are higher than the efficient prices and that improving transport has the positive side effect that parking prices approaches first best socio economic optimum. However, judging from the above, the parking prices are most likely lower than optimal which makes this effect incongruous.

Since parking spaces are priced, benefit spillovers are not relevant. For pollution spillovers I reach the classical conclusion that not caring about them leads to inefficiently low prices, especially when total demand is elastic.

Since park and ride often primarily benefits travelers from other municipalities, it is likely to be under provided for. Park and ride does not shorten car trips much, which means that the main problem with the under provision is not the environmental effect. The main problem is instead that the full benefits of the public transport investments are not attained.

There is resource flow competition between congestion charges and parking fees, but since raising congestion charges has two contradicting effects (higher transport cost, lower demand) on parking revenue it is not as straightforward as one might think. It requires that the decision maker perceives congestion as a problem that needs to be addressed, but it does not require the decision maker to choose either parking fees or congestion charges since the efficient parking fees go down when congestion charges are implemented.

REFERENCES

Andersson, M., Mandell, S., Braun Thörn, H. & Gomér, Y. (2016) "The effect of minimum parking requirements on the housing stock", *Transport Policy* 49, 206–215.

Arnott, R. & Inci, E. (2010) "The stability of downtown parking and traffic Congestion", *Journal of Urban Economics*, 68(3), 260–276.

Arnott, R. & Rowse, J. (1999) "Modeling parking", *Journal of Urban Economics*, 45(1), 97–124.

Arnott, R. & Rowse, J. (1999) "Curbside parking time limits", *Transportation Research Part A*, 55, 89-110.

Bertrand, J. (1883) "Review of Theorie mathematique de la richesse sociale and of Recherches sur les principles mathematiques de la theorie des richesses", *Journal des Savants,* 67, 499–508.

Bonsall, P. & Young, W. (2010) "Is there a case for replacing parking charges by road user charges", *Transport policy*, 17(5), 323–334.

Brennan, G. & Buchanan, J. M. (1980) "The Power to Tax: Analytical Foundations of a Fiscal Constitution", Cambridge: Cambridge University Press.

Brueckner, J. K. (2003) "Strategic interaction among governments: An overview of empirical studies", *International regional science review*, 26(2), 175-188.

Calthrop, E., Proost, S. & van Dender, K. (2000) "Parking Policies and Road Pricing", *Urban Studies*, 37(1), 63-76.

COST Action 342 (2005) "Parking Policies and the Effects on Economy and Mobility", Report on COST Action 342.

De Borger, B. & Proost, S. (2012) "Transport policy competition between governments: A selective survey of the literature", *Economics of Transportation* 1, 35–48.

Dresner, S., Dunne, L., Clinch, P., Beuermann, C., (2006) "Social and political responses to ecological tax reform in Europe: an introduction to the special issue", *Energy Policy* 34, 895–904.

Eriksson, L., Garvill, J. & Nordlund, A.M., (2008). "Acceptability of single and combined transport policy measures: the importance of environmental and policy specific beliefs", *Transportation Research Part A,* 42, 1117–1128.

Fujii, S., Gärling, T., Jakobsson, C. & Jou, R.-C. (2004) "A cross-country study of fairness and infringement on freedom as determinants of car owners' acceptance of road pricing", *Transportation* 31, 285–295.

Genschel, P. & Schwarz, P. (2011) "Tax competition: a literature review", *Socio-Economic Review*, 9(2), 339-370.

Glazer, A. & Niskanen, E. (1992) "Parking fees and congestion", *Regional Science and Urban Economics,* 22(1), 123–132.

Hamilton, C. & Braun Thörn, H. (2013) "Parkering som styrmedel för en Fossilfri fordonstrafik", Centre for Transport Studies Report.

Hotelling, H. (1929) "Stability in Competition", *Economic Journal*, 39 (153), 41–57.

Hotelling, H (1938) "The general welfare in relation to problems of taxation and of railway and utility rates", *Econometrica*. 6 (3), 242–269.

Kallbekken, S., Garcia, J. H. & Korneliussen, K. (2013) "Determinants of public support for transport taxes", *Transportation Research Part A*, 58, 67-78.

Mandell, S. & Proost, S. (2016) "Why truck distance taxes are contagious and drive fuel taxes to the bottom", *Journal of Urban Economics* 93, 1–17.

Mintz, J. & H. Tulkens (1986) "Commodity taxation between member states of a federation: equilibrium and efficiency", *Journal of Public Economics* 29, 173-197.

Oates, W. E. (1972) "Fiscal federalism", Harcourt Brace Jovanovich, New York

Oates, W. E. (2005) "Toward A Second-Generation Theory of Fiscal Federalism", *International Tax and Public Finance*, 12, 349–373.

Parkhurst, G. & Meek, S (2014) “The Effectiveness of Park-and-Ride as a Policy Measure for More Sustainable Mobility” , in Stephen Ison , Corinne Mulley (ed.) *Parking Issues and Policies (Transport and Sustainability, Volume 5)* Emerald Group Publishing Limited, 185 – 211.

Roth, G.J. (1965) “Paying for Parking”. http://trid.trb.org.

Shoup, D. C. (1997) “The High Cost of Free Parking”, The University of California Transportation Center UCTC No. 351.

Stern, P.C., Dietz, T. & Kalof, L. (1993) “Value orientations, gender, and environmental concern”, *Environment and Behavior* 25, 322–348.

Tirole, J. (1988) “The Theory of Industrial Organization”, MIT Press.

Verhoef, E., Nijkamp, P. & Rietveld, P. (1995) “The economics of regulatory parking policies: the (im)possibilities of parking policies in traffic regulation”, *Transportation Research Part A,* 29(2), 141–156.

Williamson, O. E. (2000) “The New Institutional Economics: Taking Stock, Looking Ahead”, *Journal of Economic Literature*, Volume 38, No. 3, 595-613.