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Garage and curbside parking competition with search congestion☆

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ABSTRACT

We consider a parking market with privately operated parking garages, publicly operated curbside parking, and drivers who differ in parking duration. In equilibrium, long-term and short-term parkers can allocate themselves to garages and curbside parking in various ways. The equilibrium is generally inefficient because garage operators exercise market power, and drivers have to search for curbside parking which creates a search cost externality. A city planner can achieve the social optimum without regulating garage prices if it can charge differentiated curbside parking fees. Many cities still have parking meters that can only levy uniform fees, and it is very costly to replace them. However, numerical results show that the efficiency loss due to uniform pricing is modest in most cases.

1. Introduction

Downtown parking markets can be rather complex. Parking is often available both on and off the street. Parking garages provide bulk capacity at discrete locations and can extend over multiple storeys above or below ground. The friction of space gives them market power. Curbside parking, on the other hand, is located more widely but it is frequently in short supply and difficult to find. According to some estimates, cruising for parking accounts for roughly 30% of traffic at certain times of day (Shoup, 2005, 2006). Time spent searching for parking increases the full price or generalized cost of curbside parking and limits the degree to which curbside parking constrains garages' market power.

Garage and curbside parking differ in how they are priced. Garages generally cater to drivers who park for different lengths of time, and they usually charge hourly parking fees that vary with parking duration. Curbside parking is typically priced at a uniform hourly rate in North American cities where conventional parking meters are used. However, nonlinear pricing is sometimes practiced in cities where labor is relatively cheap. For example, in Istanbul, employees collect parking fees using hand terminal technology and the hourly fees vary by parking duration. Finally, administration arrangements vary. Curbside parking is publicly operated in most cities whereas garage parking can be publicly or privately operated and/or regulated. For example, some Dutch cities such as Maastricht and Almere regulate garage parking fees, while garages in London and Boston are free to choose their prices.

In this paper, we study downtown parking markets in which spatial competition between garage and curbside parking, nonlinear pricing, and curbside parking search congestion are simultaneously at play. To facilitate analysis, the model is kept simple by treating total parking demand as fixed, ignoring through traffic congestion, and considering only two types of individuals that differ in the amount of time they wish to park. Nevertheless, curbside parking search congestion creates an interdependence between parking submarkets and nonconvexities in garages' profits, and the derivation of market equilibria in this setting is new to the spatial competition literature. In such an environment, we attempt to answer some questions about downtown parking markets: How does competition between parking garages play out when

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curbside parking is available as a substitute? How can garage parking fee schedules be explained? How should curbside parking fees be set to control cruising congestion and parking garage market power? Is a uniform hourly fee optimal, or should hourly fees be varied with parking duration? Is regulation of garage parking necessary to achieve a social optimum, or can curbside parking fees do the job?

Several strands of literature cover part of the ground required to address these questions (see Arnott, 2011 and Inci, 2015, for comprehensive literature reviews). Some studies consider curbside parking in isolation (Arnott and Inci, 2006, 2010). Others incorporate garage parking but omit heterogeneity with respect to parking durations (Arnott and Rowse, 2009; Arnott et al., 2015). Parking duration is considered by Glazer and Niskanen (1992) and Calthrop and Proost (2006), and parking time limits by Arnott and Rowse (2013). Spatial competition between parking garages has been studied (Arnott and Rowse, 1999, 2009; Anderson and de Palma, 2004, 2007; Calthrop and Proost, 2006) but without including price discrimination. Yet other studies analyze parking and pricing of parking when traffic congestion occurs at a bottleneck (Arnott et al., 1991; Zhang et al., 2005; Fosgerau and de Palma, 2013). Shoup (2005, 2006), Arnott and Inci (2006, 2010), and Arnott et al. (2015) emphasize the importance of curbside parking search congestion externalities in downtown districts, and van Ommeren et al. (2011) and van Ommeren et al. (2012) estimate the externalities empirically. Perhaps the most thorough analysis of parking market competition to date is by Arnott (2006), who analyzes spatial competition between parking garages in his core model, which he later enriches to include curbside parking. However, he assumes that drivers are identical and he does not consider price discrimination.

Understanding the effects of driver heterogeneity and price discrimination on downtown parking markets is important. It highlights the market power of parking garages that should be considered in designing optimal parking policy. For example, a parking garage may increase the parking fee it charges to short-term parkers, some of who will then park on the curb and increase curbside parking search congestion. This in turn increases demand from long-term parkers for parking in the garage, which allows the garage to charge a higher fee to them. Such effects cannot be studied in models with identical drivers and no price discrimination. Another important insight is that if parking garages price discriminate according to parking duration, it is welfare-enhancing to differentiate curbside parking fees as well.[2] Indeed, in our model the social optimum can be achieved without any regulation of garage parking fees by differentiating curbside parking fees.

Spatial competition and price discrimination have been extensively studied in the industrial organization literature (see Gabszewicz and Thisse, 1986, Varian, 1989, and Stole, 2007, for literature reviews). Spatial competition models such as Salop's (1979) allow for the possibility that some potential customers choose not to buy a product or service from any firm, but select an outside option instead. These models can be adapted to the downtown parking market by treating parking garages as firms offering services that differ by location, and curbside parking as an outside option that is ubiquitous. The standard models typically assume that utility from the outside option is exogenous. However, in the parking market, expected utility from curbside parking decreases with the number of individuals who use it because of search congestion. Our setting is unique in incorporating such an endogenous outside option into a Salop-type model.

A few empirical studies of competition in parking markets have recently appeared. Kobus et al. (2013) examine the effects of parking fees on drivers' choices between curbside and garage parking. Froeb et al. (2003), Choné and Linnemer (2012), and De Nijs (2012) focus on the effects of mergers in the parking industry. Lin and Wang (forthcoming) examine the relationship between competition and price discrimination. Several general lessons emerge from these studies which inspired the general structure of our model. First, hourly garage parking fees generally decline steeply with parking duration. Put another way, total payment or outlay is an increasing but steeply curved concave function of parking duration. Second, the degree of curvature in the outlay curve declines with increased competition. Third, the (short-run) marginal supply cost of parking is close to zero for garages. Fourth, drivers are reluctant to walk more than a few blocks from a parking garage to their destination.

The paper is organized as follows. Section 2 describes the model. Section 3 characterizes various possible equilibrium allocations of driver types between garage and curbside parking. Section 4 derives the socially optimal allocation of driver types between garage and curbside parking space and shows how the allocation can be decentralized using differentiated hourly curbside parking fees. Section 5 uses a numerical example to illustrate how the welfare gains from implementing optimal differentiated fees depend on such parameters as the distance between parking garages, parking search costs, and walking time costs. Section 5 also assesses the relative efficiency of setting optimal uniform curbside fees. Section 6 discusses extensions, and Section 7 concludes. An (online) appendix provides derivations of the various equilibria, and technical and computational details.

2. The model

Consider a fixed set of individuals (henceforth drivers) who travel to a downtown area by car. Drivers differ in their destinations and lengths of stay. A *long-term parker* (denoted by L) requires parking for l_L hours, while a *short-term parker* (denoted by S) requires parking for l_S hours, where $l_S < l_L$.[3] A type i driver, $i = L, S$, receives a benefit of B_i from a trip. The B_is are large enough that all potential trips are made, and total parking demand is therefore price inelastic.

Each driver has a given trip destination. Destinations are uniformly distributed around a circle with densities d_L for long-term parkers and d_S for short-term parkers. Demand for parking by type i drivers in hours per unit distance is $h_i \equiv d_i l_i$. Parking is available at parking garages and on the curb.[4] Curbside parking is operated publicly and distributed continuously around the circle. Parking garages have fixed locations a distance D apart. Each garage is operated by a separate private firm. Garage parking space is lumpy because of scale economies in garage capacity (Arnott, 2006).[5]

Curbside parking in many cities is priced at a constant fee per hour. However, to allow for price discrimination and the use of curbside parking fees to enhance market efficiency, it is assumed that curbside parking fees can differ, with type i drivers paying an hourly fee of p_{ci}, $i = L, S$. Short-term parkers, therefore, pay $p_{cS} l_S$ to park for l_S hours, and long-term parkers pay $p_{cL} l_L$ to park for l_L hours. Depending on how parking fees are levied and enforced, incentive compatibility constraints may apply. If $p_{cS} < p_{cL}$, a long-term parker might be able to

[2] Although parking meters in many North American cities can only charge uniform fees, the practice of not charging for parking in the evening introduces an element of second-degree price discrimination. Time limits on parking are common in other countries. However, varying curbside parking rates in hourly increments according to duration of stay is very rare.

[3] One interpretation is that long-term parkers are commuters and short-term parkers are making business trips. Another is that long-term parkers are multipurpose or comparison shoppers who shop for an extended period of time, whereas short-term parkers are one-stop shoppers who need to park for a shorter time.

[4] Parking is sometimes also available at surface lots. Surface lots are typically built as transitory uses of land after buildings are torn down and therefore offer only temporary additional space to park. Surface lots are similar to garages in that they do not contribute appreciably to search congestion. In our model setting, lots can be treated as equivalent to garages. There are also parking spaces supplied by businesses to employees (van Ommeren and Wentink, 2012) and customers (Hasker and Inci, 2014), which we ignore. Their presence lowers garages' local market power.

[5] We abstract from safety issues in different parking forms. In some countries, a lot of crime is committed in parking garages. According to the Bureau of Justice Statistics, more than 1 in 10 property crimes occurred in parking lots or garages between 2004 and 2008 in the US. In Istanbul, cars parked on the curb have a higher risk of burglary or damage due to accidents than cars parked in garages.