UNIVERSITAT DE BARCELONA

The Economics of Parking: Essays on Regulation, Competition and Information Frictions

Albert Gragera

PhD in Economics

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PhD student:
Albert Gragera

Advisor:
Daniel Albalate

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A Carol, Gerard i Guillem

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Contents

1 Introduction

1.1 Motivation

Most cities face traffic related externalities (notably, congestion and pollution) that give rise to serious economic and environmental problems. The welfare impact of congestion has been reported to be as high as two per cent of national GDP in some countries (OECD, 2007); while the health costs of air contamination attributable to road transport in the OECD member states have been estimated at about $0.85 trillion per year (OECD, 2014). These externalities have seen the adoption of travel demand management (TDM) initiatives by public authorities seeking to establish the necessary incentives to rationalize the use of cars in urban areas. Among these initiatives, parking regulations have been broadly adopted given their relatively low implementation costs, comparatively better public acceptance (when compared with road pricing) and the fact that they can be directly controlled by the local authorities (Ison, 2014). Parking regulations consist of many regulatory tools, including the supply of parking spaces and their spatial distribution, parking time limits, parking fees, residential parking permits, dedicated parking spaces and the level of enforcement, all of which impact car travel costs and affect many dimensions of travelers' behavior. In the short run, such regulations can result in travelers changing their destination, cancelling or modifying their activities, altering the trip time or switching modes of transport (Shiftan, 2002); but in the long run it can also affect car ownership and residence/job location (Guo, 2012 and 2013).

The importance of parking for cities, the economy and the environment is largely underrated. Considerable attention has been paid to the problems generated by cars when they are in motion, yet vehicles are usually stationary 95% of the time, which imposes a major demand on land use and generates other inefficiencies that are equally relevant (Shoup, 2005). After all, every car journey begins and finishes with a parked vehicle, which makes parking and the search for a parking space a key element of a driver's behavior. It also means that parking is one of the most relevant intermediate goods in the economy (Hasker and Inci, 2014). Thus, distortions in the parking market not only have

an impact on the transportation sector and its associated externalities, they also impact land use and the price of almost every other good.

Parking is a private good (rivalrous and excludable). Yet, public provision is often justified on the grounds that "sufficient" parking has to be provided in order not to serve as a disincentive to trips to Central Business Districts (CBD) – owing to excessive travel costs – and to guarantee the economic vitality of cities (Still and Simmonds, 2000). Parking is generally provided publicly both on-street[1] and off-street, competing with privately operated garages. It is also assumed that private initiative alone cannot provide sufficient parking to meet demand and that private firms might not be able to afford private land prices in old/dense neighborhoods (Barter, 2010).

Public intervention in this market is economically justified on the grounds of the economic distortions it faces, namely from: (i) the search externality imposed by drivers having to cruise to locate empty parking spaces; and (ii) the garages' localized market power, associated with construction scale economies that imposes the discrete spacing of lots (Arnott, 2006).

The welfare loss associated with cruising is a relevant factor, as it affects a substantial number of trips and its external cost is not negligible. Shoup (2005) shows that about 30% of trips are affected and that drivers spend, on average, eight minutes cruising. Inci et al. (2015) estimate the external cost of cruising to be about 15% of the average wage rate per trip in the case of Istanbul (equivalent to $2.7/h in the US). In the case of Amsterdam, van Ommeren et al. (2011) estimate that the cruising cost is about 1 €/day per resident.

Competition in the parking market is generally assumed to drive the overall price level down, while a dominant market position will increase it (see Lin and Wang, 2015; De Nijs, 2012; Choné and Linnemer, 2012). It is clear that both distortions are interrelated, as garage operators can take advantage of curbside congestion (they do not internalize the search externality) by increasing prices as market equilibrium is reached and the full cost of curbside is equated to

[1] Curbside parking spaces remain in the scarce public domain and public authorities are responsible for allocating the use of this public good to the activities and transport modes that coexist in a city.

garage parking. In turn, higher garage prices make curbside parking a preferable option shifting demand to the on-street option and increasing congestion levels.

Policy makers and practitioners do not design their parking policy interventions on the understanding (mindset) that parking is a market good. On the contrary, following Barter (2015) the most widespread approach has been to consider parking as a kind of infrastructure that needs to be provided in keeping with engineering guidelines. The conventional approach assumes that enough parking needs to be provided on-site to meet demand (avoiding spillovers to neighboring areas). In this policy mindset, it is assumed that private initiative provision will not meet demand, so minimum parking requirements (MPRs) are needed.

The impossibility of constantly increasing on-site parking provision in areas of high demand and the need to use parking as a TDM measure forced a slight change in mindset towards an "area management" approach, where policy interventions seek to promote public-access garages and a more intense regulation of curbside parking in order to foster a modal switch. However, policy makers have tended to keep curbside fees low and to make garage parking provision (supply expansions) their main tool to accommodate excess curbside demand, even though private operators already provide a sizeable off-street parking supply.

New trends in curbside regulations mean policy interventions are adopting a much more market-oriented approach, taking their inspiration form the parking policy reforms outlined by Shoup (2005). Although most researchers in this field advocate the implementation of such an approach, local authorities are reluctant to adopt it given its complexities and political economy considerations (Button, 2006).

For all these reasons, we believe it is important to analyze and understand the links and distortions that arise within the parking market and to explore potential solutions and policy recommendations.

1.2 About this thesis

1.2.1 Background

Parking policy has attracted considerable research interest in the past, but it is currently a hotly debated topic given the market-oriented turn taken by the sector and the complexities of the market's intrinsic distortions.

Theoretical studies have suggested various policy interventions to achieve full efficiency or, at least, to induce welfare gains (see Inci, 2015, for an extensive review). Studies dealing with spatial competition between garages and curbside parking stress the need to maintain an appropriate fee differential between curbside and garage fees in order to achieve a social optimum and to eliminate cruising, by allocating excessive curbside demand to available garage supply (Arnott, 2006; Arnott and Rowse, 2009; and Inci and Lindsey, 2015). They show that increasing the fee differential in favor of garage parking will increase the stock of cars cruising for curbside spots. This magnifies the distortion caused by underpriced curbside parking and promotes inefficient market structure, yielding a spatial equilibrium characterized by an excessively low capacity and garages that are spaced too close together.

This conclusion is backed up empirically, as van Ommeren et al. (2012) suggest that cruising is mainly a parking regulation issue, given that cities with curbside regulated parking spaces and a proper fee differential with respect to garages report almost no cruising levels. Lengthy cruising times are experienced in cities where there is a large differential in favor of garages (Shoup, 2005) while short cruising times are reported in the case of those that face higher curbside fees (van Ommeren et al., 2012). Unfortunately, when we look at current market price settings in cities around the world the former is far more usual than the latter, which suggests the existence of a relevant pricing distortion. For example, in New York (Manhattan) the curbside fee is around $3.50/hour, while the average garage fee is $12.67/hour with a standard deviation of $4.4/hour (Lin and Wang, 2015). The Paris curbside fee is 4€/hour and garage fees range between 4 and 4.80€/hour (Île de la Cité). The London curbside is priced at £4.90/hour and garage fee range between £7 and £13/hour (Trafalgar Square). The Milan curbside fee is 2€/hour and garage fees are fixed between 3 to 5€/hour (Duomo).

Empirical studies have largely focused on the impact of curbside parking regulations on commuter modes and parking location choices. Some have analyzed the garage issue (most notably Shiftan, 2002; Khodaii et al., 2010; Simicevic et al., 2012a, 2013; Tsamboulas, 2001; Kobus et al., 2013; Froeb et al., 2003; Chone and Linnemer, 2012; De Nijs, 2012 and Lin and Wang 2015), giving rise to highly relevant conclusions. Essentially, this body of research suggests that the behavior of curbside and garage users is affected by different sets of criteria (Tsamboulas, 2001) and that the two parking options might not be perfect substitutes as some theoretical studies have assumed (Kobus et al., 2013). Users might value curbside parking more highly, meaning that even small reductions in the fee differential between garage and curbside parking would have a marked impact on on-street demand. This could be exacerbated further by the fact that garage operators might have considerable pricing power (Lin and Wang, 2015), which suggests that when drivers are willing to pay a premium to park on the curb it can lead to an even higher pricing distortion (if garage fees are higher than those for curbside parking).

The empirical literature tends to focus on curbside parking and generally considers garage parking simply as an outside option. However, garage parking is just as relevant as curbside parking, to the extent that the vast majority of parking spaces in European cities are provided by off-street parking garage facilities (Rye and Koglin, 2014). Indeed, none of the previous studies take into account the impact of curbside parking regulation instruments on garage demand and private operators' price setting behavior, nor do they analyze the potential contribution of public garage provision to correct market distortions (as a means to counterbalance private garage localized market power).

In addition, theoretical studies tend to assume that drivers have perfect information, but this assumption might not hold in practice, as drivers: (1) may not know all the options available in their parking choice set; (2) may lack the necessary information (prices and quality) to evaluate them; and (3) even if they want to acquire this knowledge, they must be prepared to undertake a considerable search effort, which is costly. The existence of this distortion further exacerbates cruising and the garages' market power, as private operators can simply exploit drivers' ignorance by increasing prices and increasing the price differential with the curb.

1.2.2 Research purpose and design

This thesis turns the focus on garage parking and seeks to analyze empirically a number of broad issues.

- What role is played by public authorities in curbside and parking regulations?

We test whether garage demand is affected by curbside regulation; the extent to which curbside and garage parking are substitutes; and whether one is preferred over the other. We focus on these issues while seeking to determine whether the current curbside and garage pricing schemes are in line with those proposed theoretically to achieve efficiency. To do so, we test the existence and extent of the potential pricing distortion in the market, in order to identify desirable public interventions. We also test whether occasional parker and garage subscriber behaviors are affected differently by curbside regulations. This last question is of relevance as they are the two demand segments targeted by garage operators. Additionally, we analyze whether dedicated curbside spaces influence these demand segments, given that it is common practice for cities to regulate which vehicles are allowed to park in each parking space as part of their TDM strategies. Indeed, resident permits are used to boost the acceptability of parking regulations, but not much evidence exists regarding their effects.

- What role is played by private garage operators in the pricing distortion?

We test whether the pricing behavior of private garage operators is affected by curbside regulation, public garage provision and market structure. We test whether the relative scarcity of curbside spaces and their fee are drivers of garage prices and investigate how public authorities should respond to private garage operators' price reactions when seeking to correct the pricing distortion in the parking market. We also test whether the level of competition drives prices down (as is generally assumed) and whether a garage's position of market dominance allows it to increase its mark-up. We also investigate whether the current provision of public authority managed and contracted-out facilities is introducing a competitive incentive that affects private operators' prices. Additionally, we also analyze how provision costs and quality shifters determine their prices, to gain insights into how public authorities should consequently change their pricing approach. We are especially interested in providing

guidelines for public authorities and other stakeholders on how private garage operators should be taken into account when designing interventions in the parking market.

- What role is played by consumer ignorance in the pricing distortion?

We analyze evidence concerning the level of knowledge parkers have about the parking market and whether parkers engage in any type of search activities to gain information, our hypothesis being that search costs are very high, meaning it is not optimal for them to be fully informed. This allows garage operators to exploit their ignorance with higher mark-ups. We test whether this hypothesis holds by verifying whether parkers' ignorance does indeed translate into their paying higher prices, thus confirming the existence of a previously neglected additional parking market distortion. We also test whether garage operators might, for strategic purposes, fail to disclose or even to obscure relevant information (obfuscation) to increase drivers' search costs. We analyze this issue as the existence of information frictions might hinder any potential intervention, as cruising will remain even with direct control on garage prices.

In summary, this thesis analyzes how parking policy instruments interact, how garage demand and private operators' price setting behavior is affected by curbside regulation and competition; and whether parking market outcomes are also distorted by information frictions (imperfect information) that might exacerbate already existing distortions in the market (cruising and garages' market power).

Our specific research design is applied to the analysis of the city of Barcelona, a city that is comparable to other cities in Europe and the USA (ITDP, 2010 and 2011) and an urban area that has set the trend in parking policies worldwide (GPALs, 2013). Indeed, this case study is of particular interest as it offers a good opportunity to review one of the most comprehensive city-wide parking regulations and policy reforms introduced in recent years. The role played by the public sector in Barcelona's parking market is extremely relevant as the city authorities manage both curbside parking and a good share of public-access garages (public operator and price-regulated facilities in a concession regime), yet this provision coexists with a large number of private garage operators in what is a highly atomistic market structure.

We undertake various empirical analyses using a number of newly constructed datasets, which are described below.

We provide an empirical estimation of the responsiveness of aggregate demand for garages to price and to the characteristics of curbside regulations, for both occasional parkers and subscribers.[2] We use a panel from Barcelona's public parking authority (BSM) that covers 34 garage facilities with yearly transaction data summaries for the period 2006-2012. This method is far less data-demanding than microeconometric approaches, and it can be applied easily to other cities, regardless of their technology for gathering parking data.

We explore the determinants of private garage prices, focusing specifically on cost shifters and on the impact of curbside regulation on garage price-setting decisions expanding previous empirical evidence. We estimate a price equation using a new self-constructed database for all the garages in the city of Barcelona (garage inventory of 508 facilities), which accounts for (1) cost drivers; (2) the market structure of the surrounding area; (3) specific garage characteristics that customers might value; and (4) the specific curbside regulation of the given area. We restricted the analysis to 396 garages, dropping all observations for publicly operated and contracted-out facilities with publicly regulated prices.

In order to evaluate the level of knowledge that parkers have about the parking market and test whether this translates into undesirable market outcomes (their paying higher prices), we conducted a survey among 576 respondents among the garage parkers at 61 different facilities located throughout Barcelona, but concentrated mainly in the CBD and surrounding areas. We gather information on garage parkers' trip and demographic characteristics, their search activity and their knowledge of prices and available alternatives. The information was gathered in a single wave over two consecutive weeks in February 2016, during business hours. The survey was conducted with parkers that were either about to leave the garage facility after parking their vehicle or when they returned to pick it up (before payment). Garage prices and characteristics are extracted from the previously mentioned parking inventory conducted during the same period.

[2] Occasional parkers are considered to be those who search for parking on the spot and pay on an hourly basis (even though they might be relatively regular visitors to the area). Subscribers are regular visitors that have signed a garage subscription plan and pay on a monthly basis.

In all these analyses, curbside information is provided by BSM and the neighborhood data is made publicly available by the Barcelona City Council Statistics Department.

1.3 Contributions

We contribute to the literature by analyzing the interrelation between curbside regulation and garage demand, providing the first empirical estimation of its impact. This is useful in order to test for the existence of pricing distortion in the parking market and for offering guidance on how it might be corrected. Our study provides a low data-demanding method to evaluate the parking pricing distortion that can be applied to any city, regardless of its technology for gathering parking data.

We find that garage demand is negatively related to garage fees, but only occasional parkers show a clear substitution effect with a preference for on-street parking (positive curbside fee cross-elasticity). Comparing both, we estimate an average curbside premium of €0.55/hour, which supports theoretical claims that curbside fees should be set higher than garage fees (above the curbside premium, to eliminate cruising). This highlights the current pricing distortion in Barcelona's parking market, where an uncoupled public curbside and garage operator pricing strategy introduces a pricing efficiency gap of between €0.45 and €1.05 per hour. This gap is even larger for private garage operators, rising to as much as €3.50 per hour with an average of €0.76/hour. Additionally, we find that the characteristics of curbside space regulation have an impact on demand as well as on pricing. Commercial spaces help to shift long-term parkers to garages, but also attract occasional parkers to the curb. Mixed-use spaces show no statistically significant impact on garage demand, which suggests that providing parking permits for residents does not add additional demand or shift the potential of occasional parkers towards garages. In fact, mixed-use spaces slightly reduce the number of garage subscribers, and shift long-term parking to the curb.

We contribute to the scarce literature on garage prices offering the first analysis of the interactions of these prices with curbside regulations (fees and the regulated use of spaces). We find that most of the price variation in the market can be explained by provision costs and quality shifters (land value,

capacity, number of opening hours and type of payment), which suggests that any policy intervention will need to take into account the heterogeneity of garages. We also find that the ratio between garage and curbside supply is positively related to garage fee, reflecting curbside parking scarcity. More importantly, the relation between garage and curbside fee is negative, capturing just how inefficiently the curb is used. Lower fees are associated with higher cruising levels in areas of high demand, with curbside parking generally being preferred to the garage option. This gives garage operators the opportunity to further exert their market power, increasing their mark-up and aggravating the preexisting distortion. In this case, increasing curbside fees should help reduce these distortive market outcomes.

We also find that private operators react neither to the level of market concentration (competition) in the area nor to the actual provision levels of public garages. Besides curbside regulation, only the positon of dominance of private operators in the relevant market (share of garages owned by the home garage company) is a major positive driver of prices. Additionally, we also provide the first empirical confirmation of the link between parking and retail prices as suggested in theoretical studies, as garage facilities associated with commercial activities charge lower fees (parking is a loss-leader), generating a positive externality to non-clients.

All this stresses that the public authority should integrate curbside and garage parking into a single-market regulation approach so as to overcome distortions and achieve efficiency, paying special attention to interactions with the private sector.

We also contribute to the literature by providing the first empirical evidence of the existence, and the degree, of information frictions in the garage market, which is relevant as it exacerbates the cruising externality and garage market power. This issue has not previously been taken into account in the parking literature, which implicitly assumes perfect information. Our study, therefore, is a relevant contribution for both theoretical and empirical studies that address parking competition and demand modelling. Moreover, our research stresses the fact that addressing existing information frictions is a relevant policy issue if parking market efficiency is to be achieved. It also points to the need to test empirically whether imperfect information can be considered relevant in other cities.

We show that parkers' ignorance does affect their garage-choice behavior and translates into undesired market outcomes. We find that information frictions are so pervasive that active search during a given trip does not help drivers reduce the fees they pay. Only passive information acquisition through experience seems to increase parkers' knowledge of the available garage stock and help them obtain cheaper parking options. We also find evidence of price obfuscation that might allow garage operators to exploit the consumers' lack of knowledge, which points to the need for public intervention.

1.4 Overview of the chapters

The reminder of the thesis is organized as follows. Chapter 2 analyzes the impact of garage fee and curbside regulation characteristics (fee and type of dedicated spaces) on garage parking demand (for both occasional parkers and subscribers). It presents an empirical estimation of garage demand elasticity to the garages' own fee and curbside fee cross-elasticity, which suggests that both goods are not perfect substitutes and curbside parking is preferred. As such, it identifies a relevant pricing distortion in the case of Barcelona. The chapter also provides evidence that the characteristics of curbside space regulation (commercial, mixed or resident-exclusive) has an impact on demand, but not always the one initially intended. Based on these results, we suggest policy interventions to address the pricing distortion and stress the need for an integrated market policy approach.

Chapter 3 explores the determinants of private garage prices, focusing specifically on cost shifters and the interaction between curbside regulation and garage price-setting decisions, while also analyzing the role of market structure. It shows that the main price drivers are provision costs and quality shifters (land value, capacity, number of opening hours and type of payment). It suggests a negative relation between garage fee and curbside fee, capturing just how inefficiently the curb is used (cruising) and so giving garage operators the opportunity to further exert their market power. The chapter also challenges the assumption that more competition drives prices down, and shows that current public garage provision does not affect them. It shows that only the dominant position of private operators in the relevant market is positively related to garage prices. Additionally, our findings also confirm the possible theoretical link

between parking and retail prices. Given these outcomes, the chapter examines potential policy interventions to address parking market distortions.

Chapter 4 provides compelling evidence of the existence, and of the degree, of information frictions in the garage market. It also empirically tests whether parkers' lack of knowledge affects the level of prices they end up paying, suggesting that information frictions do translate into undesired market outcomes. It shows that information frictions are so pervasive that active search during a given trip does not help drivers reduce the fees they pay and only passive information acquisition through experience seems to help them. The chapter also suggests that garage operators might engage in price obfuscation, which allows them to exploit the consumers' lack of knowledge. Addressing existing information frictions therefore is a relevant policy issue if parking market efficiency is to be achieved and we make some recommendations regarding policy interventions that might be useful in this regard.

Chapter 5 outlines the general conclusions that can be drawn from the thesis and identifies the policy implications derived from the study. The chapter stresses how the curbside premium represents an important price distortion in Barcelona's parking market and highlights the roles that the private sector and information friction play in this. We specifically stress the need to change current curbside and publicly provided garage parking pricing schemes and the added need of taking the private sector into account in an integrated parking market approach. In this chapter, we also identify the need to address the issue of imperfect information and practices of price obfuscation if market efficiency is to be achieved. Here, we propose a number of policy interventions that exploit the leading role played by the public sector in Barcelona's parking market and explore potential initiatives for public-private collaboration. Although our recommendations focus on the specific case of Barcelona, they may very well apply to other cities that face parking market distortions. Finally, based on the work conducted, we identify further lines of research.

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2 The impact of curbside parking regulation on garage demand.

SUMMARY:

Parking regulation is seen as a good option to encourage modal shift in order to tackle congestion and pollution in metropolitan areas. Market-clearing curbside pricing is rarely implemented and policy makers have tended to make off-street parking provision their main tool to address excessive curbside demand. Research devoted to garage parking is far less well developed, even though public authorities provide both curbside and garage parking that compete with privately operated facilities.

In this paper the impact of garage fee and curbside regulation characteristics (fee and type of dedicated spaces) on garage parking demand are investigated. Aggregate occasional and subscribers parking demand is analyzed by means of two different econometric models estimated using a panel from Barcelona's public parking authority (BSM) that covers 34 garage facilities with yearly data for the period 2006-2012.

We find that both demand segments show a negative elasticity to garage fee. Only occasional parkers show a clear substitution effect with a curbside premium (€0.55/hour). Our finding suggests that the actual pricing efficiency gap in Barcelona can range between €0.45 and €1.05 due to the mismatch between curbside and garage pricing regimes; for which we propose some policy alternatives. This stresses the need for a single integrated market approach to parking management, in order to overcome market distortions and achieve efficiency. Additionally, our results show that the characteristics of curbside parking spaces (allowance and time limits) play a role in garage demand determination, yet pricing is much more efficient trigger for behavioral change.

Keywords: Parking; Off-street parking; On-street parking; Garage parking; Curbside parking; Parking regulation, Price elasticity

A joint work with prof. Albalate based in this chapter is published at Transport Policy. Gragera, A & Albalate, D. (2016) 'The impact of curbside parking on garage demand', *Transport Policy, 47, 160-168*.

2.1 Introduction

Major urban areas have broadly adopted parking regulations and pricing as their main travel demand management tool to tackle excessive traffic demand-related externalities (like congestion and pollution). This tool has relatively low implementation costs, better public acceptance than road pricing, and can be controlled directly by local government (Litman, 2006; Button, 2006; Ison, 2014; and Rye and Koglin, 2014).

Although parking is a private good (rivalrous and excludable), it is often publicly provided both on-street (curbside) and off-street (in garages) (ITDP, 2010 and 2011). Public provision is justified on the grounds of market distortions: (i) a search externality imposed by drivers cruising for empty spots (excessive curbside demand); and (ii) garages' localized market power that arises from the discrete spacing of lots, due to construction scale economies (Inci, 2015). In order to achieve efficiency in this market, cruising must be eliminated by setting the right fee differential between curbside and garage parking, and by allocating the right quantity of demand to the most suitable lot at each moment (first-best). The fact that users are willing to pay a premium for on-street parking (Kobus et al., 2013) suggests that the curbside fee should be higher than the garage fee, in the presence of a search externality. Thus, if curbside and garage parking strategies are not coordinated, inefficient use of resources is likely to arise. If curbside parking is underpriced, it tends to be congested, slow down through traffic, and cause underutilization of public garages.

However, policy makers have tended to keep prices low and have focused on the expansion of controlled parking zones containing different types of dedicated curbside spaces, with a clear bias towards residential permits (i.e. mixed use or resident-exclusive, rather than commercial spaces).[3] The main tool used to address excessive demand is still to increase garage supply (despite its high cost), to the extent that the vast majority of parking spaces in European

[3] Mixed use spaces are implemented in cities such as Amsterdam, London, Paris, Munich, Copenhagen, Stockholm and Chicago. Resident-exclusive schemes are implemented in London, Munich, San Francisco and Seattle (See ITDP, 2010; 2011).

cities are provided by off-street parking garage facilities (ITDP, 2010; 2011; and Rye and Koglin, 2014).[4]

In this context, the paper aims to study the complex role of public authority in simultaneous garage and curbside parking provision, by analyzing how both regulatory instruments interact with garage demand. It should allow public authorities to efficiently coordinate both instruments, adopt sounder parking pricing and space regulation schemes, and advise on the potential impacts of policy changes (also for private garage operators).

We provide an empirical estimation of the responsiveness of aggregate demand for garages to price and to the characteristics of curbside regulations, for both occasional parkers[5] and subscribers[6]. We use a panel from Barcelona's public parking authority (BSM) that covers 34 garage facilities with yearly transaction data summaries for the period 2006-2012. This method is far less data-demanding than microeconometric approaches, and it can be applied easily to other cities, regardless of their technology for gathering parking data.[7]

We find that both occasional parkers and subscribers show a similar negative elasticity to garage fees, but only occasional parkers show a clear substitution effect with a preference for on-street parking. We estimate an average curbside premium of €0.55/hour, which supports theoretical claims that curbside fees should be set higher than garage fees (above the curbside premium, to eliminate cruising) (Arnott, 2006; and Inci and Lindsey, 2015). This highlights the current inefficiency in the city of Barcelona's pricing scheme; that ranges between €0.45 and €1.05 per hour for users facing no discounts due to the uncoupling between curbside and garage policies. In order to bridge this gap we propose different

[4] The ratio of garage to curbside spaces is clearly above 2, except in cities where underground parking construction would be extremely expensive (ITDP, 2010; 2011).

[5] Following Tsamboulas (2001), we use the term "occasional" to describe those parkers who search for parking on the spot and pay on an hourly basis; even they can be relatively regular visitors to the area but not enough to sign a garage subscription plan (non-subscribers).

[6] Parkers who have signed a garage subscription plan payed on a monthly basis that grants them a reserved space, also described elsewhere as monthly parkers.

[7] Note that our data is gathered from the public parking authority; private operator counterparts would rarely be available.

policy options; that include a bold increase of curbside fee, a cut on garage fee and a cross-subsidy from the curb if it needs to be set below average cost.

Additionally, we find that the characteristics of space regulations have an impact on demand as well as on pricing. Commercial spaces help to shift long-term parkers to garages, but also attract occasional parkers to the curb. Mixed use spaces show no statistically significant impact on garage demand, which suggests that providing parking permits for residents does not add additional demand or shift the potential of occasional parkers towards garages. In fact, mixed use spaces slightly reduce the number of garage subscribers, and shift long-term parking to the curb.

All this stresses that the public authority should integrate curbside and garage parking into a single-market regulation approach, to overcome distortions and achieve efficiency. And it also suggests the need to consider the interactions with the private sector that might devote further research.

The paper is organized as follows. Section 2.2 reviews relevant literature on the issue at stake. Section 2.3 briefly presents the case study of Barcelona. In Section 2.4 we describe the methodological approach and the data used in the analysis. Section 2.5 presents and discusses the results of models, and Section 2.6 highlights the main conclusions.

2.2 Literature review

Theoretical research work has focused on the optimal curbside parking regulation problem. In recent years, relevant contributions have also been made that introduce the interaction of curbside parking regulations with garage parking in spatial competition models; see Inci (2015) for a complete review.

Spatial competition models proposed by Arnott (2006) and Inci and Lindsey (2015) show that the full price of parking is the outcome of the interaction between garage operators and the cruising level that makes curbside and garage parking equally costly. They point out that the key to eliminate cruising by allocating excessive curbside demand to garage parking is to keep the appropriate fee differential between them. This suggests that, in the case of inelastic demand, it will be welfare-enhancing to increase curbside fees, as they do not modify the full cost of parking, but convert cruising time costs into meter

revenues. Additionally, Inci and Lindsey (2015) also suggest that efficiency can be attained regardless of the curbside fee by regulating prices in the garage sector, overcoming the localized market power issue, and even through the tacit or explicit collusion that may arise in a market where the same players interact for long periods (Froeb et al., 2003).

However, none of the previously mentioned studies took into account the role of public administration in the simultaneous provision of garage and curbside parking, and the potential competition effects this might induce in the private garage sector.

Empirical studies on parking demand have largely focused on the impact of on-street parking regulations on commuters' travel choices, using stated or revealed preference surveys; see Marsden (2006) and Concas and Nayak (2012) for a complete review. The literature suggests that curbside parking demand is negatively related to curbside fee, but its sensitivity depends on user and trip characteristics. Curbside demand decreases with income (Gillen, 1977; Shoup and Wilson, 1992), increases with stay duration (Khodaii et al, 2010; Kobus et al., 2013), depends on trip purpose (Kelly and Clinch, 2006; Simicevic et al., 2012b) and increases with the level of alternative transportation modes (Hess, 2001; Weis et al., 2012). Additionally, it is expected to be non-linear and heterogeneous among demand segments (Kelly and Clinch, 2006; Tsamboulas, 2001). Based on a meta-analysis regression, Concas and Nayak (2012) report an average demand elasticity of -0.39 with respect to parking fee, which is slightly lower for the US (-0.30) and much higher for non-US studies (-0.86).

Only some of the most recent works take advantage of parking transaction data; see Kelly and Clinch (2009), Ibeas et al. (2011), Pierce and Shoup (2013) and Ottosson et al. (2013), Madsen et al. (2013) and Kobus et al. (2013). And very few studies have analyzed the specific behavior of garage users, and the interactions between on-street and off-street parking regulation tools (i.e. fees, time limits, parking permits, type of spaces and their spatial distribution or the level of enforcement); see Shiftan (2002), Khodaii et al. (2010), Simicevic et al. (2012a, 2013), Tsamboulas (2001) and Kobus et al. (2013).

Kobus et al. (2013) and Simicevic et al. (2013) found that both curbside and garage parking demand are negatively related to parking fee; but only Kobus el al. (2013) reports garage demand elasticity estimates ranging from -2.2 to -1.5 for 1 hour and 20 minute stays respectively.

The substitution effect between garage and curbside parking was first empirically suggested by Kobus et al. (2013), who estimated probit models on the choice between curbside and garage parking, based on stay duration. They found that users are willing to pay a premium for on-street parking that ranges from €0.37 to €0.60 per hour, and users who park for longer durations are more sensitive to fees. Simicevic et al. (2013) reached a similar conclusion from the fact that the off-street option becomes more likely to be chosen the tighter the time limits on the curbside. This implies that even small reductions in the fee differential would greatly increase curbside demand and therefore cruising, which could be worsened by the fact that garage operators hold potentially high pricing power with inelastic parking demand, especially for short-stay trips. However, no cross-price elasticity estimates are available in the literature.

Additionally, Tsamboulas (2001) highlights that occasional garage parkers' and garage subscribers' changes in parking location and transport mode depend on a different set of criteria. This is of special relevance for garage operators as they offer parking spaces to both demand segments to make the most of their available capacity, and subscribers tend to be residents of the area who may be eligible for parking permits for the curbside.

The aim of this paper is to investigate the effects of curbside regulations' characteristics on aggregate garage parking demand, both for occasional parkers (OCC) and subscribers (SUB), and to try to combine previous findings in a single framework. This is extremely relevant for public authorities, as they need to quantify the complex interactions between parking regulation instruments in order to take policy actions. Our empirical model is fairly simplistic with low demands on data. It can be applied to any city, regardless of the level of its parking data-gathering technology.

2.3 Parking in Barcelona: context and policy

Barcelona is the second largest city in Spain, with a population of 1.6M inhabitants (4.5M in its metropolitan area). It is the largest Mediterranean city, and one of the most densely populated in Europe (15,900 inhab/km^2). Since the 1960s, it has experienced a process of progressive suburbanization that has increased traffic demand and associated parking needs.

Following a conventional approach, curbside regulated spaces were first introduced in 1983 to deter long stays and promote turnover in the central business district's (CBD) commercial streets, reaching 7,158 regulated parking spaces in 2004. To promote the shift of curbside long stay parking to off-street, and to specialize curbside parking for short stays, the public authority followed a policy of increasing off-street supply by promoting the construction of 11,000 garage parking spaces between 1997 and 2004.

Despite these measures, congestion kept increasing, which drove urban mobility towards total gridlock. The RACC (2007) estimated that congestion in Barcelona implied about 26M hours lost per year, equivalent to a global cost of €384M (about 0.3% of Catalonia's GDP). In order to overcome this situation, a city-wide curbside parking regulation initiative called ÀREA was introduced in the CBD in 2005, and was extended to almost the entire city by 2009. It was introduced as a trip deterrence measure, aimed at alleviating congestion and reducing cruising by transforming free curbside spaces to regulated spaces, and integrating all the previous on-street parking measures under a single management parking authority (BSM). It currently consists of 55,000 regulated parking spaces with dedicated uses: (i) commercial activities (blue); (ii) mixed use, including both residents and commercial parking (green); (iii) resident-exclusive (green exclusive); (iv) hauling; and (v) free spaces for motorbikes. These parking spaces are split into 22 regulatory zones covering almost the entire area of the city, with 4 fixed fee/hour bands operating during traffic peak time (i.e.: Monday to Friday 8h-14h and 16h-20h) with a maximum stay limit (1 to 2 hours).[8]

The expansion of curbside regulation has largely involved the introduction of mixed-use spaces, as these offer a virtually free parking permit to residents but charge visitors, which reduces opposition to the measure. Similar approaches have been used elsewhere, as reported by the ITDP (2010, 2011). This system is justified by the assumption that granting access to residents will impose further limitations on visitors (besides pricing), and push them to park off-street in a well-developed garage network. However, this somewhat

[8] Parking meters accept coins and credit cards, but since 2015 they have been upgraded to accept smartphone payment via App.

contradicts both the theoretical and empirical evidence (Van Ommeren et al, 2011).

The expansion of the public garage network reached a plateau with the implementation of curbside regulations, although some facilities have been completed and others are still under construction. It is interesting to note that the supply of public garages has increased twice as much as that of curbside regulated spaces. Only in recent years, the supply of public garages has been dramatically reduced after several facilities were closed due to urban transformations. Currently, BSM owns more than 100 facilities with a total supply of about 43,000 parking spaces. Following city council estimates for 2012 (no official data exists on private operators), this means that the public parking operator directly controls roughly 23% of the total public access garage supply in the city. Publicly managed garages apply a homogeneous fee/hour pricing scheme (non-progressive), regardless of their spatial location, which shows no evident linkage to on-street regulation. However, the garage subscription cost is defined at each facility.

It is also important to stress that no other relevant change in the parking sector has been detected during the ÀREA implementation, as parking minimum requirements in new constructions, broad private supply and regulation has remained the same.

2.4 Methodology

2.4.1 Aggregate demand function

We estimate an aggregate demand function using a panel data approach, where cross-section observations correspond to parking garages repeatedly observed throughout a time span. This allows us to model variations in demand resulting from policy and socioeconomic changes over time and across garage facilities.

We assume, as described in (1), that aggregate demand (y_{it}) in each parking facility (i) and period of time (t) is a function of garage characteristics (x_{it}), the characteristics of alternative on-street parking (o_{it}) and other neighborhood

characteristics affecting car usage demand (n_{it}) within each garage facility catchment area (defined as a buffer of radius D around each facility),[9] garage-specific unobserved heterogeneity (α_i) and time-specific effects (γ_t) to cope with area expansions or specific shocks (i.e. economic recession). The demand function also depends on an idiosyncratic error term (ε_{it}).

As we are interested in analyzing two demand segments, namely occasional parkers who pay on an hourly basis and parking subscribers (who pay on a monthly basis), we also develop two models with slightly different variables specification, as in Tsamboulas (2001). In our case, we specify two aggregate demand functions using different aggregate demand measures. The characteristics of each of them impose the adoption of two differentiated econometric approaches: the occasional parking (OCC) model is specified as an event count model estimated by means of negative binomial specifications, adapted to panel data; whist the subscribers parking (SUB) model is estimated by least squares. The data used and each model specification are described in detail in the following subsections.

$$y_{it} = f(x_{it}, o_{it}, n_{it}, \alpha_i, \gamma_t, \varepsilon_{it}) \quad (1)$$

Where

x_{it} = own garage characteristics

o_{it} = alternative on-street parking characteristics (parking spaces, types and fees)

n_{it} = neighborhood characteristics affecting car usage (income, motorization rate)

α_i = garage-specific fixed effects

γ_t = time-specific effect

ε_{it} = idiosyncratic error term

[9] The catchment area of each facility is defined as the area within a fixed distance buffer for each garage facility.

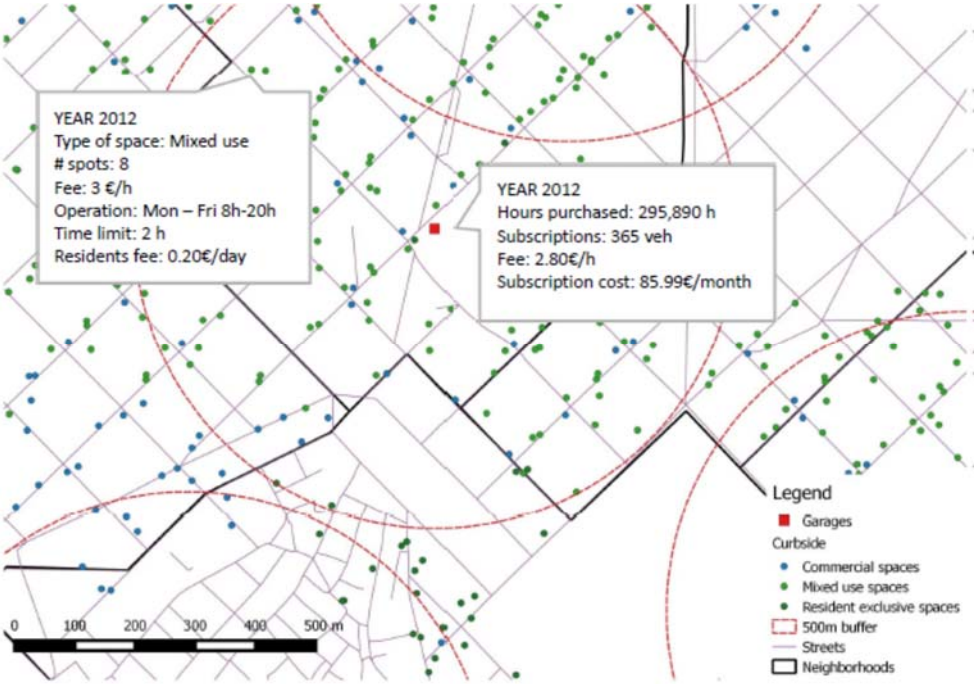
2.4.2 The data

Our dataset covers 34 of BSM's garage facilities for the period 2006-2012 (*238 observations*). BSM does operate some other facilities, but their demand behavior is assumed to be pretty different due to the parking policy context in their surroundings. In order to keep atypical observations out of our sample, we eliminated specific facilities that are located in the urban fringe, where ÀREA is not fully implemented and free parking is extensively available. We introduced both garage and curbside characteristics in a GIS software, which translates into a series of points that embed the information of parking regulation for each year; Figure 2-1 shows an example of the available data. In order to compute our explanatory variables related to curbside and neighborhood characteristics we specify the catchment areas as a buffer around each facility with a radius of 500 meters.[10] The main descriptive statistics for all variables included in the OCC and SUB models are displayed in Table 2-1.

The dependent variable for the OCC model is garage parking demand at each garage facility, measured as yearly purchased parking hours (H_{it}) at each facility (i) and period (t); made available in BSM parking facilities' annual reports. The latest studies using parking transaction data tend to define demand by occupancy rate (Ottosson et al., 2013; Madsen et al., 2013). However, we believe that yearly purchased parking hours is a better demand indicator in our case. The fact that occasional parkers and subscribers share the same facility raises awareness about the validity of occupancy rate changes to measure demand changes, as parking subscribers purchase the right to park in advance, and thus their parking spaces are unavailable to other users, whether they park or not. Additionally, yearly purchased parking hours can be used to directly compute occupancy rates, revenues and changes in average stay length.

[10] We estimated the model for 500 and 800 meters (0.3 and 0.5 miles), following evidence reported by Lin and Wang (2015), and the maximum acceptable outdoor walking distance described in Smith and Butcher (1994). The results are consistent across buffers, but can be made available upon request. In this case, we only report the results for the 500-meter buffers, as this distance is generally used by practitioners as a rule of thumb for the catchment area. Additionally, note that the minimum feasible radius is constrained to the existence of sufficient variation in the data.

Figure 2-1. Detail of the information integrated in a GIS software to compute explanatory variables within 500m buffer around each garage facility in the sample.



It has to be noted that this dependent variable specification does not follow a normal distribution, but a negative binomial one. The preponderance of relatively small numbers suggests that the regression approach can be improved by using the event count method, which takes into account the issue of overdispersion (negative binomial), as the variance for H is far higher than its mean.

Table 2-1. Summary of descriptive statistics, information source, and expected signs in OCC and SUB models

		Std. Dev.			
Variable	Mean	Overall	Between	Within	Source
H	207528.50	192055.40	188200.70	48605.20	BSM
VEH	281.30	119.84	116.54	33.55	”
GF	1.72	0.25	0.20	0.14	”
GS	98.66	22.59	22.44	4.41	”
CPS	218.58	133.38	130.20	35.60	”
MPS	661.31	538.57	502.65	209.27	”
RPS	148.56	285.04	287.17	29.42	”
FPS	138.55	301.69	190.00	236.29	”
RF	2.49	0.21	0.17	0.13	”
POB	22570.68	10172.79	10287.97	568.25	BCN Stat.Dept.
RCAR	354.18	83.93	83.33	16.58	”
LANDV	403.59	122.69	105.12	65.45	DTES Gencat

In the SUB model we measure garage parking demand as the number of 24 equivalent parking contracts subscribed (VEH_{it}), as there are different subscription modalities that allow parking access at different times (day, noon, overnight and weekends). In this case, changes in occupancy rate provide no information about subscribers' demand, as we are interested in how many parkers want to buy the right to parking spaces for a certain period of time, not how long they stay each time. This figure follows a normal distribution, and can be found in the annual reports of BSM parking facilities (only in aggregate terms).

The characteristics of the garages are also extracted from the BSM parking facilities' annual reports. Garage fee (GF_{it}) is measured as the average hourly fee by computing the ratio between yearly revenue raised from short stay vehicles and yearly purchased parking hours (including cash-in advance options). The fact that the public authority has adopted a city-wide garage pricing scheme eliminates a possible endogeneity issue, as the garage parking fee does not change in response to garage demand.

Subscription cost (GS_{it}) is measured as the average monthly subscription by computing the ratio between the yearly revenue raised from long stay vehicles and the yearly number of subscribed vehicles, divided by 12 months. Unlike garage fees in the OCC model, garage subscription costs do not follow a uniform pricing scheme. However, the correlation coefficient between the log of subscription cost and the log number of subscribers is only 0.11, which suggests that there is no special problem of endogeneity.

We assume that demand is only affected by on-street parking characteristics within a garages' potential catchment area (D). Thus, alternative parking supply is captured by the number of free (FPS_{it}), commercial (CPS_{it}) and mixed use parking spaces (MPS_{it}) within the 500-meter catchment area. For facilities where ÀREA was initially not fully implemented, free parking supply is computed as the difference between the maximum total number of parking spaces before the ÀREA extension and the regulated supply. After full extension, it is set to 1, in order to avoid problems with the log specification, even it was set to zero as all free parking was eliminated.

The on-street parking fee (RF_{it}) is computed as the weighted average fee for commercial and mixed use spaces within the catchment area. The SUB model

additionally includes resident-exclusive parking spaces (RPS_{it}) within the 500-meter buffer around each facility.

All these figures are conveniently estimated using geographic information systems (GIS) software, based on BSM data maps and BSM (2013).[11] The inclusion of garage-specific fixed effects controls for the endogeneity of the on-street fee, as garage demand may be high where on-street demand and fees are also high. However, this still excludes the case where changes in the on-street fee over time are a response to garage demand changes. As long as these adjustments in prices are a political decision rather than a response to demand changes, we find our previous assumption to be valid, as stated in Madsen et al. (2013).

In order to cope with a neighborhood's time-varying characteristics, we computed the number of thousands of inhabitants (POP_{it}) within the catchment area. This figure is computed as the neighborhood-weighted average population with a weight proportional to the neighborhood area, overlaid with the 500-meter buffer for each BSM garage, using GIS software. This is obviously a proxy for the number of residents in the catchment area, as it assumes that population is uniformly distributed in each neighborhood. This assumption is fairly reliable for all neighborhoods except the city fringe (facility locations from this area are not included in our sample).

The same procedure has also been applied to account for the density of cars ($RCAR_{it}$) per thousand of inhabitants registered within each buffer. Additionally, we introduce the average real estate selling price ($LANDV_{it}$) in thousands of euros at district level as a proxy for income.[12] All previous neighborhood figures are reported by Barcelona City Council's statistics department.

Other neighborhood characteristics that affect parking demand and vary over facilities but remain fixed over time, such as economic activity or commercial areas, are assumed to be captured by garage-specific fixed effects (α_i). However, some intrinsic catchment area characteristics that affect long stay parking

[11] Previous data maps were provided by BSM. The current version of this map is available at the ÀREA web page: http://www.areaverda.cat/en/map/

[12] All monetary units are expressed in current terms.

demand are not fixed and may vary randomly, for example, the amount of private parking that is available. Additionally, we include a time-specific effect (γ_t) to explore possible ÀREA expansion effects, any potential time trend, or specific shocks affecting demand (such as economic recession).

2.4.3 Model specifications

In the occasional parkers (OCC) model, the aggregate demand function dependent variable is defined as yearly parking purchased hours (H_{it}). We specify this variable using negative binomial regression with a common log-linear specification for the λ_{it} parameter and explanatory variables as expressed in (2).[13] The estimated parameters in (2) can be interpreted as demand semi-elasticities.

In the subscribers' parking (SUB) model, the aggregate demand function dependent variable is defined as the number of vehicles or parking contract subscribers (VEH_{it}), specified in a log-linear form with explanatory variables as depicted in (3).[14] Least squares estimated parameters are interpreted as demand elasticities.

In order to account for unobserved heterogeneity, we estimate fixed (FE) and random effects (RE) specifications for both models.[15] To choose between them, we check for the correlation between unobserved heterogeneity and the regressors, using the Hausman test. All the previous models' specifications are estimated using cluster-robust standard errors, with clustering on the garage

[13] We also estimated the Poisson counterparts of these models, but the Lagrange Multiplier test allows us to reject the null of no overdispersion. The need to consider unobserved heterogeneity either by NBFE or NBRE is confirmed by the LR test. See Hausman et al. (1984) for further detail on the negative binomial regression specification

[14] We tested three alternative functional forms and decided on goodness of fit (log-likelihood). Additionally, log-linear functional form was adopted in similar empirical works, such as Ottoson et al. (2013).

[15] The need to consider garage-specific effects is highlighted by a joint significance test with a null hypothesis of equality between all garage-specific dummies' coefficients.

facilities to control for the remaining heteroskedasticity and serial correlation within facilities.

We estimate both OCC and SUB models with the parking regulation and neighborhood characteristic variables for a 500-meter buffer around each garage facility. The aim is to analyze the interactions between garage demand and curbside regulation, and check the area around each garage for which it is relevant.

$$ln(\lambda_{it}) = \alpha_i + \gamma_t + \beta_1(GF_{it}) + \beta_2(FPS_{it}) + \beta_3(CPS_{it}) + \beta_4(MPS_{it}) + \beta_5(RF_{it}) + \beta_6(POP_{it}) + \beta_7(INC_{it}) + \beta_8(CAR_{it}) + \beta_9(MOT_{it}) + \varepsilon_{it} \quad (2)$$

$$ln(VEH_{it}) = \alpha_i + \gamma_t + \beta_1 ln(GS_{it}) + \beta_2 ln(FPS_{it}) + \beta_3 ln(CPS_{it}) + \beta_4 ln(MPS_{it}) + \beta_5 ln(RPS_{it}) + \beta_6 ln(RF_{it}) + \beta_7 ln(POP_{it}) + \beta_8 ln(RCAR_{it}) + \beta_9 ln(LANDV_{it}) + \varepsilon_{it} \quad (3)$$

where:

α_i = garage-specific fixed effects

γ_t = time-specific effect

H_{it} = number of yearly purchased parking hours (in facility i and period t)

VEH_{it} = number of parking contract subscribers (in facility i and period t)

GF_{it} = weighted average garage parking fee (€/h)

GS_{it} = weighted average garage subscription cost (€/month)

CPS_{it} = number of commercial use parking spaces within D

MPS_{it} = number of mixed use parking spaces within D

RPS_{it} = number of resident-exclusive parking spaces within D

FPS_{it} = number of free parking spaces within D

RF_{it} = on-street weighted average parking fee within D

POP_{it} = number of inhabitants within D

$RCAR_{it}$ = ratio of cars per inhabitant within D

$LANDV_{it}$ = average real estate selling price (€) within D

2.5 Results and discussion

In this section, we present and discuss the results for the demand functions estimated for the two demand segments: occasional parkers (OCC) and parking subscribers (SUB). As all tests indicate a preference for the fixed-effects model, we only show its results for both models. [16] Additionally, to facilitate the comparison between both demand segments, we also report the elasticities at mean values for both models. All these figures are shown in Table 2-2.

In this Table, we can see that both OCC and SUB demands are negatively related to the garage fee/hour (GF) and the monthly subscription cost (GS), respectively. For OCC, a 1€/hour increase in garage fee yields a 69% reduction in the number of purchased parking hours, which translates into an average elasticity at the mean of -1.19. In a similar way, the elasticity of SUB demand to monthly subscription cost across buffers is -1.11. If we compare the estimated coefficients, we can see that both OCC and SUB demands are fairly elastic, and below the estimates reported by Kobus et al. (2013) for an average stay of 1.2 hours, but in the upper bound of the range reported for curbside demand by Concas and Nayak (2012).[17]

Using a z-test, we checked the null hypothesis that the coefficients for OCC and SUB are equal. This result does not appear to agree with Tsamboulas's (2001) finding that subscribers' response to the fee differential is twice that of occasional parkers. However, Tsamboulas's estimates refer to a change in parking location when occasional parkers really can reduce their parking duration, park elsewhere, shift mode or desist from travelling. In contrast, subscribers are unlikely to change parking duration, avoid traveling or change transport mode as their trip is very frequent and probably highly constrained, leaving only a change in parking location as a feasible option. This reasoning

[16] In order to choose between fixed-effect and random-effects, the Hausman test is computed for both models. In the case of OCC, the test indicates the rejection of the null of no correlation between unobserved heterogeneity and the regressors (H = 15.48 with a p-value lower than 0.03), which suggests that NBFE should be used as it is surely consistent. A similar conclusion can be drawn for the SUB (H = 35.68 with a p-value lower than 0.01). Alternative estimation results can be made available upon request.

[17] In their sample, average fee elasticity was -0.48, with a standard deviation of ±0.65. If we only consider non-US studies with higher average price elasticities (-0.69), the range is expanded.

suggests that the impact on aggregate demand can plausibly be of the same magnitude, as we report.

Interesting differences arise in curbside parking spaces, as both demand segments show quite different sensitivities to the types of regulated spaces. OCC demand is negatively related with the number of commercial spaces (CPS), with an estimated elasticity at the mean of -0.27. In contrast, commercial spaces show a positive relation with SUB demand of +0.13. This suggests that commercial spaces act as a curbside substitute for occasional garage parking, but act as a curbside constraint for subscribers. This opposite effect in each garage demand segment should be taken into account by public authorities when they change curbside regulations, as it might transfer demand to the curb and alter garage revenues.

Changing the provision of mixed use parking spaces has no statistically significant impact on OCC or SUB demand at any given buffer. The widespread extension of this particular type of spaces has been justified by the assumption that resident parking permits act as an additional constraint to occasional parkers, and might help to shift demand to off-street facilities, regardless of the pricing strategy. Our results clearly do not backup this assumption. We hypothesize that residents' monopolization of the use of these spaces translates into more cruising, while commercial spaces can further help to shift demand towards garages.

Changes in the provision of free parking spaces negatively affect SUB garages' demand, with an estimated elasticity of -0.01. The fact that we found no relevant impact on OCC does not mean that increasing the number of free spaces does not potentially undermine the demand for garages, as it is expected that occasional parkers are far more sensitive to walking time (Tsamboulas, 2001). This suggests that occasional parkers will only be affected by changes in the provision of free parking within an acceptable walking distance, which we assume from our results will be far less than 500 m to the garage facility.

Additionally, resident-exclusive spaces (RPS) do show a negative relation with subscribers' parking demand, with estimated elasticities of -0.05 (higher than the response to FPS).[18] This confirms that residents represent a relevant

[18] Note that RPS is not included in the OCC model as these spaces are restricted only to residential parking, and no alternative is available for occasional parkers.

share of garage subscribers, and suggests that granting parking permits to residents does undermine the shift of long stay parking to off-street facilities.

The curbside weighted average regulated fee also has a different impact on both demand segments. We find positive cross-elasticity for occasional parkers, as a €1 increase in curbside fee shifts 31% of demand to garage parking, which is equivalent to 0.77 elasticity at mean values. This indicates a clear substitution effect between curbside and garage parking, as previously suggested in Kobus et al. (2013), even though there are no cross-elasticity estimates to compare ours with.

Table 2-2. Estimated demand equations for OCC and SUB models. For the OCC model (2), reports estimated semi-elasticities and (2') the elasticities at mean values. For the SUB model (3), reports estimated elasticities.

	OCC		SUB
Variables	(2)	(2')	(3)
GF	-0.695***	-1.195	
	(0.0780)		
GS			-1.109***
			(0.290)
MPS	-2.68e-05	n/s	-0.00495
	(7.69e-05)		(0.0303)
CPS	-0.00124***	-0.271	0.132**
	(0.000306)		(0.0508)
RPS			-0.0546*
			(0.0245)
FPS	-0.000108	-0.014	-0.0102*
	(7.39e-05)		(0.00421)
RF	0.308***	0.768	-0.100
	(0.119)		(0.776)
POP	-1.12e-05	n/s	1.118***
	(8.96e-06)		(0.191)
RCAR	-0.000347	n/s	0.734**
	(0.000666)		(0.201)
LANDV	0.000607**	0.244	0.190**
	(0.000287)		(0.0736)
Constant	5.015***		-6.356**
	(0.497)		(2.541)
Obs.	238		238
R2			0.22545943
F			28863381
LL	-22,674,052		
Chi2	32846132		

Standard errors are reported in parenthesis. *, ** and *** denote significance at 10%, 5% and 1% respectively. Time dummies are not reported.

Additionally, the fact that cross-elasticity is below own-elasticity suggests that the curbside might be preferred to garage parking. Computation of the ratio between garage and curbside fee semi-elasticities in OCC yields a curbside premium of €0.55,[19] which is in line with the figures reported in Kobus et al. (2013). This is of special relevance in the case of Barcelona, as garage parking fees are systematically higher than curbside fees. Our finding suggests that in 2012 pricing efficiency gap for the users that face no garage fee discount can range between €0.45 and €1.05 depending on the area, the type of space, and the associated fee scheme implemented around each garage facility;[20] as shown in Figure 2-2. This is the case as BSM applies a uniform garage parking fee policy, in fulfillment of the political agreement reached by city council;[21] which also sets fee increases indexed to CPI. These measures translated into uniform fees have usually been justified by policy makers on the grounds of fairness and equity. However, this mismatch between curbside and garage pricing regimes shows the uncoupling in the political perception of such substitutive goods. This is highlighted by the fact that on-street and off-street parking fees are set by independent political agreements and public authority manages both as separate business units (with their own operating accounts). In this regard we would recommend the public authority to follow a non-homogeneous and coordinated curbside and garage parking pricing scheme.

The price efficiency gap highlights the key role of a garage versus curbside fee differential in parking regulations, as relative reductions in curbside fee will transfer users towards the curb, reducing performance and increasing associated externalities. This stresses the need for the public authority to undertake a single integrated market regulation approach. To correct the price efficiency gap public authority can either increase curbside price, reduce public garage prices or chose some middle ground combination of both. We would recommend public authority to equate garage prices to marginal cost and increase curbside price up

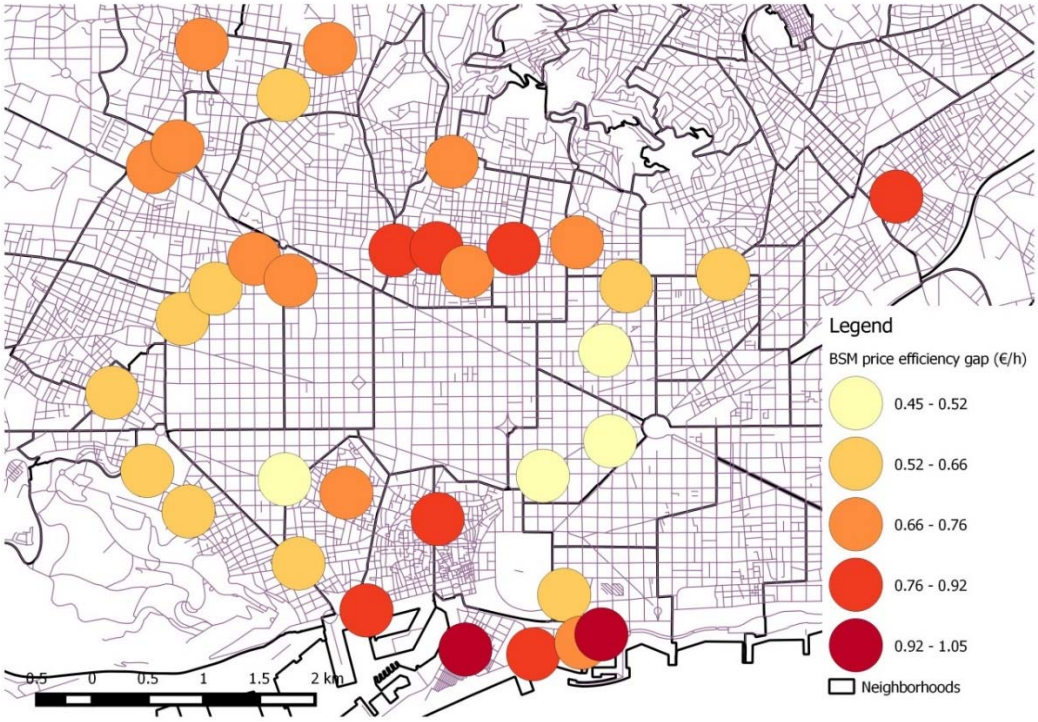
[19] Equating the demand changes induced by a €1 curbside fee increase with respect to a €1 increase in the garage fee, we obtain the proportional valuation of one over the other. The remaining part up to equivalent valuation is assumed to be the curbside premium ($1 - \beta_5/\beta_1$) per each euro increased.

[20] The price efficiency gap we provide is computed by subtracting curbside average weighted fee to the regular garage fee per hour with no discounts (2.80€/h – RF); then adding up the estimated curbside premium (0.55€/h). Note that regular users that purchase a garage pass with discount fees will face much lower gap.

[21] City Council Agreement adopted by the Mobility and Security Comission on July 12th 2007.

to a premium above garage prices. If this curbside price increases is politically unfeasible we would recommend to explore the option to increase curbside price as much as possible and reduce garage price below marginal cost, setting a cross subsidy between the curb and garages as suggested in Arnott (2006).

Figure 2-2. Price efficiency gap for the garage facilities included in our sample in 2012 (Computed as the difference between GF and RF plus the proxied curbside premium).



It is relevant to highlight that the price efficiency gap issue is even bigger for the private garage sector, as public garages are on average about 8% cheaper (BSM, 2013). Public authority needs to include private sector on its integrated market regulation approach, otherwise private operators might act strategically taking advantage of curbside price increases and the impact of policy intervention would be hampered. Inci and Lindsey (2015) suggest that efficiency can be reached by regulating private sector prices; however this kind of regulation would be highly unlikely due to political constraints. In a market with high sunk cost and long assets time span this type of change in regulation will translate into a major cut in profitability that will imply a strong opposition, discouraging private investment and compromising off-street garage supply. Thus, we would rather recommend the public authority to explore the introduction of competition to discipline private sector prices. And taking into

account that a cross-subsidy might be welfare enhancing it might also be advisable to explore potential public-private partnerships that link curbside management to garage concessions. However, the interaction between public and private agents in this market is not well stablished and needs further research.

Additionally, this substitution effect also endorses the dependence between garage and curbside demand. According to our estimates, it cannot be neglected, as also stated in Madsen et al. (2013). This indicates the need to further develop existing curbside transaction data demand models to simultaneous curbside and garage modelling for occasional parkers; an approach that has not yet been taken into account in the empirical literature (Ottosson et al., 2013; Madsen et al., 2013; and Ibeas et al., 2011). This is very relevant as all previous parking demand elasticity estimates are potentially biased (including the ones we report).

However, the curbside fee has no statistically significant impact for subscribers, which indicates that there is no substitution effect for this demand segment between on-street and off-street. This is in line with Khodaii et al. (2010) and Kobus et al. (2013), as short stay parkers are more sensitive than long stay users. However, our results go one step further and indicate that garage subscribers are not sensitive at all. This additionally suggests that subscribers and occasional parkers might be pretty independent demand segments. But yet, even we do not consider it in this paper, an issue that needs further consideration is the fact that subscribers might find closer substitutes in off-street private parking supply (monthly rents) which will be affected by parking minimum requirements, private parking office availability and specific regulations.

All this shows that curbside parking regulations are a relevant determinant of garage demand, and public authorities should make an effort to manage them as a single system. Our results indicate that the way curbside parking spaces are regulated (parking allowance and time limits) has a considerable impact. Reducing the total supply of curbside spaces will shift occasional parkers to garages; even curbside fee policy is an even more efficient trigger for behavioral change. This advocates for shifting Barcelona's actual parking policy to embrace pricing full potential implementing more complex schemes (Shoup, 2005). If the goal is to shift cars from on-street to off-street parking while ensuring cost recovery, then the proper combination of pricing and spaces in the policy can help to achieve this.

Finally, OCC and SUB models differ in the impact of neighborhood characteristics on aggregate demand. The population (POB) shows no statistically significant relation with OCC, which could be due to the fact that occasional parkers do not need to reside in the garage area. In contrast, as expected SUB is strongly positively related to population, as residents are probably the largest group of users in need of a parking subscription.

The car ownership ratio (RCAR) is only positively related to SUB, with an estimated elasticity in the number of cars per inhabitant of 0.73. This shows that car ownership changes are an important driver of parking subscriptions. As expected, OCC shows no statistically significant relation with the car ownership ratio, as occasional parkers' demand is mainly driven by visitors.

Land value changes (LANDV) do show a positive relation with OCC and SUB of about the same magnitude, even though the interpretation of the meaning of this variable in each case is different. OCC estimated elasticity at mean values is about 0.24, which could capture the type of economic activities that take place in the area (unobservable for us), suggesting the need to further consider the spatial distribution of economic activity. However, SUB estimated elasticity is 0.19, which is in line with the range of estimates reported by Gillen (1977).

2.6 Conclusions

The impact of curbside parking regulation on garage parking demand is investigated in this paper. Specifically, we analyze the aggregate demand behavior of two demand segments: occasional (OCC) and subscribers' parking (SUB). Two econometric models are proposed, one for each of these demand segments. The aggregate demand functions of the OCC and SUB models are estimated using a panel from Barcelona's public parking authority (BSM) that covers 34 garage facilities with yearly data for the period 2006-2012. The OCC model is specified as an event count model estimated by means of negative binomial specifications, and the SUB model is estimated by least squares adapted to panel data; both accounting for garage-specific fixed effects and time-specific shocks. This method is far less data-demanding than existing microeconometric approaches and it can be easily applied to any cities,

regardless of their parking data-gathering technology; where only enough yearly summaries need to be available.

This approach allows us to provide the first empirical estimates reported in the literature for garage demand responsiveness by segments (occasional parkers and subscribers). Our estimates show that both garage demand segments are fairly responsive to their own price, with elasticities close to the curbsides' upper bound figures. Both occasional parkers and subscribers of garages show the same sensitivity to garage fee and subscription cost, respectively.

Regarding curbside pricing interaction, we find that occasional parkers show high curbside fee cross-elasticity; while subscribers hold no statistically significant relation. This indicates a clear substitution effect between curbside and garage parking for occasional parkers. Whether subscribers might find closer substitutes in off-street private parking supply (monthly rents) or not, which will be affected by parking minimum requirements, private parking office availability and specific regulations, will need further research as it is beyond the purpose of our analysis.

The fact that the cross-elasticity for occasional parkers is below own-elasticity suggests that the curbside might be preferred to garage parking (curbside premium). All this highlights the key role of a fee differential between curbside and garage to achieve efficient parking demand allocation, and the relevance of undertaking an integrated curbside/garage market management approach, as already claimed in theoretical works (Arnott, 2006; Inci and Lindsey, 2015). In our specific case, the estimates also show the huge pricing efficiency gap that exists in Barcelona, driven by a homogeneous public garage parking fee policy and uncoupling between curbside and garage regulation.

Regarding regulations on curbside spaces, we find that both demand segments show quite different sensitivities to the types of regulated spaces. OCC demand is negatively related to the number of commercial spaces, while the relation with subscribers is positive. This suggests that commercial spaces act as a curbside substitute for occasional garage parking, but act as a curbside constraint for subscribers.

Mixed use spaces have no statistically significant impact on OCC or SUB demand at any given buffer, which contradicts the common assumption used to justify these spaces, as resident permits do not seem to lead to any additional

demand shift from the curb to garages (as in the case of commercial spaces). The provision of free and resident-exclusive parking spaces has a small, negative effect on subscribers' demand, while occasional parkers show no response, presumably due to the comparatively higher walking cost.

All this shows that curbside parking regulations are a relevant determinant of garage demand, and public authorities should make an effort to manage the curbside/garage parking market as a single system. Our results show that the characteristics of curbside parking spaces (allowance and time limits) and the pricing strategy play a role in garage demand determination, with relevant differences between demand segments. Curbside fee policy is an even more efficient trigger for behavioral change, and the proper combination of pricing and spaces policy needs to be applied to avoid counterbalancing its effects. Thus, the development of future parking pricing schemes must take into account curbside and garage interactions.

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3 The determinants of garage prices and their interaction with curbside regulation.

SUMMARY:

The market for parking is characterized by intrinsic distortions such as cruising in search of a parking space and garage market power. Theoretical studies stress that the price differential between curbside and garage parking fees is critical in addressing this inefficiency; yet, the interactions between the two have received little attention to date in the literature. By drawing on a new self-constructed database for all the garages in the city of Barcelona, we empirically explore the determinants of garage prices. Our results indicate that prices are mainly influenced by fixed and variable cost drivers, the dominance position of the garage in its surrounding market and the garage's interaction with curbside parking. We also find that prices react to the scarcity of parking spaces in the street and to the curbside price fixed by the public authority.

Keywords: Garage parking; Curbside parking; Price distortion; Parking regulation

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3.1 Introduction

Parking policy forms an integral part of mobility management strategies for tackling congestion and improving the environmental quality of big cities. Yet, policy-makers face a severe challenge when having to design efficient parking policies in a scenario of scarce resources, high supply expansion costs and an increasing attention to quality of life (Mingardo et al., 2015). Curbside parking regulation has been widely implemented (and even expanded), but prices have typically been held relatively low. To address excessive curbside demand, parking supply has been expanded through the provision of garage facilities, despite economists' recommendations of the need to solve the common-property resource problem (Anderson and de Palma, 2004; Shoup, 2005: Inci, 2015).

Although curbside regulation has begun to adopt market-oriented perspectives,[22] the question of parking charges remains controversial from a political economy perspective. Some interest groups, including retailers and motorist associations, lobby for lower prices, while others, most notably environmentalists, seek the introduction of policies that will limit private transport use, seeing parking prices as a readily and more feasible alternative to road pricing. Private operators already provide a sizable off-street parking supply, to the extent that the vast majority of parking spaces in European cities are provided by off-street parking garage facilities (Rye and Koglin, 2014). Municipalities are responsible for curbside parking and in many instances they also manage a significant share of the garage supply that coexists with private operators.[23]

Spatial competition models that integrate both garage and curbside parking (Arnott, 2006; Inci and Lindsey, 2015 or Arnott et al., 2015) show that the equilibrium in the garage market is reached when the full price of parking at the curb (including the search cost) is equated to the full cost of parking in a garage (including the walking cost) and adjusted through the variation in the levels of

[22] See Pierce and Shoup (2013) and Millard-Ball et al. (2014) for evaluations of the case of SFPark in San Francisco.

[23] See ITDP (2010, 2011) and Gragera and Albalate (2016) for reviews of the US, Europe and the specific case of Barcelona, respectively.

cruising for curbside spaces, as both goods are substitutes. The parking market is distorted by both the negative externality associated with cruising for empty curbside spaces and the garages' localized market power attributable to their discrete location, which they exploit by setting fees above the marginal cost. Garage operators take advantage of curbside congestion, as they do not internalize the search externality.[24] They stress the need to maintain an appropriate price differential between curbside and garage fees to eliminate cruising. The external cost of cruising is very relevant, as shown by van Ommeren et al. (2011) and Inci et al. (2015); and the role of the price differential is supported by the evidence of the lengthy cruising times experienced in cities where there is a large differential in favor of garages (Shoup, 2005) and the short cruising times for those that face higher curbside fees (van Ommeren et al., 2012).

Few empirical studies of competition in the garage market have been published; but the interactions between curbside and garage parking have received little attention. Lin and Wang (2015) is the only previous study to have examined price determinants, with a specific focus on the relationship between competition and price discrimination in Manhattan's garage market. They investigate how market concentration affects overall garage prices and the curvature of their hourly price schedules. Their results suggest that competition drives the overall price level down and market dominance position increases it.[25] They also show that zoning density is positively associated with garage prices and that price discrimination diminishes as competition intensifies, indicating that prices for short-term parking decrease at a proportionally higher rate than prices for long-stay parking (price schedules become less curved), due to differences in search behavior.[26] Other available empirical works focus on garage mergers. Both, De Nijs (2012) and Choné and Linnemer (2012) undertake a retrospective merger evaluation, analyzing the takeover of GTM by

[24] Inci and Lindsey (2015) stress that the market failure level varies with the distance between garages, the unitary search costs associated with cruising and the level of curbside fees.

[25] A unitary decrease in the Herfindahl Hirschman Index (HHI) measured as the squared fraction of facilities managed by a company within the relevant market buffer around each garage reduces the price by 95%, while a unitary increase in the owned share of competitors increases the price by 53%.

[26] Long-stay parkers are assumed to undertake more intense searches, as their expected gain is greater and more likely to be repetitive.

Vinci in Paris.[27] Their findings suggest that the reduction of competition increased price levels, while proportionally larger discounts were applied to long-stay parkers resulting in further price discrimination.[28] Froeb et al. (2003) analyze the role of capacity constraints in the welfare effects resulting from a merger using computational experiments. Their results suggest that when capacity is binding on the merging firms this factor attenuates merger price effects much more than the corresponding effect in a scenario without a merger, due to the prevention of share-stealing quantity responses.

None of the previous empirical works have specifically integrated the competition between curbside parking and garages in their analyses.[29] Such relation has only been empirically tested from a demand perspective by Kobus et al. (2013) and Gragera and Albalate (2016). The first analyzes the impact of parking prices on drivers' choice between curbside and garage parking; while the last studies the impact of curbside regulation on public garage demand. Both studies conclude that these goods are not perfect substitutes and that drivers generally might prefer curbside parking (in the analyzed city settings).[30] Likewise, they both find that users are willing to pay a premium for curbside parking, ranging from €0.37 to €0.60 per hour in Almere (Netherlands) and €0.55 per hour in Barcelona. This can further exacerbate the pricing distortion when garage fees are higher than those at the curbside increasing cruising externality. Additionally, Gragera and Albalate (2016) show that curbside parking regulations are a key determinant of garage demand, and that the characteristics of curbside parking spaces (parking allowance and time limits)

[27] The merger between GTM and VINCI gave rise to Vinci Park, the largest garage operator in the French market; currently known as INDIGO.

[28] De Nijs (2012) findings suggest that a unitary increase in the HHI represents a 68% increase in prices. Likewise, Choné and Linnemer (2012) reported that the merger increased city-owned garage prices by 3%. The authors stress that city-owned garages under concession contracts are subject to price-cap regulations, even though this constraint has never been binding.

[29] Only Froeb et al. (2003) include an outside/no-purchase option, though it is not specifically considered as curbside parking, and they assume that garage parking is always preferred to the outside option.

[30] In many EU and US cities curbside parking tends to be relatively ubiquitous and might offer a walking cost or information salience advantage with respect to garages, even this will depend on city specific characteristics. Note that safety or weather conditions might even counterbalance such advantages if they exist.

play only a minor role while the pricing strategy is the most efficient trigger of behavioral change.

This paper contributes to the literature by exploring the determinants of private garage prices, focusing specifically on cost shifters and on the impact of curbside regulation on garage price-setting decisions expanding previous empirical evidence presented in previous literature. As such, the paper contributes to the scarce literature on garage prices and offers the first analysis of the interactions of these prices with curbside regulations (fees and the regulated use of spaces). By drawing on a new self-constructed database for all the garages in the city of Barcelona, we estimate a price equation that accounts for a variety of price determinants including (1) cost drivers; (2) the market structure of the surrounding area; (3) specific garage characteristics that customers might value; and (4) the specific curbside regulation of the given area. Our results are useful for examining potential policy interventions to address parking market distortions. To the best of our knowledge, this is the first empirical paper to investigate the interactions between curbside and garage parking prices.

The paper is organized as follows. Section 3.2 briefly presents the data and the model considered. Section 3.3 presents and discusses the results of the model, while section 3.4 offers the main conclusions and presents the policy implications of our results.

3.2 Garage price determinants

3.2.1 The model

To analyze private garage operators' price-setting behavior, we estimate a price equation for a cross-section of garages as shown in (1). We assume that the price of each "home" garage (p_i) is a function of its characteristics (c_i), market structure conditions (m_i), curbside parking regulation (k_i) and public transport availability (t_i) within a given catchment area around each facility (with buffer radius D).

$$p_i = f(c_i, m_i, k_i, t_i, \alpha_i, \varepsilon_i) \quad (1)$$

The price equation is estimated by least squares, using cluster robust standard errors to account for any possible remaining heteroscedasticity. We chose a log-linear functional form, as also adopted in Lin and Wang (2015).[31]

The price function also depends on area-specific effects – most notably, potential demand and cost shifters, which we introduce to control for unobserved heterogeneity. In our case, we introduce district-level-specific effects. This strategy also allows us to control for the potential endogeneity of curbside fees, given the expectation of higher curbside prices when higher garage fees are in place (although these might be fixed by the public authorities, as suggested in Madsen et al., 2013). However, it does not allow us to fully control for the potential endogeneity of market concentration measures, where there might be a bias towards zero.[32] The price function also depends on an idiosyncratic error term (ε_i).

This approach expands the considerations made by Lin and Wang (2015) by including both cost shifters and curbside regulation characteristics, which have not previously been taken into account in the empirical literature.

[31] We also tested two alternative functional forms (linear and log-log) and opted for goodness-of-fit (log-likelihood).

[32] Lin and Wang (2015) also highlight that area specific effects might only partially solve the problem of Cov(ε_i, c_i)≠0, as performance might feed back into market structure (Evans et al., 1993). This could be solved by means of instrumental variables, but it is very difficult to find instruments that proxy market structure while being uncorrelated with unobserved factors that affect garage prices. Even the garage market faces huge entry barriers (high sunk costs) and past evidence shows extremely low entry/exit rates in Barcelona. We must therefore be cautious when making any interpretation of the market concentration variable even it is not the focus of our analysis. However, we include it in the model for sake of comparability with Lin and Wang (2015).

3.2.2 The data

In order to estimate our model, we conducted a cross-sectional inventory survey of all public-access garages currently operating in Barcelona.[33] For each garage, we gathered information on their physical characteristics and price menus. The physical characteristics that were not directly observable were self-reported by garage employees to our interviewers. The same approach was adopted for price menus that were not openly displayed. The information was gathered in two waves. The first was conducted from 9-27 February, 2016. The second was organized to correct missing information and corroborate data, and took place from 1-15 March, 2016. We collected complete information on prices for 508 garages (see Figure 3-1), representing a total of 114,417 parking spaces. Following City council estimates public-access garages only represent about 18% of total off-street parking supply (650.000 parking spaces) in the city, and more or less match the available curbside parking supply (140.000 parking spaces) (DB Aj.BCN, 2015).

The garage market in Barcelona is led by the public sector, with a public operator (BSM) directly managing 40 facilities and indirectly participating in a further 20 in an institutional public-private partnership (PPP) known as BAMSA. The principal private operator, SABA, participates as the sole private shareholder in this PPP. In addition, Barcelona City Council owns a further 48 facilities that are operated under a concession regime subject to price-cap regulation. Despite its very limited presence, there exists another public operator owned by the provincial entity "*Consell Comarcal del Barcelonès*" (REGESA), which owns 4 facilities in the city also operated under concession regime.

The private sector is atomized in Barcelona, with only NN (a local real estate company) and SABA (world leading parking operator) managing a relatively large number of garages – with 26 and 17 facilities, respectively.[34] Other multinational parking operators, including INDIGO, EMPARK and INTERPARKING, manage/own between four and five facilities each.

[33] Barcelona's public curbside and garage parking operator (BSM) provided us with various price studies, but sample homogeneity was not maintained across these studies and information gathering characteristics varied. This precludes us from using this data to conduct a panel approach.

[34] It is relevant to stress that only three of the facilities managed by SABA are out of the concession regime.

However, almost 80% of the private facilities are managed by a garage operator that is affiliated to the garage union (*Gremi de Garatges de Barcelona*). A summary of the ownership structure of the garage market in Barcelona is shown in Table 3-1.

Figure 3-1. Public-access garage inventory and ownership structure in Barcelona (Source: Authors' survey)

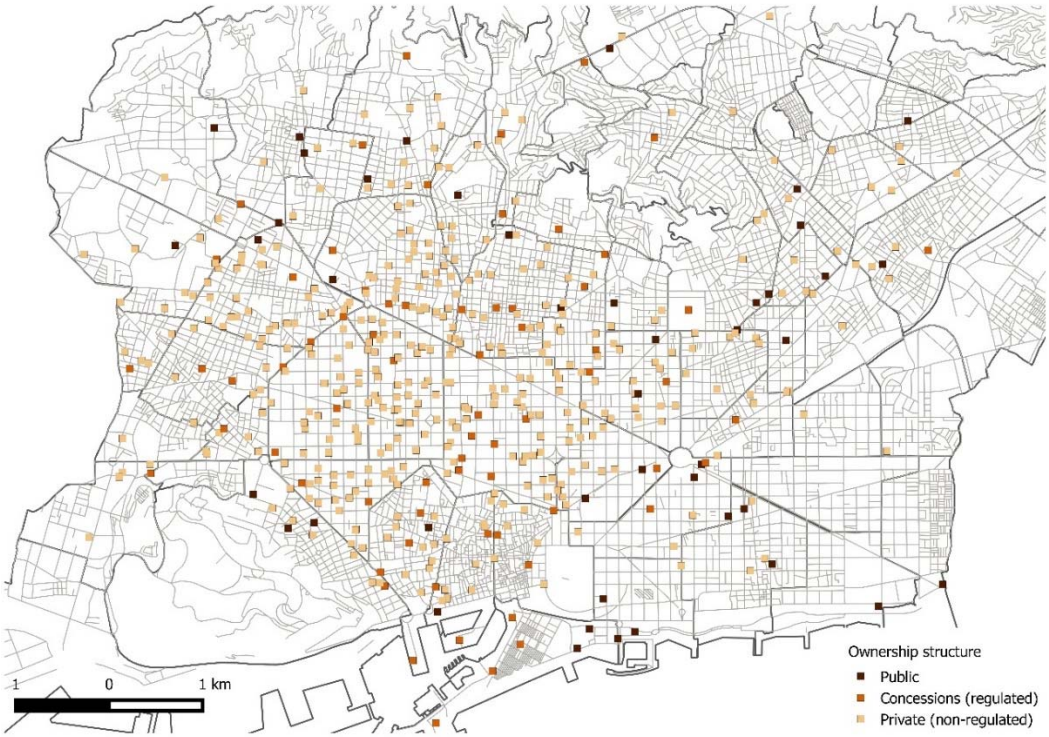


Table 3-1. Ownership structure of the garage market in Barcelona.

Type of facility	Num. Garages	Num. Companies	Perc.
Public	40	1	7,87%
Regulated prices	72	28	14,17%
Non-regulated prices	396	326	77,95%
Op. > 5 facilities	26	1	5,12%
Op. = 5 facilities	5	1	0,98%
Op. = 4 facilities	8	2	1,57%
Op. = 3 facilities	24	8	4,72%
Op. = 2 facilities	38	19	7,48%
Op. = 1 facilities	295	295	58,07%
Total =	508	355	

The global HHI for market concentration, computed as the square of the share of managed facilities, is just 0.01, given that 295 garages are managed by single-facility companies.[35] It should also be stressed that the leading role played by the public sector is a reflection of the market's inherent entry barriers that are largely dependent on land acquisition costs. The public sector has been able to reduce these by placing garages underground on public land.

Although we collected information for 508 garages, our dataset is restricted to just 396, as we do not include the garages of the public operator and those operating under concessions in the estimation.[36] The reason for this is that the prices charged by public garages are fixed by the public authority and respond solely to political decisions, not to demand or changes in market structure.[37] Here, it should be stressed that in the case of Barcelona all concessions are subject to price-cap regulation, which is usually binding, in contrast to the situation reported by Choné and Linnemer (2012) for the case of Paris. In short, we study the determinants of those garage prices that are freely set by private operators.

Price information is typically visible to drivers when entering the garage. Price menus establish a differentiated fee per minute depending on parking duration, generally decreasing with the length of the stay (though from the customers' point of view the calculation of the price to be paid is far from straightforward). There are also discounts for overnight stays of 8, 12 and 24 h, but these are not always clearly stated. Discounts for subsequent days are also quite generally applied. However, price differentiation with respect to the time of the day is

[35] Figures derived from the information available in de Nijs (2012) and Lin and Wang (2015) suggest that the case of Barcelona might be somewhat extreme. For the case of Paris, we can compute an equivalent market concentration figure yielding an HHI of 0.11 before and 0.18 after the Vinci/GTM merger. For the case of New York City this is not possible, but the authors report that four companies control about 50% of facilities, the six biggest controlling 60%, with 15% being controlled by companies that own more than one garage (20) and the remaining 25% being operated by single-garage companies. The equivalent figures for Barcelona are 20, 22, 20 (37) and 57%, respectively.

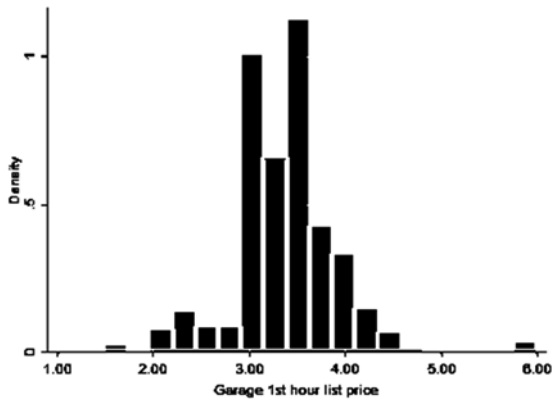
[36] Note that we further eliminated from the sample some facilities that only partially reported relevant information and show missing values for the explanatory variables included in the different specifications of our model.

[37] BSM sets a uniform price for all its facilities, aiming at cost recovery and spatial fairness based on a City Council Agreement (i.e., Mobility and Security Commission Act, 12 July 2007). Contracted-out facilities set prices based on the price-cap regulation applied.

practically non-existent in Barcelona. Discounts are also offered to frequent costumers, purchasable in advance, and special rates or valet services for commercial and recreational activities. All in all, it should be stressed that drivers, in general, lack perfect information about both prices and the facilities available to them (Albalate and Gragera, 2017b). However, note that here the dependent variable in our model is measured as the list price for the first hour of parking computed according to the "official" fees and not applying any specific discount.[38] In this regard, we follow the approach taken in Lin and Wang (2015).

The city mean overall garage fee for the first parking hour is 3.32€/hour (Std.Dev 0.50€/hour). Publicly managed garages apply a flat 3.05€/hour fee in all their facilities; while the price-regulated ones (concession) charge on average a little higher fee (3.09€/hour, Std.Dev. 0.38€/hour). Non-regulated price facilities charge on average 3.38€/hour (Std.Dev. 0.53€/hour). The frequency distribution of prices in our sample is shown in Figure 3-2; while its spatial distribution is shown in Figure 3-3.

Figure 3-2. Garage first hour list prices in our sample (not includes public and price-regulated garages).

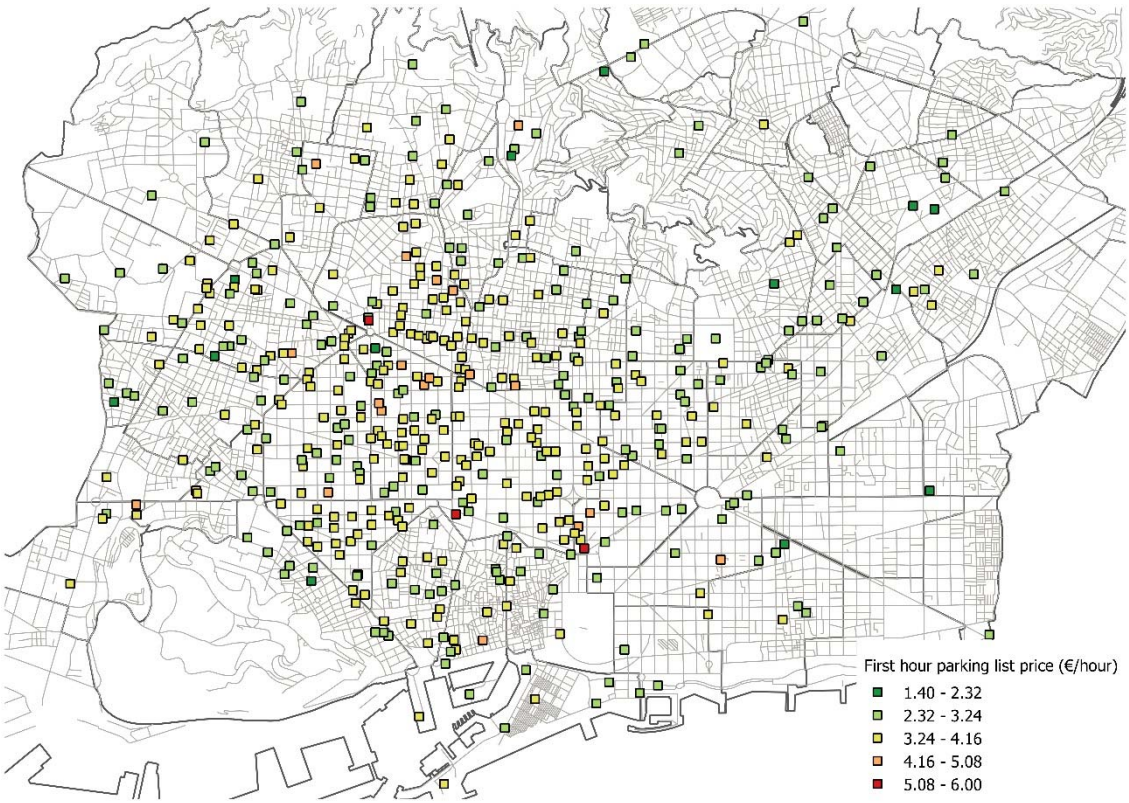


We introduced all this information, plus curbside parking and neighborhood characteristics, in a database using geographic information systems software

[38] Information on the distribution between discount and non-discount users is not available for private garages. However, according to our knowledge on public garage demand non-discount transactions represent above 75% of all visitors in the BSM garage network – the largest in Barcelona-; and above 50% if we also include all types of garage subscriptions (that do only apply to every day parkers).

(QGis). In order to compute spatially related explanatory variables, we specify the catchment area around each garage facility as a buffer of 500m.[39] The curbside information has been provided by BSM and the neighborhood data is made publicly available by the Barcelona City Council Statistics Department.

Figure 3-3. Spatial distribution of garage first hour list prices in Barcelona



[39] We estimated the model for a continuum of buffers, yet we only report the results for the 500m (0.3 mile) buffer. This is our preferred market definition as it is the largest buffer with statistically significant estimates for the variables at stake. Note that the minimum feasible radius is constrained to the existence of sufficient variation in the data for these variables. This 500m radius allows us to compare our results with Lin and Wang (2015) and matches the maximum acceptable outdoor walking distance criterion described in Smith and Butcher (1994). Additionally this distance is generally used by practitioners as a rule of thumb for a garage catchment area.

3.2.3 Variables

We considered a variety of garage price determinants. In this section, we describe the variables employed in the analysis and discuss their expected impact on our dependent variable.

3.2.3.1 Garage characteristics (costs and quality drivers)

First, we account for garage capacity (CAPACITY) by including the number of parking spaces in each garage facility. This variable is expected to capture the cost component associated with investment costs related to construction (potential scale economies), but it also reflects the scarcity of the supply in relation to potential demand. The question of scarcity may also play a role in price determination, as garages will tend to set higher mark-ups the higher the potential demand is with respect to their available capacity.

Similarly, we include a land-value proxy computed as the real estate average selling price (LANDVALUE) in euros per square meter.[40] This is expected to capture the differences in investment costs but also, in part, the intensity of demand in different areas. The inclusion of this variable precludes us from using other neighborhood characteristics so as to avoid issues of multicollinearity (i.e., zoning density, level of economic activity, etc.). It should be stressed, however, that the correlation between CAPACITY and LANDVALUE is low (-0.07), so while both variables proxy investment costs they capture different dimensions of it, with CAPACITY capturing garage size and LANDVALUE capturing the investment cost per unit for the corresponding garage size.

We also include the number of operating hours per week (OPERHOURS), in order to account for personnel costs and other expenses associated with the operation of the facility. We expect to find a positive impact of both variables on garage prices.

Additionally, we include other garage characteristics that can be expected to impact price-setting behavior. Using dummy variables, we test whether garage type (within a building, stand-alone or associated with a specific activity),

[40] Source data are provided at the neighborhood level, so we compute the weighted average real estate selling price proportional to the neighborhood area that overlaps with the relevant market buffer.

payment options (manual, automatic or teletac) as a proxy of technology and price salience (visible from the outside, only visible inside or not made visible at all) translate into a price differential. Similarly, we would also expect garages that invest more in technology (occupancy sensors, guiding systems and more advanced payment tools) to show a different pricing behavior, based on higher investment costs (albeit presumably lower personnel needs). Moreover, there is an expectation that high technology garages will attract drivers with a higher willingness-to-pay due to a perception of greater quality (e.g., some companies offer teletac to employees using company cars to facilitate the control of the firm's expenses). Price salience is not expected to provide statistically significant differences for our sample as very few private operators show price menus outside the facility. The vast majority of garages do not make prices visible until drivers actually enter the facility, which might make no difference with respect to those facilities that do not report them (reference category).

3.2.3.2 Market structure

Our model also accounts for market structure factors by including a market concentration measure, specified as the HHI. We compute this index as the squared fraction of facilities managed by each company within the relevant market buffer around each garage.[41] This figure moves between 0 and 1, with the latter value denoting a monopoly firm.

We also include the share of competitors owned by the same company as that which owns the home garage (SHOWN) within the relevant market buffer, as a measure of its market power. In addition, we test whether the actual level of competition induced by the presence of contracted-out garage facilities (SHCONCES) within the relevant market buffer has an impact on the pricing behavior of private operators. This variable is measured as the proportion of competitors to the home garage that are contracted out by the City Council (recall, all concession terms establish a price cap). Likewise, we include alternative specifications in order to check whether publicly managed (BSM), mixed (BAMSA) and contracted-out facilities have any impact, taken separately or grouped, on private sector prices. The leading role played by the public sector

[41] Alternative specifications were also computed using the share of garage parking spaces. The specification chosen is equivalent to that used in Lin and Wang (2015) but with the opposite sign; however, they suggest that this is the one most closely related to garage pricing behavior.

in Barcelona suggests the need to test whether the actual pricing strategy followed by the City Council helps bridge the pricing efficiency gap, as reported in Gragera and Albalate (2016).

Additionally, we also control for a potential difference in the behavior of affiliates with respect to non-affiliates by including a garage union dummy (UNIONaffiliate). We control for this as there is evidence that the union has, in the past, been fined by the Antitrust Agency owing to the garage subscription and hourly price recommendations made to its affiliates, causing an increase in prices.[42] We try to simply check whether prices are higher or lower than non-affiliated garages. Note that collusion in a market where agents repeatedly interact during a very long time span does not need to be restricted to union affiliates. There are no current evidences of either tacit or explicit collusive behavior that might bias our estimation, but if it exists we should expect that our estimates are upward-biased. Yet any further analysis on potential collusive behavior falls outside the scope of this paper and data availability.

3.2.3.3 Curbside parking and transit (outside options)

Barcelona applies a city-wide parking regulation policy, known as ÀREA, in which no free curbside spaces are available, except in the city's outskirts (see Figure 3-4). A specific branch of the public operator (BSM) is responsible for about 52,000 regulated curbside spaces with dedicated uses (i.e., commercial, residential, mixed uses, etc.). These spaces are split into 22 regulatory zones with four fee/hour bands for commercial spaces and two bands for mixed use spaces (see Table 3-2). Commercial spaces are only available to visitors; while mixed use spaces are also open to residents (0.20€/day) and charge higher fees to visitors. Fee bands are set according to actual parking demand, although no occupancy level target is fixed. It should be stressed that the curbside pricing strategy presents no evident links with garage fees, not even in the case of the BSM-managed garages.

Our main contribution is the inclusion of curbside regulation features in the model in an effort to account for the impact of on-street alternatives to garage parking. We account for the level of supply using the density of commercial and mixed-use parking spaces (DENSPACES) set within the relevant market buffer,

[42] See *Comisión Nacional de los Mercados y la Competencia* (CNMC) Expte. 336/93.

measured in spaces per hectare.[43] We also include the weighted curbside price per hour (CURBFEE) to capture the way in which private operators respond to curbside price setting, as both theoretical and empirical studies stress its relevance in the allocation of parking demand.

Figure 3-4. Regulated curbside parking space fees per hour.(Source: Barcelona de Serveis Municipals, BSM)

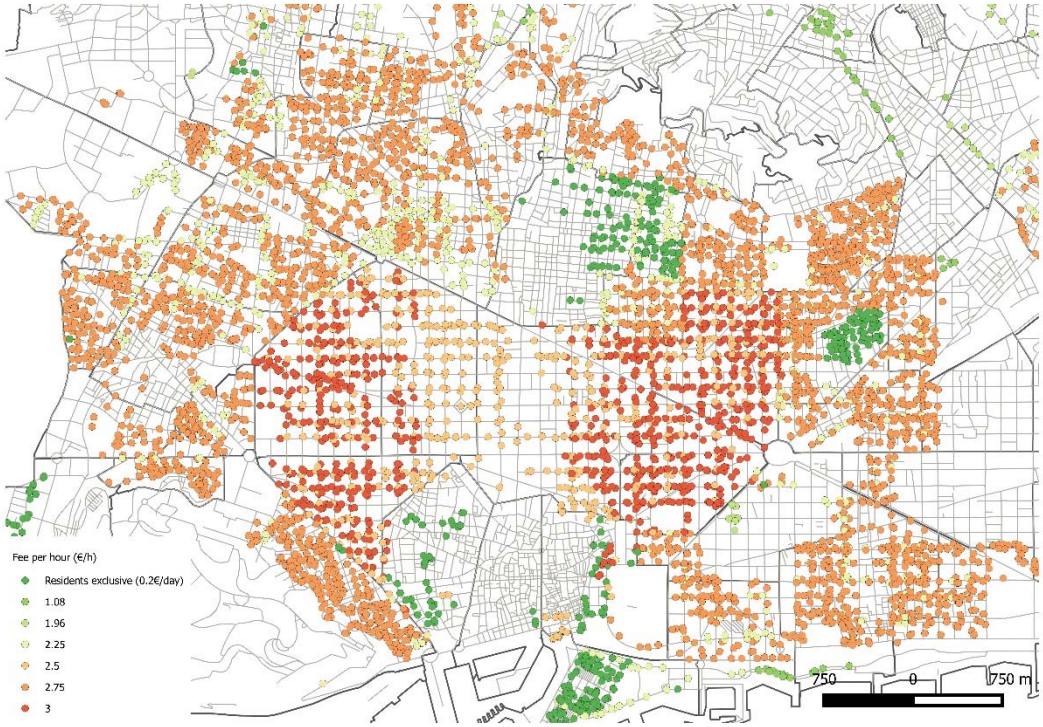


Table 3-2. Curbside regulated space fee scheme for commercial (blue) and mixed use (green) spaces.

	Commercial spaces		Mixed use spaces	
Band	Fee	Time limit	Fee	Time limit
A	2.50 €/h	1-2 h	3.00 €/h	1-2 h
B	2.25 €/h	2 h	2.75 €/h	1-2 h
C	1.96 €/h	3 h		
D	1.08 €/h	4 h		

Additionally, we include a measure of the garage's position of dominance over the curb to account for relative scarcity, measured as the ratio of home

[43] Note that 1 hectare is equivalent to a 10,000 square meters, equivalent in turn to a standard block in the *Eixample* district of Barcelona (CBD).

garage parking spaces to curbside spaces for commercial and mixed uses (GCratio).

To capture additional options to garage parking, we also include a measure of the availability of high capacity transit services, based on the number of access points to train, subway or tramway stations within the relevant market buffer area (TRANSIT). This measure captures both the availability and intensity of these services, as the number of station access points is correlated with the number of lines serving the area and, to a certain extent, with the volume of passengers. Alternative specifications are tested by means of a robustness check (dummy variable for the availability of a station).

Table 3-3 shows the descriptive statistics of the previously mentioned variables, with the exception of dummies.

Table 3-3. Summary of descriptive statistics for the variables included in our model. Dummy variables are not included.

Variable	Obs	Mean	Std. Dev.	Min	Max
FEE1stH	396	3.377449	0.5312005	1.5	6
CAPACITY	396	171.053	160.9266	9	1500
LANDVALUE	396	3527.959	724.9933	1517.27	4996.998
OPERHOURS	396	123.3283	45.17525	18	168
HHI	396	0.1240499	0.1636493	0.03125	1
SHOWN	396	0.0026863	0.0150682	0	0.1428571
SHCONCE	396	0.1224065	0.111487	0	1
TRANSIT	396	8.373737	5.80063	0	40
DENSCURB	396	11.20878	6.228112	0	25.75764
GCratio	392	52.51028	304.9318	0.4384977	5609.987
CURBFEE	392	2.654956	0.2113508	1.08	2.919482

3.3 Results and discussion

In this section, we present and discuss the results of the estimation of the price equation for our data sample. The results for the various alternative specifications are reported in Table 3-4. We build up the model from (1) to (4) by successively incorporating additional groups of variables: thus, Model (1) includes garage characteristics that account for the cost and quality drivers; Model (2) adds market structure characteristics; Model (3) adds both curbside

parking and transit options; and, Model (4) also includes area specific-effects.[44] It is apparent that the parameter estimates differ markedly with and without the area-specific effects and so Model (4) is our preferred specification. However, the only area-specific effect that is shown to be statistically significant is that of the district of St. Andreu (a residential district that concentrates low income levels and less added-value economic activities), where garages charge a first hour fee that is 22.5% lower than that charged in the reference area (Ciutat Vella – historic district).

Table 3-4 shows that the result for CAPACITY (estimation 4) is negatively related to the garage fee, reflecting both the cost and scarcity dimensions. The sign obtained can be interpreted as evidence of horizontal scale economies in garage construction, as suggested by Arnott (2006), so that garages with higher capacity would be able to operate at lower marginal costs and, thus, charge lower fees.[45] However, it also reflects the fact that in areas of excessive demand (when the garage becomes capacity constrained), the garage might well set a higher mark-up, implying that low capacity garages set higher fees. As Froeb et al. (2003) note, we can expect a garage with demand exceeding capacity to set prices in such a way that potential demand at the given price is equated to available capacity. Overall, we find that each additional garage parking space reduces the fee for the first hour by 0.01%.

LANDVALUE is found to be positively related to prices, reflecting both the cost and demand dimensions. High-value residential areas are also characterized in our data sample by high levels of economic activity which attract demand to

[44] As a robustness check, we additionally estimated this model specifications including in the sample also concessions. We find that parameter estimates are not significantly changed, besides the fact that facilities placed in public land exhibit lower prices (11%). Note that not all concessions are placed in public land. Additionally, the inclusion of concessions introduces higher variability in price salience dummies and shows that those facilities posting prices in the street charge a significantly lower price (5%). However, a dummy included to control for concessions different price behavior is found to be not statistically significant. Moreover, we do also estimate a restricted model just including concession observations to find out that none of the parameters for cost shifters, market structure or curbside regulation turns out to be statistically significant. Note that model 3 and 4 have a lower number of observations as 4 garages placed in pedestrian only area are dropped from the sample, having no information on curbside parking variables.

[45] Arnott (2006) suggests that scale economies arise from the fixed cost (and space) imposed by the need for a ramp that connects different parking floors. We tested for the linearity of scale economies but $NUMPLACES^2$ was not statistically significant.

the area. This correlation precludes our disentangling the land value from the zoning density effect, as is done in Lin and Wang (2015). Here, a 1,000€/m2 increase in the land value translates into a 3.31% increase in the garage fee. This reflects one of the main entry barriers to the market and explains why new entries have been largely undertaken by the public sector by means of publicly managed or contracted out facilities located underground in public spaces. This is the only way to alleviate land acquisition costs in a densely populated city.

Table 3-4. Estimated alternative specifications of the price equation for a 500m-buffer around each garage facility. (1) Incorporates only costs and garage characteristics, (2) adds market structure, (3) adds outside options; and (4) includes area-specific effects.

Dependent variable:	Log(Price)			
Variables:	(1)	(2)	(3)	(4)
CAPACITY	-0.000124**	-0.000135***	-0.000142***	-0.000109**
	(4.79e-05)	(4.88e-05)	(4.99e-05)	(4.45e-05)
LANDVALUE	6.74e-05***	6.30e-05***	6.33e-05***	3.31e-05**
	(9.88e-06)	(1.09e-05)	(1.13e-05)	(1.31e-05)
OPERHOURS	0.000705***	0.000697***	0.000755***	0.000646***
	(0.000190)	(0.000196)	(0.000201)	(0.000201)
PAYteletac	0.0673*	0.0538	0.0504	0.0561*
	(0.0366)	(0.0348)	(0.0348)	(0.0339)
TYPEactivity	-0.109***	-0.0974***	-0.0965***	-0.0811***
	(0.0249)	(0.0258)	(0.0256)	(0.0270)
HHI		-0.0599	-0.0664	-0.0348
		(0.0620)	(0.0597)	(0.0610)
SHOWN		0.532***	0.557***	0.574***
		(0.197)	(0.204)	(0.218)
SHCONCE		0.108	0.112	0.0818
		(0.0743)	(0.0801)	(0.0944)
DENSPACES			0.000326	0.000700
			(0.00143)	(0.00171)
GCratio			-1.87e-05**	-1.90e-05*
			(8.20e-06)	(9.98e-06)
CURBFEE			-0.0133	-0.115**
			(0.0396)	(0.0557)
Constant	0.870***	0.871***	0.900***	1.274***
	(0.0512)	(0.0602)	(0.133)	(0.184)
Observations	395	395	391	391
R^2	0.234	0.246	0.247	0.283

Standard errors are reported in parentheses. *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. Area-specific dummies and non-statistically significant controls that are not the focus of our analysis are not reported.

The cost measure of OPERHOURS, which reflects the operational costs associated with the number of opening hours, is found to increase the fee for each additional hour by 0.06%. We also find that the type of payment tools employed, as a proxy of investment in technology, shows a positive relation with prices. Specifically, we find that garages deploying teletac payment systems

(PAYteletac = 1) charge 5.61% more for the first hour of parking, ceteris paribus. In general, these facilities also employ parking space sensors and guidance systems that increase drivers' perceived quality. However, note that this variable might also capture a specific demand segment, which shows a greater willingness-to-pay (given that teletac is usually provided by firms to employees using company vehicles in order to facilitate the monitoring of expenses).

We also find a statistical difference in the pricing behavior of garages associated with a pre-defined activity (TYPEactivity = 1 for hotels, shopping centers, supermarkets and cinemas). In such cases, parking is seen as a commodity to attract customers and the excess capacity is made available to non-clients as a means of increasing revenue. We find that facilities of this type charge prices that are 8% lower than those of their standard counterparts, regardless of the potential discounts the latter may apply to their customers. Ersoy et al. (2016) argue that parking is a commodity bundled together with the commercial activity to attract customers, and cost recovery does not necessarily dictate the price setting behavior. Indeed, parking is a loss-leader for shopping activities.[46] Our result is providing a first empirical evidence on the suggested link between retail and parking prices when bundled, and additionally this suggests that parking operators associated with commercial activities appear to see each driver as a potential customer, thus, further expanding the loss-leader concept. This implies that the lower than average garage fees in facilities tied to commercial activities may result in the imposition of a positive externality on other users. Thus, the public authorities may encourage other facilities to open up their available capacity to the general public so as to help close the price efficiency gap. In this regard, our data also show that garages tied to commercial activities do not generally price discriminate with respect to the length of stay, probably as this would create further incentives for long-term parkers to avoid high fees by simply becoming customers with the right to discounts.

No significant impact is found in relation to price salience, either for facilities advertising their prices outside the garage or those displaying them inside the parking lot. Based on the discussion of imperfect information as reported in Albalate and Gragera (2017b), this suggests that actual price salience is not relevant as knowing the prices appears to impose an excessive cognitive burden

[46] Hasker and Inci (2014) shows why it is in the best interest for shopping malls to offer free parking.

on drivers and they fail to integrate this information properly in order to affect their decision.

In the case of the market structure variables, we find no statistically significant relationship between prices and market concentration (HHI), based on the fraction of garages owned by each company, unlike the findings reported in Lin and Wang (2015).[47] But, in line with these authors, we find that the share of garages owned by the home garage company does have a positive impact on prices (SHOWN), where a 1% unitary increase in the share of owned competitors increases the price by 0.57%. In this case, a market dominant position gives garages the opportunity to further exploit their localized market power. This figure closely matches that reported by Lin and Wang (2015) for the case of New York City.

These results suggest that the general statement that competition drives down prices (as proposed by Lin and Wang, 2015) might not always directly transfer to all parking markets, as it appears to be highly dependent on specific market characteristics. Some differences may arise simply from disparities in parking regulation. The number of regulated curbside parking spaces in NYC is much lower than that in Barcelona; and many blocks have been designated as parking-free spots. This might explain the huge price differential between garages and the curb in NYC. In the case of Barcelona, competition with on-street parking is much more intense and fee differentials are much lower.

However, it might also be that this difference arises from the presence of imperfect information (see previous discussion in relation to the findings of Albalate and Gragera, 2017b), an argument that has long been recognized in the information economics literature (Stiglitz, 1989). In atomistic markets, such as the parking market in Barcelona, it is difficult for drivers to keep abreast of price changes and the best available offers. This means garage operators have few incentives to instigate price cutting strategies that might even yield a negative relation between market concentration and prices. Garage markets with low price dispersion reduce the incentives for drivers to gain information, given that the expected gain from the search is lower than its cost. In this regard, a number of differences between NYC and Barcelona are striking. Lin and Wang (2015)

[47] As a robustness check we also estimate the model without including this variable and estimates do not change substantially.

report a 1h parking price of $12.67 with a standard deviation of $4.4 (34%); while we find a mean price of €3.38/h with a standard deviation of €0.53 (15%). Thus, we would expect the drivers of Barcelona to be less informed, which might translate into less true competition between garages (Albalate and Gragera, 2017b). We can conclude that the specific impact of imperfect information and its interplay with competition needs to be examined in greater depth in the parking market.

Additionally, and somewhat unexpectedly, we found no evidence that public garage provision has any impact on private garage operators' price setting behavior (SHCONCES). Moreover, no alternative specification considering publicly managed, mixed use and contracted out facilities, separately or as a group, yields a statistically significant impact. However, this is perhaps unsurprising if we take into account the fact that the public operator's price setting behavior does not deviate greatly from that of the private operators.[48] The City Council's price setting objective for both publicly managed (BSM) and contracted-out facilities resembles that of revenue maximization taken by the private sector. The City Council ensures cost recovery and return on investment, constrained by political agreements.[49] In the case of BSM, this imposes a city-wide homogeneous fee to promote equal spatial treatment; yet, contracted-out facilities only face a price cap to limit private operator revenues and ensure the attractiveness of the area. We should stress that this approach is generally oriented to reinvest earnings in new facility developments and, moreover, that curbside and garage pricing strategies are not coordinated (as explained in Gragera and Albalate, 2016) and no cross-subsidy yet exists.

If we examine the alternatives to garage parking, we find that the level of supply of curbside spaces makes no statistical impact on prices (DENSPVISIT), but their scarcity does. We find that the ratio of garage spaces to curbside spaces (GCratio) has a positive impact on prices. That is, the dominance of the home garage with respect to the curb drives up prices, although the effect is almost

[48] When we estimate our preferred model specification including the observations for concessions we find no statistical difference in prices with respect to private operators. If we estimate a restricted model only for concessions we find that the only driver that accounts for its price variability is whether it is placed in public land, showing no response to any other cost shifter, market structure or curbside regulation.

[49] See, for example, the City Council Agreement adopted by the Mobility and Security Commission on 12 July 2007.

negligible at an hourly fee level (0.002% for each additional curbside space). Yet, when added up its impact for all parkers and the duration of their stay is undeniable. These results are closely in line with those reported by Gragera and Albalate (2016) in the sense that even the characteristics of curbside parking supply have an impact on garage demand, pricing being a much more efficient trigger for parking choice. This result is also relevant from a policy perspective, as Barcelona City Council is substituting parking spaces for dedicated bus or bicycle lanes, which, in the light of our results, will increase garage fees if the scarcity increase is not matched by a modification of the curbside fee.

In this regard, we find that the curbside fee is negatively related to garage prices, meaning that when these fees are lower, garages charge higher fees. In our case we find that a €1/hour increase drives down prices by 11.5%. We believe that the curbside fee captures just how inefficiently the curb is used, as lower fees are also associated with longer parking stay. Moreover, lower fees are associated with commercial spaces in the vicinity of the city's CBD, where demand is still high. We believe that this captures the fact that the cost of curbside parking is higher in this area due to higher cruising levels, which gives garages the opportunity to further exert their market power.

We hypothesize that regulated curbside parking reduces competition between garages. The fact that the curbside is generally preferred to garages (Gragera and Albalate, 2016; Kobus et al., 2013), and drivers might not know of the availability of alternative garages due to their imperfect information (Albalate and Gragera, 2017b), usually makes the curb the first option. These two factors increase the amount of time spent cruising for a curbside space, driving up total parking costs and giving private garage operators the opportunity to increase their mark-up simply by capturing excess curbside demand. In this scenario, the level of competition between garages is at most very mild and prices will be unaffected by concentration measures. Indeed, they will only be affected by the dominance of the home garage with respect to other garages and the curb.

Previous findings suggest that an integrated parking policy approach is not only mandatory for the public sector, as suggested by Gragera and Albalate (2016), but it should also integrate private garage reactions to curbside parking policy regulations so as not to further exacerbate market distortions. To our mind, parking policy needs to broaden the current approach being taken to parking regulation. In this regard, it might be advisable to create a specific

regulatory body (in close coordination with existing transport authorities) that can coordinate public supply, pricing strategies and land use regulations and monitor the private sector so as to guarantee parking market efficiency within a broad integrated market focus.

3.4 Conclusions

Garage parking supplied by the private sector is a critical element in parking policy, especially as theoretical studies suggest that cruising can be eliminated if the right fee differential is set between garage and curbside parking. However, the reality in the vast majority of US and EU cities is that of higher garage fees than those charged at the curbside, resulting in a significant price distortion. In this paper, we have empirically explored the determinants of private garage operators' pricing behavior, by considering costs dimensions, market structure and curbside regulation instruments. In so doing, we have extended the empirical evidence presented in the existing literature by including both cost shifters and curbside characteristics. We estimated a price equation using a new, self-constructed, cross-sectional database for all public-access garages in the city of Barcelona (508 facilities). We restricted the analysis to 396 garages, dropping all observations for publicly operated and contracted-out facilities with publicly regulated prices (as they respond to political decisions rather than to demand or changes in market structure).

Our results suggest that curbside regulation has an impact on private garage operators' price setting behavior, supporting evidence from previous spatial competition theoretical models. To achieve pricing efficiency, the public authorities need to focus their attention on the ratio between garage and curbside supply and more specifically on curbside fees. We found curbside fees to be negatively related to garage prices, capturing just how inefficiently the curb is used. Lower fees are associated with higher cruising levels in areas of high demand, with curbside parking generally being preferred to the garage option. This gives garage operators the opportunity to further exert market power, increasing their mark-up and aggravating the preexisting distortion. Therefore, the implication is that an increase in curbside fees should help reduce these distortive market outcomes.

If the public authorities seek to address the cruising issue simply by expanding public garage supply (which likewise adopts revenue maximization as a principle for setting prices), it would not, in the light of our results, be an effective strategy. Private operators do not seem to react to actual provision levels of public garages in Barcelona; they appear only to react to curbside regulation. The only effective way to impact private sector prices using public garage provision would be to target new facilities in order to reduce the dominance enjoyed by the private operators' dominance position, given that the share of garages owned by the home garage company in the relevant market is a major positive driver of prices. Public intervention by means of increased public garage supply should focus therefore on breaking the dominance of the private sector and on introducing true competition by exploiting potential cross-subsidies from the curb. This further stresses the need for an integrated parking market approach.

However, we report that most of the price variation in the market can be explained by provision costs and quality shifters (land value, capacity, number of opening hours and type of payment), which provide both the public and private sectors with further information about the heterogeneity of marginal costs and, consequently, how best to adapt public pricing strategies. In the case of pricing heterogeneity, we should also highlight the empirical confirmation of parking bundling in garages associated with commercial-activities, which impose a positive externality. Ours is the first empirical evidence of the theoretical suggestion of parking is a loss-leader for such activities. The public authorities may want to encourage more facilities to open up their available spaces to the general public as a way of narrowing the pricing efficiency gap.

We believe that neither direct price regulation nor the aforementioned public interventions are capable of providing full efficiency, since the data analyzed here points to the existence of imperfect information in the parking market. It seems highly likely that drivers are unaware of price distributions and/or the availability of alternative garages. This situation gives garages the opportunity to exert greater market power, allowing them to increase their mark-up and aggravate preexisting distortions. In this scenario, some cruising may continue, even with direct price differential regulation. In the case of Barcelona this point seems relevant, and it might potentially represent a problem in many other cities, depending on search costs and garage price distributions. Public authorities need to invest in systems that make parking information more readily available

to drivers (including details about set price quotation/salience standards; garage quality labeling; on-line platform/App); however, further research is needed on parker information and decision-making so that public interventions can achieve full efficiency.

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4 Empirical evidence on imperfect information in the parking market.

SUMMARY:

The main focus of the literature on the economics of parking has been on the cruising-for-parking externality and garage market power. However, all studies to date assume the existence of perfect information. Yet, imperfect information may well arise as drivers (1) may not be aware of all the options available in their choice set and (2) lack the information required to evaluate them, thus exacerbating the aforementioned distortions. We provide compelling evidence for the existence of information frictions in this market by examining the case of Barcelona and we test whether users' lack of knowledge translates into undesirable market outcomes.

Keywords: Parking; Imperfect information; search cost; obfuscation; cruising; competition

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4.1 Introduction

Parking policy has recently attracted much attention as it is seen as both a convenient and effective travel demand management tool for boosting the efficiency of transport systems that seek to tackle car usage-related problems. However, the complex behavior of the parking market is not readily assessed and policy makers require support as they attempt to design policies that might drive the market towards efficiency. This need has given rise to a growing body of literature, largely focused on the analysis of parking market distortions and on ways of fixing them.

The general tendency to set low (or free) curbside prices translates into excessive parking demand, which forces some drivers to cruise around for an empty spot and where each parker imposes an external cost on all other drivers (search cost). This phenomenon is pervasive (Shoup, 2005; Van Ommeren et al., 2012) and its associated welfare loss is especially relevant (Inci et al., 2015).[50] An additional distortion is the fact that garage parking (the main alternative to curbside parking) is characterized by construction scale economies for garages, imposed by their discrete spacing and that confers on them some degree of localized market power (Arnott, 2006). Theoretical studies have suggested various policy interventions to achieve full efficiency (for example, the elimination of cruising) or, at least, to induce welfare gains. These include regulating the price differential between garage and curbside parking, differentiated hourly curbside parking fees, time-varying and uniform curbside parking fees (see Inci, 2015, for an extensive review).

However, these conclusions rely on the assumption that parkers have perfect information. Spatial competition models (see, for example, Arnott, 2006; Calthrop and Proost, 2006; Inci and Lindsey, 2015) assume that drivers choose whether to search for an empty curbside spot or whether to drive directly to a garage. This implies that only the curbside parking search is costly, while the time required to locate a garage and to park there is neglected. Thus, such

[50] Shoup (2005) shows that about 30% of trips are affected and that drivers spend, on average, eight minutes cruising. Van Ommeren et al. (2012) suggest that cruising is mainly a parking regulation issue as cities with curbside regulated parking spaces and a proper fee differential with respect to garages report almost no cruising levels. Inci et al. (2015) estimate the external cost of cruising to be about 15% of the average wage rate in the case of Istanbul (equivalent to $2.7/h in the US).

models implicitly assume that garage locations and their attributes (such as, price) are known and perfectly observed by drivers. But a closer inspection of the parking market calls into question the validity of this assumption.

It is quite plausible that imperfect information may arise from the fact that drivers: (1) may not know all the available options in their parking choice set; and (2) lack information to evaluate them (prices and quality). Even if they want to acquire this knowledge, they must undertake a certain amount of search, which is also costly. The absence (or limitation) of this information does not allow them to maximize their utility and this has consequences on market outcomes that have not, to the best of our knowledge, been considered before.

The importance of imperfect information for market failure in a wide variety of sectors has long been recognized in the information economics literature (Stigler, 1961; Akerlof, 1970; Diamond, 1971; Stiglitz, 1989, 2000 and 2002), and the car parking market is no exception. Information is costly, so it is rational that consumers will not be fully informed. In such a situation, markets tend to be characterized by price dispersions that cannot be explained by differences in product characteristics. Salop and Stiglitz (1977) suggest that when individuals have different search costs, low-price firms will sell to both the well-informed customers and the uninformed customers that have the chance to purchase there (random); while high-price firms will only be able to sell to the uninformed consumers. In this case, imperfect information allows firms to imperfectly discriminate consumers depending on their respective information levels.[51] Garages will take advantage of non-optimal choice decisions made by consumers, allowing them to charge higher prices even with a large number of firms in the market or when search costs are relatively low. Furthermore, garages can also act strategically increasing the consumers' search costs through obfuscation, that is, simply by not disclosing all relevant purchase information or by making it more complex to understand; and, so, they are able to increase their prices (Ellison and Wolitzky, 2012). All this suggests that the parking market distortions described above (cruising and localized market power) might be further exacerbated by the interplay with imperfect information. In this

[51] The authors stress that well-informed consumers impose a positive externality on uninformed consumers by incentivizing the existence of low-price firms. If there are enough well-informed consumers, the market equilibrium price will tend to the competitive price.

scenario, full efficiency cannot be attained even if the interventions suggested by theory are implemented, as some cruising is likely to remain.

The presence of imperfect information in the parking market can be inferred from the fact that there is a growing demand for this good, with many specialist, information- gathering start-up firms currently providing it as pre-trip or in-route information.[52] The parking behavior literature has focused on measuring the parking search and characterizing the strategies adopted by drivers (see, for example, Polak and Axhausen, 1990; Bonsall and Palmer, 2004; Weinberger et al., 2017; Karaliopoulos et al., 2017). The relevance of the parking search issue and recent technological developments have motivated a large body of literature devoted to the design of parking assistance systems (see Caicedo, 2009, 2010 and Shin and Jun, 2014), which constitute information provision and guidance tools for drivers aimed at reducing their search cost.

However, all previous studies seem to assume implicitly that parkers know the spatial/temporal availability and characteristics of the garage stock as the primary substitute for curbside parking. However, it is our contention that the impact of imperfect information on market outcomes has yet to addressed in the parking literature, that is, no attention has been given to the impact on drivers of the lack of information regarding garage prices and "quality".

In this paper, we report evidence regarding the existence, and degree, of information frictions in the garage market of Barcelona. Moreover, we examine whether this level of information affects garage-choice behavior that translates into market outcomes (prices). We find that information frictions are so pervasive that active search during a given trip does not help drivers reduce the fees they pay. Only passive information acquisition through experience seems to increase parkers' knowledge of the available garage stock and so to obtain cheaper parking options. We also find evidence of price obfuscation that might allow garage operators to exploit the consumers' lack of knowledge.

To the best of our knowledge, this is the first paper to analyze imperfect information distortions in the parking sector. Our findings constitute a relevant contribution both to theoretical parking models, which seek to account for the exacerbating distortions of cruising externality and garage market power, and to

[52] Examples of such firms include Parkopedia, ParkMe, SpotHero and Bestparking.

empirical studies concerned with parking competition and demand modeling. They also suggest the need to empirically test whether imperfect information can be considered as relevant an issue in other cities. Addressing existing information frictions shows itself to be a relevant policy issue if parking market efficiency is to be achieved and one that deserves more attention in future research.

The rest of this paper is organized as follows. Section 4.2 describes the parking market in Barcelona and the drivers' level of knowledge and presents evidence for the latter and for parkers' search costs. Section 4.3 reports our empirical test of the role played by information on the prices paid by parkers and discusses these results. Section 4.4 summarizes our main conclusions.

4.2 Barcelona's parking market and garage parkers' knowledge levels

Barcelona operates comprehensive curbside parking regulations covering almost the entire city area (ÀREA). Introduced in 2005 and expanded in 2009, they include dedicated spaces for commercial activities, mixed-use spaces (where residents are permitted to park but visitors are charged a fee), resident-exclusive spaces and spaces assigned to haulage activities. The current global curbside parking supply is about 140,000 car park spaces (DB Aj.BCN, 2015), 52,000 of which are regulated following BSM provided information.[53] These spaces are distributed across regulatory zones with four fee/hour bands for commercial spaces (from 1.08 €/hour – 2.50 €/hour) and two bands for mixed-use spaces (2.75 €/hour – 3.00 €/hour). In the case of commercial spaces all parkers are considered as visitors, while mixed-use spaces allow both visitors and residents to park (the latter at a reduced fee of 0.20 €/day). Free parking only remains available during operating hours in the city's outskirts where parking demand is much lower.

Off-street parking supply in Barcelona is extensive, with a global estimated figure of 650,000 parking spaces (DB Aj.BCN, 2015). However, according to

[53] Of the global city parking supply about 73,000 are free parking spaces, the remaining include haulage and other reserved spaces where regular car parkers are not allowed to park.

Albalate and Gragera (2017a), only about 114,000 spaces are provided by public-access garages. The public-access garage supply is provided mainly by the private sector (78% of facilities) in what is a highly atomized market structure. Thus, two firms, NN and SABA, which manage a relatively large number of garages under the same brand name and image, account for just 5 and 3% of the market, respectively. The public sector is characterized by public operators (8%) and price-regulated facilities under concession (14%). Indeed, in recent years, the public sector has been the only new market entrant in the city's policy of expanding off-street supply as a means of shifting curbside demand to garages, because of high land acquisition costs (which the public sector have been able to circumvent by building garages on public land). The City Council has integrated both regulated curbside spaces and publicly managed garages under a single operator (BSM), although each mode represents a different business unit within the same company.

Garages charge a fee per minute, although many differentiate the fee charged according to the length of stay. Indeed, some fee schedules are so complex that they appear to interfere with the consumers' ability to calculate the price. The city's mean garage parking fee for the first hour is 3.32€/hour (Std. Dev. = 0.50 €/hour), falling to 3.19 €/hour for a two-hour stay and 3.14 €/h for three. This represent a fairly mild price discrimination as the reduction for the second and third hours is just 4 and 5%, respectively.[54] Generally discounts for long, overnight and next day stays are reported on the garages' price schedule or menu. Likewise, discounts and special rates can be purchased in advance, but non-discount users represent the majority of parking transactions (according to figures reported by BSM, see footnote 17 in Albalate and Gragera, 2017a). The prices charged by public garages are fixed by the public authority and respond solely to political decisions. Publicly managed garages apply a 3.05 €/hour fee (non-progressive) in all their facilities. All concessions are subject to a price-cap regulation that is usually binding, ensuring cost recovery and return on investment to the private investor. The concessions' mean fee for the first hour of parking is 3.09 €/hour (Std. Dev. 0.38 €/hour).

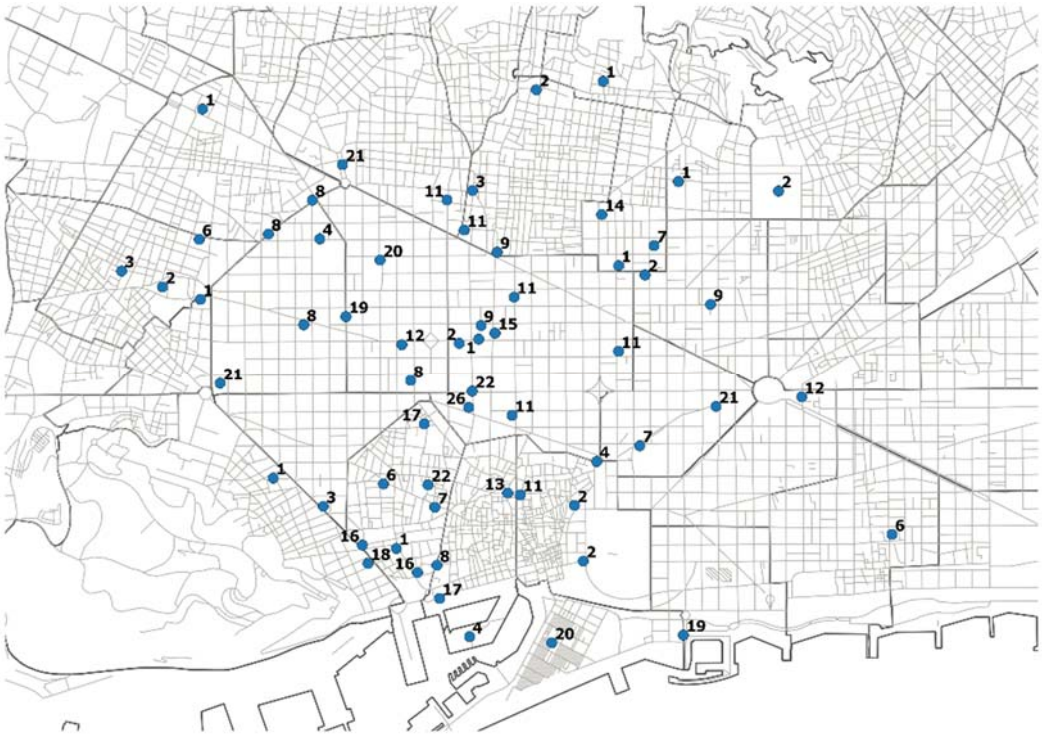
[54] A comparison of these figures with those reported by Lin and Wang for the case of New York City is striking. In Manhattan, the mean fee for the first hour is $12.67/hour (Std. Dev. $4.4/hour) while the second hour is charged at just $3.38/hour, a reduction of 73%.

Further details on the specific characteristics of the parking market in Barcelona can be found in Gragera and Albalate (2016) and Albalate and Gragera (2017a).

To evaluate the level of knowledge that parkers have about the parking market, we conducted a survey among 576 respondents among the garage parkers at 61 different facilities located throughout Barcelona, but concentrated mainly in the Central Business District and surrounding areas.[55] The specific survey locations are shown in Figure 4-1. We designed the questionnaire in such a way as to gather information on garage parkers' trip and demographic characteristics, their search activity and their knowledge of prices and available alternatives. The information was gathered in a single wave over two consecutive weeks in February 2016, during business hours. The survey was conducted with parkers that were either about to leave the garage facility after parking their vehicle or when they returned to pick it up (before payment). Garage prices and characteristics are extracted from a parking inventory conducted during the same period, as described in Albalate and Gragera (2017a). Curbside information has been provided by BSM and the neighborhood data is made publicly available by the Barcelona City Council Statistics Department.

[55] All empirical evidence is based on a sample that discarded responses from car park subscribers, parkers who report paying a discounted fee of any kind and all-day parkers. Each model uses only those observations for which complete information was available for all variables used, which means items for which respondents were unable/unwilling to report specific information were eliminated.

Figure 4-1. Geographical distribution of garage facilities and the total raw number of surveys conducted at each of them.



4.2.1 Descriptive evidence of imperfect information

4.2.1.1 Involvement in search activity

In line with previous evidence (Albalate and Gragera, 2017a), our survey data suggest that a garage might exert a significant degree of localized market power, as 96.6% of respondents reveal that their main reason for parking in a given facility is its proximity to their destination. The average walking time to final destination is restricted to just 5.8 min (Std. Dev. 5.5 min), which assuming a walking speed of 0.5 m/s translates into a 300 m walk (with more than 90% of respondents not walking further than 500 m). Walking time distribution in our sample is reported in Figure 4-2.

Figure 4-2. Walking time to destination density distribution, as reported by parkers in our sample.

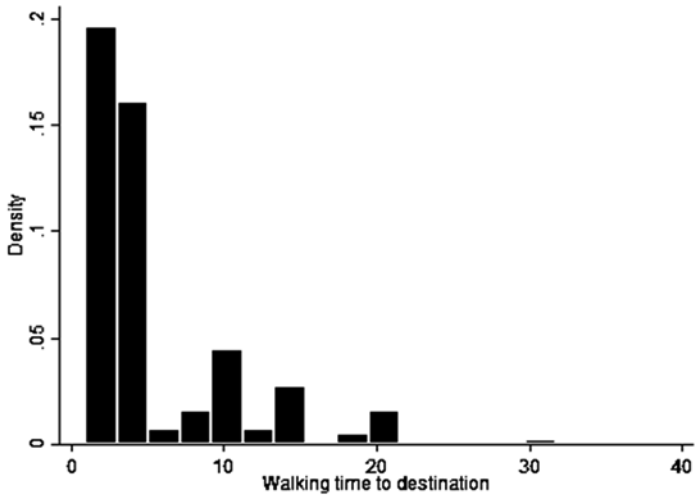


Table 4-1 shows that parkers in our sample conduct very low search activity of all types. Only 6.9% of respondents report having actively searched for a garage. Choice of garage facility seems to depend largely on previous experience, as 78% report that they already knew the facility, while the others report having found it either by following traffic signs (5%) or on seeing the garage sign while cruising around the area (17%). Only 3.4% state that they conducted any sort of pre-trip search for garage information, reflecting the fact that information platforms (start-up firms) currently have a very low market penetration. About 17.8% of respondents report that they had previously searched for a curbside spot, while only a marginal 1.2% state they searched for both a garage and an empty curbside spot. Further analysis of our data shows that no demographic or trip characteristics presents a significant difference in the mean level of garage search.

Table 4-1. Summary of respondents' answers to search activity related issues in our sample

Search activity:		Freq.	Percent
Garage search	(No)	458	93.09
	(Yes)	34	6.91
Pre-trip search	(No)	476	96.55
	(Yes)	17	3.45
Curbside search	(No)	410	82.16
	(Yes)	89	17.84
How they found it?	(Already know)	385	78.09
	(Traffics signs)	25	5.07
	(Cruising)	83	16.84
Previous visitor	(No)	106	21.37
	(Yes)	390	78.63

4.2.1.2 Knowledge of available garage alternatives

The low level of search activity reported is particularly striking as our survey data suggest that drivers have a significant lack of knowledge about their alternative parking options. Only 51% of parkers report knowing of the existence of at least one other garage in the area, but as many as 78% of these claim not to know the fee that this garage facility would charge them and 65% report not knowing its characteristics. Together with localized market power, this might plausibly impose a huge burden on competition between garages, as suggested by the results of Albalate and Gragera (2017a).

To gain further insights into these responses, we test whether the differences in the mean level of knowledge about the availability of alternative garages between the different groups in our sample are statistically significant (see Table 4-2). The mean knowledge of available alternatives is higher among those who have previously visited the specific garage facility compared to those who have not, providing further evidence of the accumulation of knowledge of available alternatives through experience. This is also the case of those who undertook an active search for a garage, while the opposite was found for those who had previously searched for a curbside spot. The fact that the latter looked to park on the curbside spot first might indicate that this is their preferred option and that they are less likely to park in a garage (having less prior experience). This is, in fact, confirmed by comparing means between both groups with a t-test.

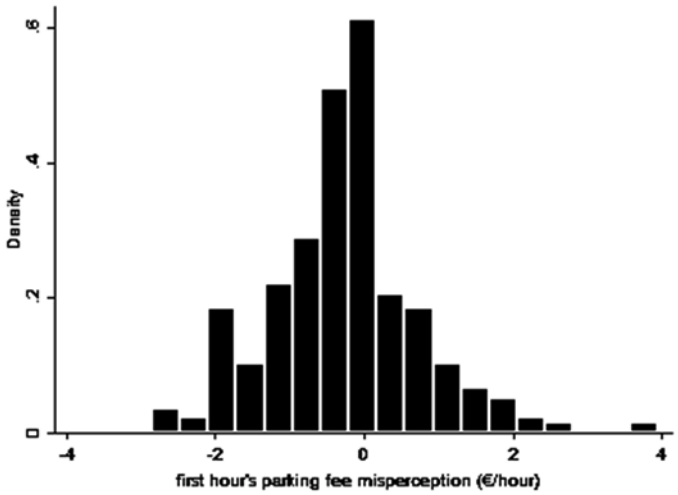
Table 4-2. One-tailed and two-tailed t-test results comparing levels of knowledge of available garage alternatives for different independent subsamples based on parkers' experience and search involvement.

Parkers' characteristic		Knowledge of garage alternatives						
		Freq.	Mean	Std.Dev.	t	Pr(T<t)	Pr(|T|>|t|)	Pr(T>t)
Previous visit	(0)	106	0.292	0.457	-5.292	0.000	0.000	1.000
	(1)	386	0.575	0.494				
Active search	(0)	454	0.5	0.5	-1.656	0.049	0.098	0.951
	(1)	34	0.647	0.485				
Pre-trip search	(0)	472	0.513	0.5	-0.611	0.271	0.541	0.729
	(1)	17	0.588	0.507				
Curb search	(0)	406	0.529	0.499	1.562	0.946	0.119	0.059
	(1)	89	0.438	0.498				

4.2.1.3 Knowledge of prices

Not only do the parkers seem to know little about the available alternatives and their characteristics, they also lack knowledge about the fees charged in the garage in which they have parked. Our survey data suggest that 75% of respondents report not knowing the fees. When asked the fee for the first hour, their average guess was 2.92 €/h (Std. Dev. 0.96 €/h) compared to a true sample mean of 3.18 €/h (Std. Dev. 0.33 €/h), there being no statistically different mean between those reporting knowing and those reporting not knowing the price. We measure their price misperception as the difference between their guess and the actual fee applied at the garage, which gives an average of -0.27 €/hour (Std. Dev. 1.04€/hour) and its distribution is reported in Figure 4-3.

Figure 4-3. Distribution of the misperception of the first hour's parking fee by parkers, measured as the difference between their price guess and the actual garage fee.



4.2.1.4 Obfuscation

Another key aspect is the fact that price menus are only visible from the street (that is, outside the facility) in 15% of the garages in Barcelona. Around 78% only display this information inside the facility, while the remaining 7% put up no visible signs, thus forcing users to ask if they want to know the fee they will be charged.[56] In our sample, 70% of respondents parked in garages that only show price information inside the facility, while the remaining 30% used garages displaying the fees outside.

All garages report their fees in terms of price per minute as stipulated by the 2006 Consumer Protection Act.[57] In describing this fee, they tend to display the price as a fraction using from between 2 to 6 decimal numbers, which makes it fairly difficult for customers to compute the actual price. Many garages do not apply a flat fee but rather use a differentiated rate per minute depending on the

[56] The provision of information in public-access garages is regulated by law 40/2002, but operators are only required to "make prices easily visible prior to formalizing the service contract", but nothing is said about the format, the means or where this should be done (http://consum.gencat.cat/temes_de_consum/aparcaments/index.html). Note that reporting the price inside the facility imposes a high cost on users if on learning the fee, they opt not to park in the facility.

[57] Ley 44/2006, de 29 de diciembre, de Mejora de la Protección de los Consumidores y Usuarios

length of stay, generally decreasing with duration. Garages also generally report all available discounts for overnight and next day stays in their price menus.

All these factors increase the complexity of the price menu and can potentially aid garage operators in obfuscating their prices, making it more difficult for users to know with any certainty the fee they will be charged (increasing parkers' search cost). Here, we include two measures to account for this potential price obfuscation. First, we measure price salience as a dummy variable, given a value of 1 if the price is not made visible outside the garage facility and 0 otherwise. Second, we account for the complexity in the way in which garages report the fee per minute, the length-of-stay price differentiation and discounts taking advantage of the coded price-menu string length, computed as the number of characters that this contains. The average price complexity faced by the respondents on our survey is 38 characters (Std. Dev. 27 characters) and its distribution is shown in Figure 4-4. Examples of some of these coded price menus and their corresponding complexity is reported in Table 4-3.

Figure 4-4. Distribution of the price complexity faced by parkers, measured as the number of characters included in the price menu coded string

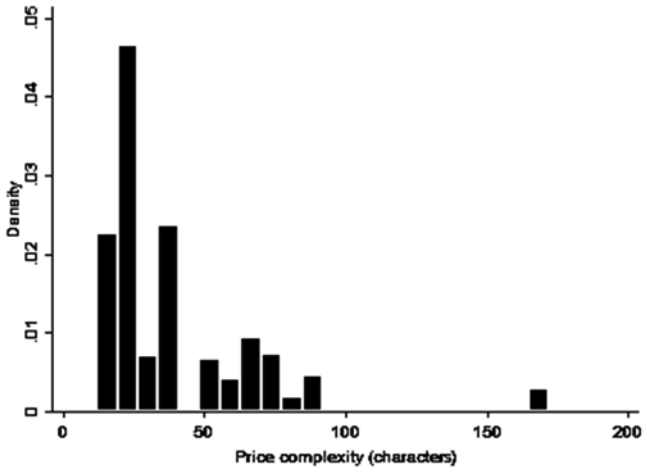


Table 4-3. Example of different price menus faced by respondents in our sample.

	Coded price menu	Price complexity (string length)
(Example 1)	0.054€/min | 35€/day (max)	26
(Example 2)	0-120min = 0.0512€/min; 121-600min = 0.0479€/min; >600min = 28.10€/day	70
(Example 3)	0-30min = 0.067€/min, 31-60min = 0.061€/min, 61-90min = 0.065€/min, 91-120min = 0.061€/min, 121-150min = 0.064€/min, 151-180min = 0.061€/min, >180min = 0.063€/min | 25€/day	172

4.2.2 The value of information: expected gains vs search cost

So far, we have seen that drivers in Barcelona conduct very low levels of search, which based on previous evidence is plausibly explained by its potentially high associated costs.[58] It is rational to believe that drivers will only involve themselves in a search if the marginal gain to be achieved by conducting such a search is higher than or equal to its marginal cost. Thus, we can measure a parker's expected gains from having perfect information as the difference between the mean fee for the first hour of parking and the lowest garage fee within the relevant market reported by each respondent, that is, a buffer zone defined by its lying within walking distance of the parker's final destination. This provides us with an intuition as to what would be the difference in the parking fee paid by a perfectly informed driver with respect to that of the expected market price paid by a user when simply purchasing at random, other things being equal.

In our sample, this yields a 0.30 €/hour differential (Std. Dev. 0.27 €/hour), at which point the user has a relatively mild incentive to search. Note that this potential cost saving is roughly equivalent to the users' price misperception, suggesting that they might not even be aware that such a saving exists.

[58] Unfortunately, the low number of parkers that engage in search activity precludes us from taking a more sophisticated, more reliable empirical approach to the estimation of this search cost.

When analyzing the deviation from perfect information, computed as the difference between the lowest market price and the fee actually paid for the first hour of parking, this yields a mean value of -0.17 €/hour (Std. Dev. 0.27 €/hour), indicating that users purchase at higher prices than the lowest fee possible. When analyzing the deviation from purchasing at random, measured as the difference between the mean fee for the first hour of parking within the relevant market and the price actually paid, this yields a mean value of 0.13 €/hour (Std. Dev. 0.31 €/hour), suggesting that parkers do possess some information that allows them to purchase at a price that is lower than the expected market price.

To obtain a clearer picture we need to compare this expected gain of having perfect information with its expected cost (search). We have no data about the drivers' search process, but we can provide an accurate enough approximation of the expected costs with a back-of-the-envelope calculation, assuming that parkers follow a sequential search approach.[59] This is an equivalent problem to that of computing the probability of a driver picking the cheapest garage option from a sample without replacement (assuming all garages are equally distant from the driver's final destination). Under this scenario, the probability of locating the cheapest facility is 1/n, where n is the number of garages in the relevant market. Using the mean values in our sample, we can compute the mean expected cost of a sequential search assuming there are four garages (Std. Dev. 2.9 garages) located 200 meters apart (Std. Dev. 97 meters), and where parkers drive from one facility to another at a velocity of 10 km/h and their time is valued at 9 €/hour.[60] The probability of finding oneself at the cheapest garage on the first visit is 0.25, as it is on the second, third and fourth visits conditional on failures on the previous visits. Thus, the expected search cost would be 1.87€,

[59] We believe this constitutes a fair enough approximation of the expected search costs, as very few drivers undertake a pre-trip search and parking information systems/platforms, as yet, enjoy little market penetration. Moreover, in our particular setting the only way to dispose of complete knowledge of all garage prices (in the vast majority of cases) would be to visit each facility, this without taking into account the fact that fees are usually not visible from the outside (imposing an additional cost if consumers want to know the price) and the cognitive burden that the price discrimination scheme might also impose.

[60] Drivers value of time is assumed 9 €/hour following the estimates of SAIT (2015), the cost-benefit analysis guide for transport investments of the Catalonia Regional Government.

which well offsets the previously computed expected gains for the respondents in our sample.

To translate this result more broadly across the whole city, the average value of perfect information in Barcelona is 0.67 €/hour (Std. Dev. 0.29 €/hour) and its distribution can be depicted as in Figure 4-5 (based on the data reported in Albalate and Gragera, 2017a). From this figure, however, it is readily seen that in many areas this is too low to offset the assumed search cost. Indeed, those sites with the higher values of information are precisely those with the higher number of competing facilities. This implies that even though expected gains might be higher, they might well also be offset by higher search costs if the drivers' main channel for gaining information is an on-site search. The more garages that are available, the greater the number of visits a user will be expected to make to find the cheapest fee. Table 4-4 shows detailed expected search costs per garage visited, suggesting it is very unlikely that drivers will search for more than two garage facilities given the value yielded by perfect information.

Table 4-4. Expected search cost assumed for a sequential search strategy at mean values in our sample for each visited facility.

Visited facilities	Exp cost/unit	Exp. Total Cost
1	0,1872€	0,1872€
2	0,3744€	0,5616€
3	0,5616€	1,1232€
4	0,7488€	1,872€

Additionally, we also find evidence that conducting an active search for a garage does not actually help drivers find the cheapest parking option for their current trip. On the contrary, those that do conduct such a search end up with an average lower deviation from the mean price, meaning they are less able to purchase at lower than the mean price, which does not differentiate from purchasing at random. This is a reflection of just how poor information actually is in this market. Indeed, the search might only constitute a cost in terms of gathering information (through experience) for future visits to the area. Table 4-5 reports the results of a t-test comparing the means for the subsamples of respondents that conduct active searches and those who do not.

Figure 4-5. Value of perfect information (€/hour) in each garage catchment area, measured as the difference between minimum and mean first hour's parking fee within a 500-m buffer around each facility.

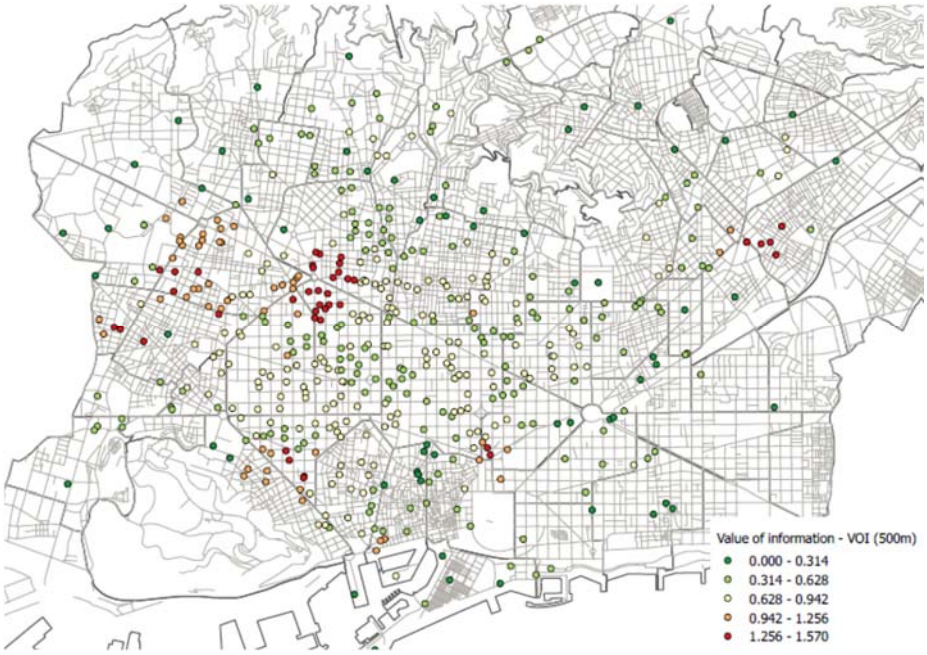


Table 4-5. One-tailed and two-tailed t-test results comparing the deviation with respect to mean prices for different independent subsamples based on parkers' active search involvement. Deviation from the mean prices is measured as the difference between the mean prices and the price actually paid for the first parking hour.

Parkers' characteristic		Deviation from mean price						
		Freq.	Mean	Std.Dev.	t	Pr(T<t)	Pr(|T|>|t|)	Pr(T>t)
Active search	(0)	458	0.131	0.314	1.401	0.919	0.162	0.081
	(1)	34	0.053	0.268				

To overcome their lack of knowledge and potentially high search costs, drivers appear to adhere to their already known options, with 77% selecting the garage facility based on previous experience (as long as they are satisfied with it). Alternatively, they seem to rely on brand names as an indication of a garage's attributes, and here 80% of respondents report knowing at least some of the main garage brand names. This argument is in line with evidence from the consumer behavior literature (Baels et al., 1981).

In short, the descriptive evidence presented shows that when choosing a garage drivers conduct very little search (of any kind); know very little about the stock of available alternatives and their prices; appear to rely heavily on previous experience; face relatively low expected marginal gains with respect to the marginal search cost: and are exposed to the potential obfuscation strategies employed by garages that might further increase their costs.

4.3 Empirical analysis of the impact of information on prices paid

The above section has provided compelling evidence of the informational frictions in the parking market. However, what is relevant is not how much drivers do not know about their parking options and prices or how many of them are inadequately informed, but whether their lack of information means that market outcomes deviate from the perfect competition scenario. Thus, next we test whether the level of information has an impact on the price paid by parkers and whether garages' obfuscation strategies might further increase parking fees.

4.3.1 Model specifications

The intuition on which our approach is based is that perfectly informed drivers would be capable of accurately identifying available garage options and their characteristics (including prices) and, consequently, of maximizing the utility they obtain from their choice of garage. Other things being equal, they should be able to choose a cheaper parking option. Those with inferior information levels might just be able to partially optimize their decision, whereas uninformed parkers can be expected to simply purchase at random. The level of information will depend on previous parking experiences associated with the area in which the trip destination is located or on their having conducted any type of search (pre-trip or on-site) to at least establish a subset of available garage parking opportunities. We test this hypothesis by estimating three types of model.

First, we estimate a regression model of the price paid for the first hour's parking on the information level of the drivers and on the provision of information from the garages (Model 1). This gives us an idea of whether the conditional mean price for the whole sample is affected by the parkers' knowledge and search activity; that is, whether information dimensions result in parkers paying higher or lower fees. In order to have comparable prices across respondents, we use the first hour's parking fee (list price), as was stated in the questionnaire when asking parkers for their price perception. We estimate Model 1 with a log-linear specification, so the coefficients reported can be interpreted as semi-elasticities.

$$Log(F_i) = \alpha \cdot active\ search_i + \beta \cdot passive\ search_i + \gamma \cdot obfuscation_i + \delta \cdot controls_i + \varepsilon_i \quad (1)$$

Second, as it is plausible that there might be decreasing marginal returns on search making it non-optimal for drivers to be fully informed (Ratchford, 1980), we estimate three binary outcome models regressing: (a) the probability of paying the lowest fee for the first hour's parking, (b) the probability of paying less than the mean fee for the first hour's parking and (c) the probability of paying more than the mean fee for the first hour's parking within the relevant market given the information dimensions (Models 2, 3 and 4, respectively).[61] In contrast to Model 1, these models give us an idea of how well drivers choose between the available garages lying in their relevant market in terms of price. They estimate how much more or less likely a user is to park in a garage in a specific price segment in relation to a change in the dimension of information. Dichotomous response variables are simply computed by comparing the fee users pay for their first hour of parking and the mean fee charged within the relevant market for each respondent. This means that the dependent variable in Model 2 takes a value of 1 when F_i is equal to the minimum F_{min} within the relevant market for parker i and 0 otherwise. The dependent variable in Model 3 takes a value of 1 when F_i is strictly lower than the mean fee ($\bar{F}$) within the relevant market for parker i and 0 otherwise. While in Model 4, the dependent variable takes a value of 1 when F_i is strictly higher than $\bar{F}$ within the relevant market for parker i and 0 otherwise. Note that models 3 and 4 can be considered

[61] We assume that the relevant market for each respondent is a buffer defined by the walking distance to their final destination in a radius around the garage facility in which the survey was conducted. The walking distance is based on a reported walking time to final destination assuming a velocity of 0.6 meters/second.

reciprocal of each other. The estimates reported by Models 2, 3 and 4 are the odds ratio for a logit regression model (exponentiated coefficients).

$$Pr(F_i = F_{min}|x) = \Lambda(\alpha \cdot active\ search_i + \beta \cdot passive\ search_i + \gamma \cdot obfuscation_i + \delta \cdot controls_i + \varepsilon_i) \quad (2)$$

$$Pr(F_i < \bar{\bar{F}}|x) = \Lambda(\alpha \cdot active\ search_i + \beta \cdot passive\ search_i + \gamma \cdot obfuscation_i + \delta \cdot controls_i + \varepsilon_i) \quad (3)$$

$$Pr(F_i > \bar{\bar{F}}|x) = \Lambda(\alpha \cdot active\ search_i + \beta \cdot passive\ search_i + \gamma \cdot obfuscation_i + \delta \cdot controls_i + \varepsilon_i) \quad (4)$$

And third, we estimate a regression model of the deviation from the mean fee within the relevant market area (Model 5), in order to be able to quantify how much each information dimension contributes to the higher/lower deviation in price with respect to purchasing at random (mean price). The dependent variable in Model 5 is defined as the difference $(\bar{\bar{F}} - F_i)$. This yields a positive deviation when the price paid is lower than the mean fee, meaning that drivers are purchasing better than at random, presumably by having a greater understanding of the available stock of garages and their characteristics, and vice versa when the deviation is negative. Model 5 reports the estimated coefficients for a linear regression model.

$$(\bar{\bar{F}} - F_i) = \alpha \cdot active\ search_i + \beta \cdot passive\ search_i + \gamma \cdot obfuscation_i + \delta \cdot controls_i + \varepsilon_i \quad (5)$$

We include several information-related variables, as the consumer behavior literature suggests that consumers (drivers) might acquire/search for information from very different sources, not only actively but passively from their past experiences or when involved in other activities (Baels et al., 1981). It is clear that this information acquisition process and its consequences in terms of consumer knowledge will depend on the technology of information production and diffusion[62], the type and the level of complexity of its attributes, the consumers' ability to use information, the amount purchased, their experience with the product, and their preferences and beliefs (Salop, 1976 and Miller, 1993). Thus, we seek to capture search activity by accounting for drivers

[62] Obviously, the costs associated with a web information search and those associated with driving to visit different garage facilities can differ considerably.

actively looking for information ($active\ search_i$) including a dummy variable that is equal to 1 when the drivers has visited at least another garage facility (and 0 otherwise) and has also visited another when conducting some kind of pre-trip search (and 0 otherwise).[63] We also seek to capture passive information acquisition ($passive\ search_i$) by including a dummy equal to 1 when the driver reports having previously searched for a curbside spot (and 0 otherwise), when the driver has previously visited the garage facility and the frequency of the trip to that specific destination, computed as the number of trips per month. In order to broadly capture the level of knowledge acquired from previous experience, we introduce a dummy equal to 1 when the driver reports knowing available garage alternatives in the area (and 0 otherwise).

Additionally, we include a number of variables to account for the potential impact of the obfuscation strategies adopted by garage operators that might increase the users' search cost ($obfuscation_i$), as highlighted in the previous section. We include a dummy variable that is equal to 1 when the garage does not display the price outside the facility (price not salient) and 0 otherwise, as well as a continuous variable that seeks to capture price complexity in the way garages report the fee per minute, and price differentiation linked to length of stay (price menu). We measure this by coding the price menus and counting the number of characters they contain so as to proxy the cognitive burden it might represent to drivers seeking to compute the price due.

We should stress that our test does not depend on any assumptions regarding the users' search behavior or the technology of information production and diffusion, as we focus solely on the impact of information levels on the price paid. However, the test does depend on our ability to control for quality differences between garages. We control for garage characteristics in terms of operator-specific effects, potential differences in garage attractiveness, the level of garage competition, as well as competitive and locational advantages.

[63] It could be argued that the amount of search can be determined by the prices faced suggesting a potential endogeneity issue. However, previous evidence reported in section **¡Error! No se encuentra el origen de la referencia.** shows that drivers tend to have very poor knowledge of prices and available alternatives, where our results suggest that those searching end up worse off; making it difficult to assume reverse causality. As a robustness check we estimate the models without this variable and results remain consistent.

Operator-specific effects are included to account for quality differences, given that each operator tends to meet a set of standards as regards facility layout, parking spaces and signaling, which can be assumed to yield similar user experiences. We control for differences in attractiveness of the area (which might enable users to achieve higher levels of utility by combining multiple activities for the same length of stay) by the density of economic activities. This is measured as the ratio between the number of square meters of economic activities that lay in the area of the relevant market for each user. The level of competing garage alternatives in the area is measured as the average distance between the garages located within the relevant market for each parker. As a measure of market dominance and to account for the competitive advantage of each garage, we introduce the share of competitors owned by the operator of the facility in which the driver left their car. Finally, a garage's locational advantage is measured by the time taken to walk to the parker's final destination.

We also control for the heterogeneity of driver and trip characteristics. We include sex, age and vehicle price as driver traits. Vehicle price is used as an income proxy and is computed as the actual selling price of the vehicle reported as being driven by the respondent.[64] We also include information about the purpose of the trip for which we establish four categories: work/study, business, shopping/leisure and personal (most of them medical appointments). And we also control for the length of the stay in the garage, as this might also give parkers higher expected gains due to greater total parking expenditure. Likewise, it may also make it more difficult for the users to make sense of the price menu when price discrimination is applied.

4.3.2 Results and discussion

Results for all models are reported in Table 4-6. For the sake of clarity, the table does not include control variables. Operator-specific effects are found to be always statistically significant, while the density of economic activities, level of competing garage alternatives, competitive and locational advantage measures, trip purpose and length of parking stay show statistically significant

[64] This is calculated using an internet price information aggregator (coches.com). As a robustness check, we also include a depreciated vehicle value taking into account the car purchase year as reported by the respondent.

coefficients in various models.[65] Note that the number of observations varies across logit models (Models 2 to 4) because by controlling for operator-specific effects means that both success and failure needs to be observed for each of them. Some operators' associated observations are dropped to avoid perfect collinearity.

Table 4-6. Estimated results for models (1) to (5).

	(1) Log-linear	(2) Logit	(3) Logit	(4) Logit	(5) Linear
Depend. Var.	$Log(F)$	$Pr(F = F_{min})$	$Pr(F < \bar{F})$	$Pr(F > \bar{F})$	$(\bar{F} - F)$
Search garage	0.00898	0.380	0.421*	2.378*	-0.128**
	(0.0130)	(0.352)	(0.209)	(1.182)	(0.0501)
Search curb	0.000167	1.307	0.628	1.593	-0.00988
	(0.0106)	(0.524)	(0.263)	(0.668)	(0.0460)
Search pre-trip	0.000806	1.279	1.403	0.713	-0.0788
	(0.0225)	(1.421)	(1.006)	(0.512)	(0.0772)
Know alternatives	-0.00777	1.501	2.165**	0.462**	0.0872**
	(0.00866)	(0.545)	(0.658)	(0.140)	(0.0379)
Prev. visitor	-0.00391	0.627	0.844	1.185	-0.0105
	(0.0110)	(0.305)	(0.329)	(0.462)	(0.0462)
Trip frequency	-0.00216**	1.098**	1.115***	0.897***	0.00837
	(0.000948)	(0.0438)	(0.0414)	(0.0333)	(0.00582)
Price not salient	0.124***	0.405**	0.0326***	30.67***	-0.169**
	(0.0112)	(0.180)	(0.0189)	(17.76)	(0.0666)
Price complexity	0.000572***	1.001	1.004	0.996	0.000268
	(0.000160)	(0.00638)	(0.00743)	(0.00737)	(0.000621)
Constant	0.814***	75.32***	400.3***	0.00250***	0.377*
	(0.0381)	(112.0)	(593.7)	(0.00370)	(0.211)
Observations	318	198	288	288	318
R^2 / pseudo-R^2	0.633	0.185	0.259	0.259	0.199

Operator-specific effects and other control variables are not reported in the table. Model (1) estimated parameters can be interpreted as semi-elasticities. Models (2) to (4) estimates are reported as odds ratios (exponentiated coefficients). Model (5) estimates are reported in levels. Robust standard errors are reported in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

The results reported in Table 4-6 suggest that active information acquisition (either by garage, curbside or pre-trip search) does not have a statistically significant impact on the level of prices paid (Model 1). Models 3 to 5 suggest that when parkers conduct some search for alternative garages they end up paying higher than mean prices. Model 4 suggests that drivers that search for

[65] We find very mild evidence that the level of price paid is inelastic with respect to walking time to final destination and no significant differences with respect to search involvement. Our data and empirical approach do not allow us to test for the potential trade-off between drivers' propensity to search and the desire to park close to their final destination, even this is an interesting issue for further research.

alternative garages are more than twice as likely to purchase above the mean price within their relevant market. Specifically, Model 5 shows they end up paying 0.13 €/hour above the mean fee for the first hour. This suggests that on-site search might be too much of an inconvenience for consumers that are inadequately informed and who are simply acquiring experience that will only pay off in future visits to the area. This seems to indicate that information frictions in the case of Barcelona are quite extreme, if parkers are unable to achieve gains from active search.

Passive information acquisition seems to be a more important determinant of the translation of user knowledge into market outcomes. Models 3 to 5 suggest that having some knowledge about the available garage parking stock increases the likelihood that parkers are able to make a better purchase than a simple random purchase. Model 3 suggests that these users are twice as likely to purchase at a price below that of the mean fee for the first hour within their relevant market. More specifically, Model 5 shows that they purchase at a price that is 0.09 €/hour below the mean price, which is half the search cost assumed for a single garage visit in the sequential search scheme reported in Table 4-4.

Trip frequency shows a mild negative relation with the level of prices paid (Model 1), the sign being in line with Sorensen (2000). Here, our results seem to suggest that familiarity with an area slightly facilitates the information gathering process. Models 2 to 4 suggest that trip frequency slightly increases the probability of purchasing at the lowest available price and below the mean price, with odds ratios of 1.098 and 1.115, respectively. However, Model 5 shows that the deviation in price from the mean is not statistically significant. This suggests that trip frequency help them just to purchase slightly better than at random, but not adding much to the broader knowledge measure of available garage stock.

One of our most important results is that we find compelling evidence to indicate that price obfuscation may well be of great relevance in the case of garage parking in Barcelona. Model 1 suggests that drivers that park at garages where the price is not salient end up paying higher prices (12%). The likelihood of purchasing at the lowest available price is cut by more than half (Model 2) and drivers are about 30 times more likely to purchase above mean prices (Model 4). Model 5 suggests that parkers presented with non-salient prices purchase 0.17 €/hour above the mean fee for the first hour's parking, that is, about the same magnitude of the search cost for a single garage visit. We also

find a positive relation between the price complexity of a price menu and the price paid by parkers (Model 1), even though this does not seem to have a statistically significant impact on the probability of purchasing below the mean or at the lowest available price. In this regard, it might only raise awareness about the potential obfuscation implications of price discrimination in relation to length of stay, which might have some relevance for the implementation of policy interventions.

All this suggests that information frictions are so pervasive in Barcelona that the only way garage users can currently overcome them is by acquiring a considerable amount of consumer experience. A casual survey of different cities' suggests that there are no significant differences in garage signage and information provision with respect to Barcelona. The fact that parking finders and reservation service apps are expanding suggests that the need for parking information is quite ubiquitous. Penetration rates may differ between cities (presumably depending on the value of information and search cost), but parking app companies reported number of users seem to suggest that they are still far from full adoption. Thus, it seems reasonable to assume that information frictions are also to be found in other cities and that their importance is a factor that needs to be investigated further.

This has obvious implications for spatial competition models for parking, which to date have assumed perfect information when making their policy recommendations, but which might well be hindered by the effects of information frictions. However, it also has implications for empirical studies that implicitly make the same assumption when parkers choose between curbside and garage parking. In this sense, the previously reported curbside premium (Kobus et al., 2013; Gragera and Albalate, 2016) might be partially capturing garage information frictions rather than just a greater willingness to pay for curbside parking.

Public authorities need to address this issue of imperfect information as it might be giving rise to substantial welfare losses and conferring additional market power on garage operators, while at the same hindering public interventions to eliminate cruising-for-parking.

4.4 Conclusions

In this paper, we have examined the existence of imperfect information in the garage parking market of the city of Barcelona. We conducted a survey among garage users at different facilities throughout Barcelona, gathering information on their trip and demographic characteristics, search activity and their knowledge of prices and the alternatives available. Based on these data, we provide compelling evidence of the degree of information frictions in this market, while testing whether the level of information affects parkers' garage choice behavior that, in turn, translates into market outcomes (prices).

On the one hand, we find that active information acquisition (either by garage, curbside or pre-trip search) does not ensure that parkers end up paying lower fees for a given trip. On the contrary, drivers that do conduct a search are more likely to end up paying more. On the other hand, passive information acquisition through experience (broad knowledge of available garage stock and trip frequency) seems to be a more relevant determinant of parkers finding cheaper parking options. Additionally, we find compelling evidence to indicate that price obfuscation is a determinant of market outcomes in Barcelona, and that this may allow garage operators to take advantage of garage users' lack of knowledge.

This implies that information frictions are so pervasive in Barcelona that the only way drivers might overcome them is by drawing on their consumer experience. While we await a more extensive penetration of information platforms, on-site search may well be the price less informed consumers have to pay to acquire information through experience, an effort that will only reap dividends in future visits to the area. Note, however, that we should be cautious about the generalization of these results to other cities and contexts. Even there are no significant differences in garage signage and information provision and the fact that the need for parking information is quite ubiquitous suggest that information frictions may apply to other cities; some features of the parking market in Barcelona might exacerbate the magnitude of the information frictions, such as the low penetration of information platforms or the extremely atomized garage market with plenty of small operators. The relevance of this issue in the parking marking will depend on the complex interplay between market structure and search costs (and the incentives to be informed). For that reason, we believe it is important to study other cities with different urban

forms, mobility patterns and parking market features to evaluate the precise role of them on information frictions.

Our findings suggest that addressing information frictions is a relevant policy issue if what is sought is efficiency of the parking market. Previous studies suggest that market interventions tend to miss a relevant issue that might impede any potential welfare gains, if they disregard such frictions. In this respect, in the presence of imperfect information, garages tend to exercise additional market power and even to act strategically to increase driver search cost through price obfuscation. This means that even so-called optimal interventions must face the fact that some cruising is likely to remain simply because parkers are unaware of the available garage stock and their prices. Thus, before implementing theoretically based interventions, imperfect information needs to be addressed.

In order to correct this distortion of the garage market, public intervention is required. Information is a public good and private agents are unlikely to have the incentives to provide optimal information quantity and quality. Ensuring parkers are better informed in all aspects of parking transactions will require a huge amount of data and standardization procedures, which are likely to be costly. The fact that information gathering firms are emerging rapidly in the parking market, combined with the level of development achieved by parking assistance systems, available technology and SmartCity schemes, leads us to think that in the near future information availability will be ubiquitous and pervasive in urban systems. A commitment on the part of public authorities to the data-gathering process (curbing costs) and to offering the right incentives to garage operators to disclose up-to-date information is clearly desirable here. Likewise, closer collaboration between public authorities, information gathering firms and market stakeholders should also be encouraged. Finally, it should perhaps be stressed that there is evidence that improved provision of pricing information can result in something of a backlash insofar as it can lead to easier collusion; thus, closer monitoring of the market is recommended.

To the best of our knowledge, this is the first paper to analyze distortions attributable to imperfect information in the car parking sector. Our findings represent a relevant contribution to both theoretical models and empirical studies of parking, as they stress the need to take information frictions into account given their tendency to exacerbate effects on the cruising externality

and garage market power. We believe their market implications should receive greater attention in future research.

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5 Conclusions and policy implications

This dissertation, comprising three specific essays, tackles the subject of parking economics. It focuses on a number of parking issues that have been largely neglected to-date in the literature, which has chosen to devote much attention to curbside at the expense of garage parking, despite this being a key element of the parking market. We specifically focus on the interaction between both parking options; the way in which curbside regulation affects garage demand and pricing behavior; and the relevance of imperfect information in the distortion of the parking market (exacerbating the cruising externality and the garages' market power).

To determine how public authorities should manage curbside and garage parking, Chapter 2 analyzes the impact of garage fee and curbside regulation characteristics (fee and types of dedicated spaces) on garage parking demand (both for occasional parkers and subscribers), revealing a marked deviation in the actual pricing scheme and the theoretically suggested optimal price differential between curbside and garage options. To analyze the role of garage private operators in producing this parking market pricing distortion, Chapter 3 explores the determinants of private garage operators' prices, focusing specifically on cost shifters and the interaction between curbside regulation and garage price-setting decisions, while also analyzing the role of market structure. In order to investigate the role of consumer ignorance and imperfect information in this pricing distortion, Chapter 4 provides compelling evidence on the existence, and degree, of information frictions in the garage market. It also empirically tests whether parker ignorance affects the level of prices consumers end up paying, suggesting that information frictions do translate into undesired market outcomes (higher prices paid).

The following paragraphs bring together the general conclusions reached in this thesis and their associated policy implications. They also include an outline of our proposed interventions based on the findings reported herein. We conclude by detailing further areas of potential research.

Our research provides evidence that both garage demand and prices are affected by curbside regulations. Both parking options are found to be imperfect substitutes, as drivers are willing to pay a premium to park on the curb

(€0.55/hour). This supports theoretical claims that curbside fees should be set higher than garage fees if cruising is ought to be eliminated, revealing the existence of a highly marked pricing distortion in Barcelona's parking market (and one that is probably replicated in other cities). This distortion not only applies to private garage operators, where the efficiency gap is on average €0.76/hour, but also to publicly managed facilities due to the homogeneous public garage parking fee policy and the uncoupling between curbside and garage regulations in Barcelona.

In this same line, we also find that both curbside fee and the relative scarcity of curbside provision with respect to garage provision have an impact on garage prices. The relationship between garage fee and curbside fee is negative, capturing how inefficiently the curb is used. Lower fees are associated with higher cruising levels in areas of high demand, giving garage operators the opportunity to exert greater market power and to increase their mark-up. In this case, increasing curbside fees should help reduce these distortive market outcomes. The garages' localized market power is a relevant issue in the case of Barcelona, as private operators' prices neither react to the level of market concentration (competition) in the area nor to the actual provision levels of public garages, only competing directly with the curb. We find that only the private operators' position of dominance in the relevant market is a major positive driver of prices.

In this regard, the leading role played by the public sector in the parking market in Barcelona offers a unique opportunity to overcome the current pricing distortion. This could be achieved by increasing curbside fee and/or reducing garage fees; changing the pricing scheme of publicly managed garages and contracted out facilities; and by taking into account private garage operators. Seeking to achieve the right price differential by relying solely on curbside fee increases might be politically unfeasible, while seeking to do so solely by lowering garage fees might compromise the profitability of the garages (or even crowd out private initiative). Thus, we suggest exploring the possibility of bundling curbside regulations to contracted out facilities making them internalize cruising external costs, which would allow the identification of the right price differential between the two options and the establishment of the necessary cross-subsidies when this might imply reducing garage fee below a minimum profitability threshold. This could also be extended to the current private garage operators as they engage in a new form of public-private

partnership that does not require the construction of new facilities. Furthermore, it would also allow the public authorities to introduce competitive incentives specifically targeting intervention in those areas where there is a higher price differential and garages have a dominant market position. It is also important to stress the need for a pricing scheme change that allows for spatial (and temporal) differentiation in fees, taking into account garages' heterogeneity (most of the price variation being explained by provision costs and quality shifters).

Additionally, we provide the first empirical confirmation of the fact that parking is a loss-leader for garages associated with commercial-activities and that it imposes a positive externality on other drivers that experience lower prices (non-clients). This suggests that public authorities may want to encourage more commercial facilities to open up their available parking spaces to the general public as a way of narrowing the pricing efficiency gap. This might additionally help alleviate, at least partially, the distortion that parking bundling represents for retail prices, if non-client parkers help to compensate parking provision costs.

Moreover, we provide evidence that the characteristics of curbside space regulation have an impact on parking demand as well as on pricing. This suggests that when public authorities think about setting up dedicated parking spaces they need to take into account the fact that commercial spaces help to shift long-term parkers to garages, but that they also attract occasional parkers to the curb. Mixed-use spaces show no statistically significant impact on garage demand, which suggests that providing parking permits for residents does not add additional demand or shift the potential of occasional parkers towards garages, which has been the main justification for their implementation (besides helping ease political opposition to parking pricing). In fact, mixed-use spaces slightly reduce the number of garage subscribers and shift long-term parking to the curb.

All this stresses the need for policy makers to change their thinking in relation to the interventions they promote and to treat parking as a market good, that is, the need to consider garage parking in conjunction with curbside regulation in an integrated market approach and the need to take into account the role of the private sector in garage provision.

We also provide the first empirical evidence of the existence, and extent, of information frictions in the garage market and confirm that car parkers' ignorance does indeed affect their parking-choice behavior, translating into undesired market outcomes (higher prices). The existence of these distortions further exacerbates cruising and the garages' market power, as private operators can simply exploit drivers' ignorance by raising their prices and widening the price differential with the curb. We find that information frictions are so pervasive in Barcelona that active search during a given trip does not help drivers reduce the fees they pay. Only passive information acquisition through experience seems to increase parkers' knowledge of the available garage stock and help them to obtain cheaper parking options. We also find that garages might be engaging in price obfuscation – either by not disclosing or by making it more difficult for consumers to discover the price – and so they artificially increase and take advantage of the search costs.

This stresses the need to address issues of imperfect information before instigating any other interventions to ensure that other market distortions can be eliminated. If information frictions are neglected, cruising and garage market power are likely to remain under direct price regulation of the private garage operators. The fact that information is a public good and private agents are unlikely to have the incentives to provide optimal information quantity and quality suggests that public intervention is required to address such distortions. Ensuring parkers are better informed in all aspects of parking transactions will require a huge amount of data and appropriate standardization procedures, which are likely to be costly. Therefore, we recommend that public authorities take advantage of the fact that information-gathering firms are emerging rapidly to ease the data-gathering process (curbing costs) and that they offer the right incentives to garage operators to disclose up-to-date information. All in all, closer collaboration between public authorities, information-gathering firms and market stakeholders should be encouraged so as to ensure a closer monitoring of the parking market and the adoption of more informed strategies of public intervention.

We believe that our work makes several relevant contributions to the literature and raises a number of new, interesting questions that can usefully be addressed in future research. It is clearly of great relevance to determine whether the parking pricing distortions and curbside premiums identified herein are to be found in other cities, and to analyze the key parking policy factors that might

underpin them. Likewise, we believe it is critical to study whether imperfect information is as relevant an issue in other cities as it is in Barcelona and to examine the role that the parking market conditions play in this state of affairs. In this regard, theoretical models need to be developed that can account for the heterogeneity shown by garages, the situation of imperfect information and the potential obfuscation practices of garage operators. In this way, we would hope to shed further light on the role of the private sector and that of public-private collaboration, and on the way in which different parking market distortions interact and, thus, guide optimal intervention design in the parking sector. Finally, it would be of particular interest to evaluate the role played by imperfect information in the parkers' greater/lower willingness to pay for curbside or garage parking.

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