

# Empirical evidence on imperfect information in the parking market

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## ABSTRACT:

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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# 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).<sup>1</sup> 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

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<sup>1</sup> 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 fare 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).

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 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.<sup>2</sup> 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 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.<sup>3</sup> The parking behavior literature has focused on measuring the parking search and

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<sup>2</sup> 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.

<sup>3</sup> Examples of such firms include Parkopedia, ParkMe, SpotHero and Bestparking.

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 be 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 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 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 3 reports our empirical test of the role played by information on the prices paid by parkers and discusses these results. Section 4 summarizes our main conclusions.

## **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.<sup>4</sup> These spaces are distributed across regulatory zones with four fee/hour bands for commercial spaces (from 1.08 €/hour – 2.50 €/hour) and two

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<sup>4</sup> 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.

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 Albalade and Gragera (2017), only about 114,000 spaces are provided by public-access garages. The public-access garage supply is provided mainly by the private sector (78 per cent 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 per cent of the market, respectively. The public sector is characterized by public operators (8 per cent) and price-regulated facilities under concession (14 per cent). 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 per cent, respectively.<sup>5</sup> 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, 2017). 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).

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

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.<sup>6</sup> The specific survey locations are shown in Figure 1. We

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<sup>5</sup> 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 per cent.

<sup>6</sup> 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

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 (2017). Curbside information has been provided by BSM and the neighborhood data is made publicly available by the Barcelona City Council Statistics Department.

[Insert Figure 1 here]

## ***2.1 Descriptive evidence of imperfect information***

### ***2.1.1 Involvement in search activity***

In line with previous evidence (Albalate and Gragera, 2017), our survey data suggest that a garage might exert a significant degree of localized market power, as 96.6 per cent 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 per cent of respondents not walking further than 500 m). Walking time distribution in our sample is reported in Figure 2.

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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.

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[Insert Figure 2 here]

Table 1 shows that parkers in our sample conduct very low search activity of all types. Only 6.9 per cent of respondents report having actively searched for a garage. Choice of garage facility seems to depend largely on previous experience, as 78 per cent report that they already knew the facility, while the others report having found it either by following traffic signs (5 per cent) or on seeing the garage sign while cruising around the area (17 per cent). Only 3.4 per cent 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 per cent of respondents report that they had previously searched for a curbside spot, while only a marginal 1.2 per cent 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.

[Insert Table 1 here]

### **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 per cent of parkers report knowing of the existence of at least one other garage in the area, but as many as 78 per cent of these claim not to know the fee that this garage facility would charge them and 65 per cent 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 Albalade and Gragera (2017).

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 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.

[Insert Table 2 here]

### ***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 per cent 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 3.

[Insert Figure 3 here]

#### 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 per cent of the garages in Barcelona. Around 78 per cent only display this information inside the facility, while the remaining 7 per cent put up no visible signs, thus forcing users to ask if they want to know the fee they will be charged.<sup>7</sup> In our sample, 70 per cent of respondents parked in garages that only show price information inside the facility, while the remaining 30 per cent 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.<sup>8</sup> 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 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

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<sup>7</sup> 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](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.

<sup>8</sup> Ley 44/2006, de 29 de diciembre, de Mejora de la Protección de los Consumidores y Usuarios

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. Examples of some of these coded price menus and their corresponding complexity is reported in Table 3.

[Insert Figure 4 here]

[Insert Table 3 here]

## ***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.<sup>9</sup> 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

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<sup>9</sup> 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.

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.

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.<sup>10</sup> 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.<sup>11</sup> 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€, 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 5 (based on the data reported in Albalade and Gragera, 2017). From this figure, however, it is readily seen that in many areas this is too low to offset the

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<sup>10</sup> 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.

<sup>11</sup> 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.



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 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.

[Insert Table 4 here]

[Insert Figure 5 here]

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 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.

[Insert Table 5 here]

To overcome their lack of knowledge and potentially high search costs, drivers appear to adhere to their already known options, with 77 per cent 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 per cent 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.

### **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.

#### ***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.

$$\begin{aligned} \text{Log}(F_i) = & \alpha \cdot \text{active search}_i + \beta \cdot \text{passive search}_i + \gamma \cdot \text{obfuscation}_i \\ & + \delta \cdot \text{controls}_i + \varepsilon_i \end{aligned} \quad (1)$$

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).<sup>12</sup> 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 reciprocal of each other. The estimates reported by Models 2, 3 and 4 are the odds ratio for a logit regression model (exponentiated coefficients).

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

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

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

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<sup>12</sup> 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.

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 ( $\bar{F} - F_i$ ). 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.

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

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<sup>13</sup>, 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 actively looking for information (*active search<sub>i</sub>*) including a dummy variable that is

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<sup>13</sup> Obviously, the costs associated with a web information search and those associated with driving to visit different garage facilities can differ considerably.

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). We also seek to capture passive information acquisition (*passive search<sub>i</sub>*) 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<sub>i</sub>*), 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.

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.<sup>14</sup> 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

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<sup>14</sup> 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.

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.

### **3.2 Results and discussion**

Results for all models are reported in Table 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 coefficients in various models. 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.

[Insert Table 6 here]

The results reported in Table 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 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.

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 per cent). 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. It seems reasonable to assume that such 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 & Albalade, 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 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.

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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## Tables and Figures

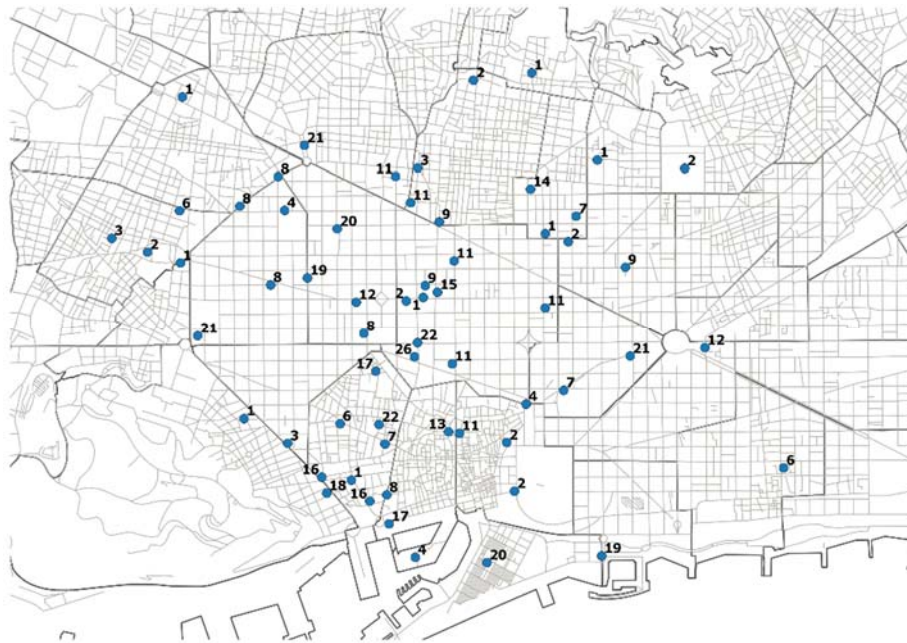


Figure 1. Geographical distribution of garage facilities and the total raw number of surveys conducted at each of them.

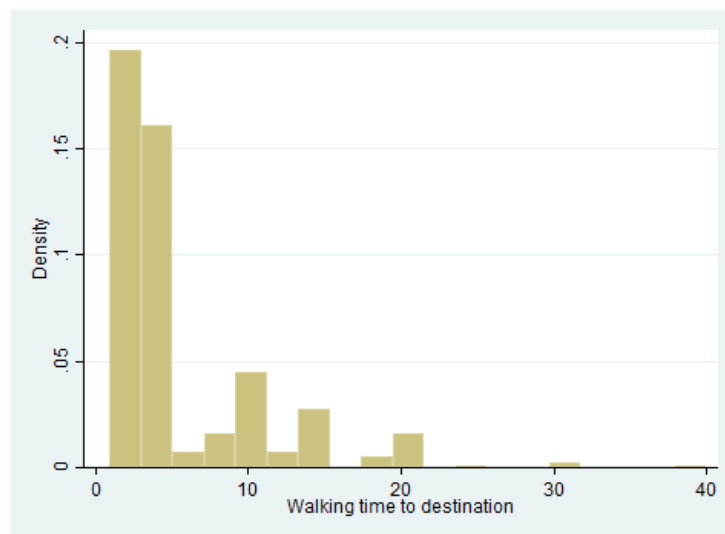


Figure 2. Walking time to destination density distribution, as reported by parkers in our sample.

Table 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

Table 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				

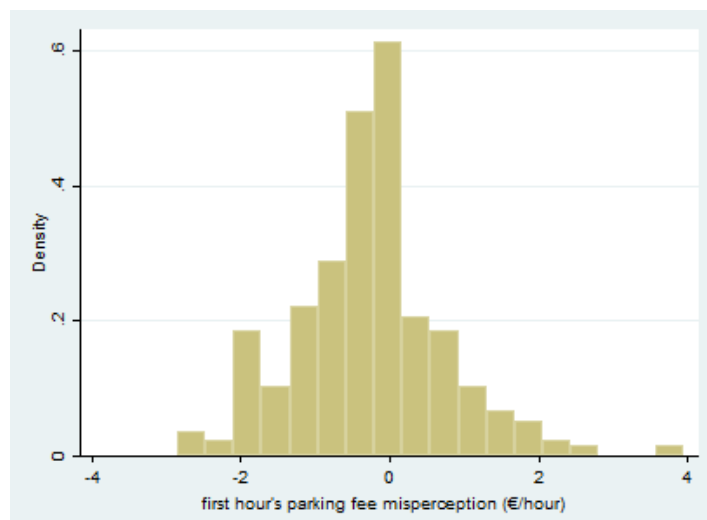


Figure 3. Distribution of the misperception of the first hour's parking fee by parkers, measured as the difference between their price guess and the actual garage fee.

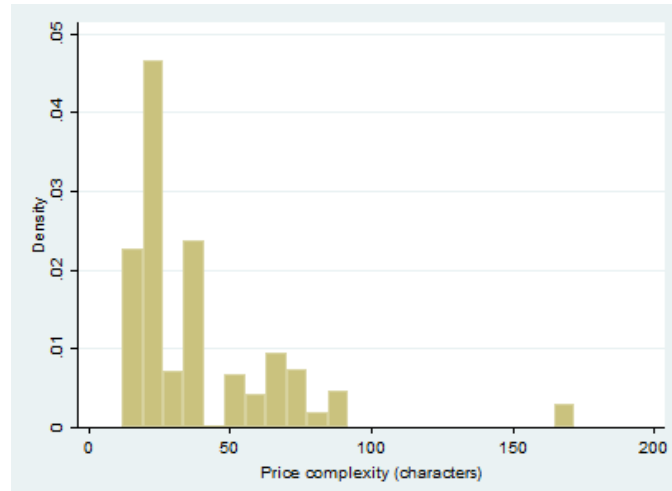


Figure 4. Distribution of the price complexity faced by parkers, measured as the number of characters included in the price menu coded string

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

	<b>Coded price menu</b>	<b>Price complexity (string length)</b>
(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

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

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

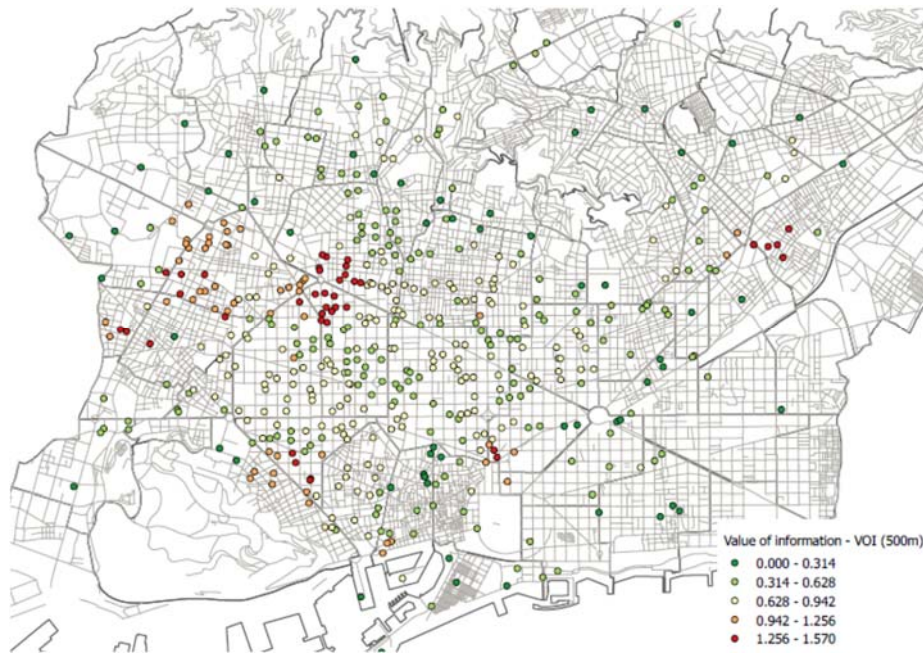


Figure 5. Value of perfect information (€/hour) in each garage catchment area, measured as the difference between minimum and mean first hour's parking fee within a 500-m buffer around each facility.

Table 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				

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

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