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A review of the economics of parking

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ABSTRACT

This paper reviews the literature on parking with an emphasis on economic issues. Parking is not just one of the most important intermediate goods in the economy; it is also a vast use of land. Many theoretical and empirical papers analyze the quantity and pricing of parking by concentrating on particular aspects of the issue. The aspects covered in this review are cruising for parking, spatial competition, (minimum and maximum) parking requirements, parking pricing and road pricing in the bottleneck model, and temporal-spatial pricing. Various forms of parking, including residential parking, shopping mall parking, and employer-provided parking, are also reviewed before identifying under-studied topics that should be on the research agenda.

1. Introduction

Economists come up with ideas to deal with imperfect markets, but the market for ideas in economics can be as imperfect as any other market. What is believed to be of general interest to economists is sometimes not important in real-world transactions; and what can have a great impact on the welfare of the many does not always attract the level of attention it deserves. The economics of parking is an example of the latter imperfection. Few economists devote full-time effort to analyzing parking markets, even though the economics of parking has a lot to say about how to improve the quality of urban life. There is also a dearth of parking studies in transportation science, transportation engineering, and urban planning. Despite the facts that cars are parked 95% of the time (Shoup, 2005b, p. 624) and that vast amounts of land are used for parking (Jakle and Sculle, 2004), more ink has been spilled trying to deal with the problems caused by cars when they are in motion than when they are parked. In fact, cars create perhaps less visible but equally serious problems when parked, as Shoup (2005b, p. 625) points out in his landmark book *The High Cost of Free Parking*.

Most transportation activities are initiated by getting into a parked vehicle and terminated by parking it again. This makes parking one of the most important intermediate goods in the modern market economy, after money and credit cards (Hasker and Inci, 2014). Realizing this should be sufficient to help us understand why an economic analysis of parking is vitally important. As Arnott and Inci (2006) state, early work on the problem treated parking only as a cost added on at the end of a trip, which, as a fixed cost, does not really affect decisions at the margin. Later work on the pricing of parking, however, has repeatedly shown that this approximation limits generality (see, *e.g.*, Glazer and Niskanen, 1992; Anderson and de Palma, 2004, 2007; Arnott and Inci, 2006, 2010). In addition to being an important intermediate good, parking is also a major use of land in any country, city, or town. All vehicles, whether parked or in traffic, occupy space. It is eye-opening to visualize the total amount of land that is taken up by parking. In the United States, it is at least as large as the total land area of the state of Massachusetts, and in Europe, it is at least one-half of the entire land area of Belgium. Now consider how the mispricing of parking can distort land use, car usage, and the pricing of other goods.

Only 79 years have passed since a driver fed a parking meter for the first time.[1] This review aims to increase awareness about the high potential for work on parking to immediately improve city-dwellers' welfare.[2] The existing work in economics, transportation science, transportation engineering, and urban planning looks at parking from various angles. In this review, I concentrate only on its *economic* aspects. These aspects address mainly the issues

[1] The first parking meter was installed in Oklahoma City on July 16, 1935. The original motivation of Carl Magee, the inventor of the parking meter, was to encourage parking turnover, not to collect revenue.

[2] Arnott (2011) provides another discussion of the economics of parking in which he lists some empirical regularities and briefly reviews the existing literature. He also applies the standard transportation microeconomic theory to parking and touches on selected issues in parking policy, one of which is parking freeze (*i.e.*, maintaining the supply of parking at the same level as it were prior to a specified date), which I do not cover in this review. Other than that, I provide a more extensive and recent literature review.

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related to the *quantity* and *price* of parking. Various distortions in the parking market need to be taken into account to determine optimal parking quantity and price. These distortions naturally determine the scope of this review.

If curbside (*i.e.*, on-street) parking demand exceeds curbside parking supply, some drivers cannot immediately find a vacant parking space; thus cruising for parking will emerge, which imposes external costs on all drivers by increasing congestion. Section 2 reviews the papers that analyze this important phenomenon. Another distortion is the parking garages' market power, which stems from the fact that they are discretely spaced throughout the city. Section 3 reviews the papers focusing on spatial competition in the parking market and parking garages' exercise of market power. In most cities, zoning regulations specify how much parking has to be supplied by each land use. Because these regulations are usually adopted *ad hoc* from city to city, they significantly distort parking supply and thus land use. Section 4 reviews the papers on such zoning regulations. Yet another source of distortion is underpriced (in fact, for most cities, unpriced) congestion. Section 5 reviews the literature linking parking prices to road prices by embedding parking into bottleneck models. Vickrey's (1954) wisdom was to charge different parking prices across time and space, which was less feasible given the technology of that time. Today we see a general movement toward such temporal-spatial pricing. Section 6 outlines the efforts in that direction. Underpriced parking is particularly an issue for some special forms of parking. Employers often provide parking to employees at no cost, shopping malls typically provide parking to their customers for free, and cities provide parking to residents at nominal prices lower than market prices. Section 7 briefly reviews the work on these parking forms. Section 8 identifies some under-researched topics.

2. Cruising for parking

One of the most studied topics in the economics of parking is the phenomenon of cruising for parking, which is a typical example of the tragedy of the commons. Parking spaces are overdemanded if they are underpriced (or free), and no one cares about his contribution to others' travel time while cruising for parking slowly around the block. Shoup (2005b, Ch. 14) recites from his field study in the 1980s that drivers lose about 100,000 hours (over 11 years) while cruising for parking in a given year on a 15-block business district near the UCLA campus. Shoup (2006) reports the findings of 16 different studies done between 1927 and 2001 in congested downtown areas from around the world. According to these studies, between 8 and 74 (on average 30) percent of all cars in traffic are cruising for parking, and they spend between 3.5 and 14 (on average 8.1) minutes on that activity. Cruising for parking is an inefficient transport activity. Cars slow down traffic while they are cruising for parking and thus contribute to traffic congestion disproportionately more than cars in transit. Cars cruising for parking increase fuel consumption and contribute to air pollution via carbon emissions. They may even increase the probability of traffic accidents. How to decrease cruising for parking has been at the top of the agenda in the literature.

Researchers have constructed a series of parking models to analyze the economic effects of cruising for parking. It is in fact a search externality. If there are no available parking spots near a driver's destination, he will search for one. There are many ways to search for a parking spot.[3] However the driver searches, this activity involves at least some time costs. Search time is an increasing function of how many others are searching and how long they park (see, *e.g.*, Glazer and Niskanen, 1992; Inci and Lindsey, 2014). The presence of cruising for parking shows that drivers' willingness to pay exceeds the price of parking; thus a standard rationing problem arises, which may result in substantial welfare losses. The drivers cruising for parking usually drive more slowly than cars in transit; thus they slow down traffic, which imposes external costs on all drivers. Any efficient parking pricing scheme should internalize this externality.

Arnott and Inci (2006) developed the first "bathtub model"[4] of downtown parking, via which they analyze the effects of cruising on traffic and provide parking pricing recommendations to remedy the problems it causes. They envisage a spatially homogeneous downtown area, which simplifies the analysis by making the density of traffic uniform over the space. One can imagine a grid network of streets like that of Manhattan. Curbside parking is the only option and drivers are identical. A driver enters the downtown area, drives to his destination, and immediately parks there if there is an empty parking spot. If there are no empty parking spots, he cruises around the destination block until he finds one.

In this bathtub model, there are three pools at any time. Arnott and Inci (2006) analyze the steady state of the model. Cars first enter into the pool of cars in transit, represented by T per unit area, by driving to their destinations. The inflow rate into the in-transit travel pool is given by demand function D per unit area. Because the in-transit trip length is m and the travel time per mile is t, the outflow rate from the in-transit travel pool is T/mt. Those who exit the in-transit travel pool enter into the pool of cars cruising for parking, represented by C per unit area. Thus, the outflow rate from the in-transit pool is also the inflow rate into the pool of cars cruising for parking. Because there are P parking spaces per unit area and each car parks for a fixed visit of l hours, the exit rate from the pool of cars cruising for parking is P/l. Finally, cars exiting the pool of cars cruising for parking find a parking spot and thus enter the pool of parked cars. They stay in the parking space for l hours and then exit the downtown area. The exit rate per unit area is also P/l.

Demand D is a function of expected full price of a trip F, which equals in-transit travel time costs, given by ρmt, where ρ is the value of time, plus cruising-for-parking time costs, given by $\rho(Cl/P)$, plus the total parking fee, given by fl, where f is the hourly parking fee:

$$F = \rho mt + \rho\frac{Cl}{P} + fl. \tag{1}$$

In-transit travel time per mile, t – in other words the congestion function – depends on the number of cars in transit per unit area, T, the number of cars cruising for parking per unit area, C, and the number of parking spaces per unit area, P: $t = t(T, C, P)$. It is assumed

[3] One may drive around the destination block until a parking spot becomes available; one may drive farther away from the destination to locations where the parking demand is relatively lower and then walk to his destination; one may even wait at the destination until someone leaves a nearby parking spot. Guo et al.

(footnote continued)
(2013) analyze the parking search behavior from a behavioral economics perspective. They compare the performance of a static game-theoretical model where drivers are completely rational with that of a model with rational and irrational types in terms of parking search behavior. In particular, they take into account optimistic and pessimistic behavior in parking search. They calibrate their model by using a genetic algorithm on video observations from some parking lots on a university campus and use this model to predict behavior on other parking lots. It turns out that the behavioral model performs more accurately than the rational game-theoretical model. There is also an extensive operations research literature on parking search (see, *e.g.*, Teodorovic and Lucic, 2006 and the references therein).

[4] See Arnott (2013) for a description of bathtub models. The "bathtub" analogy was coined by William Vickrey in an unpublished draft found after his death. Inspired by the hydrodynamic models, cars entering the traffic network are modeled as water flowing into a bathtub, cars exiting from it as water flowing out of a bathtub, and the density as the height of the water in the bathtub.