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PARKING IN LISBON

MARIA DO CARMO LEAL DA SILVA GOMES, 23924

A Project carried out on the Master in Management Program, under the supervision of:

Professor Sofia Franco

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Abstract

The parking market is characterized by two types of distortions: crusing and local market power. This thesis studies the determinants of parking facilities' prices in Lisbon using a cross-sectional database for facilities in the city, and how this can be influenced by curbside parking fees. The results show that operational costs drivers like having for instance a bathroom impact prices the most, but local market power and curbside parking density within a 500meters buffer also correlate with prices, negatively, as a unitary increase of each leads to a decrease in price of 0.4352% and 0.0001%, respectively.

Keywords: Parking facilities, Curbside parking, Lisbon, Price

Disclaimer

This thesis was conducted as part of a larger parking project by Professor Sofia Franco that aims to investigate the determinants of parking prices and availability in the city of Lisbon. Though sample cleaning and preparation and geocoding was conducted for this thesis, the raw parking dataset including the location, prices and structural attributes used in this thesis analyses was gently provided by Professor Franco.

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1. Introduction

Cars usually spend more time parked than moving. A parking space is the origin and destination of each journey and finding a space to park can be hard in urban areas. As cities expand car ownership and usage and traffic congestion rise, while available space does not, and parking becomes a more serious problem for urban residents every day. Lisbon is no exception. According to INE, in 2017, there were 506 088 individuals living in the city, owning, approximately, 374 855 cars. Note that there are still those who live outside of Lisbon but drive to the city to study, work or shop, a number estimated to be around 360 000 cars per day. These factors imply an increase in demand for parking that is no longer met by the existing supply, since there are only a total of 204 000 parking spaces (including on- and off-street parking) available.[1]

The local government, Camâra Municipal de Lisboa (CML), has already set measures aiming to decrease car usage. Such measures include improvements in the public transportation network (increasing the number of trains available, renovating metro stations and increasing metro lines), creation of Low Emissions Zones, creation of the so called only-pedestrians zones and also building cycle lanes. Nonetheless, the result of these measures has not fulfilled the expectations. According to INRIX Global Traffic Scoreboard, Lisbon scored higher in 2017 (375 points) than in 2016 (261 points), showing an increase in urban traffic.

According to Valleley (1997), there are four mechanisms through which parking supply can be affected: control the quantity of different types of parking (number of spaces provided); control the

[1] This statistic is based on "*Estacionamento em Lisboa*", a study performed by Camâra Municipal de Lisboa in 2010. Unfortunately, it was not possible to obtain a recent estimate of the total number of commercial parking spaces in the city of Lisbon other than the one obtained from the sample used in this thesis. The sample of parking facilities used in this thesis has a total of 159 567 parking spaces (71 567 off-street commercial parking spaces and 88 000 paid spaces located at the curb). However, there is anecdotal evidence that more cars exist in the city than the number of parking spaces available. As such, cruising is a serious problem in the city.

location of parking (on- and off-street parking); control access conditions to parking spaces (restrict use or not) or control the prices offered (set fees according to desired results). Unfortunately, it is difficult to increase supply making use of quantity and location mechanisms, since urban land is a limited resource and there are high investment costs, such as land acquisition and construction costs for underground facilities (Mingardo et al., 2015). Furthermore, the supply of parking facilities (off-street parking) has become a business managed mostly by private firms with local market power which in turn culminate in high parking fees. As a result, the solution depends on improving how effectively existing facilities set their prices, not only in relation to each other, but also to curbside parking fees. Arnott (2006) and Inci and Lindsey (2015) studies of spatial competition between parking facilities and curbside parking conclude that setting the right price differential between the prices charged by the facilities and the curb can lead to an efficient parking market because it eliminates cruising and transfers curbside excessive demand towards parking facilities. Note that cruising has high external costs such as traffic congestion as shown by Inci et al. (2015) for the case of Istanbul. Moreover, an efficient management of the parking supply is important to solve not only congestion, but also parking availability problems and even urban air pollution, (Simićević et al., 2012).

The goal of this thesis is to examine how prices in Lisbon are determined. It considers the relationship between the existent pricing scheme and parking facilities features, other facilities location, and on-street parking location and fees. It contributes to the existing literature by studying the connection of parking facilities and the curb, as its importance has been overlooked for the city of Lisbon. Given that the lack of the right price differential leads to an inefficient market, the results of this thesis will be relevant to both local authorities and other players in the parking market in Lisbon, hopefully shedding some light towards a more effective government intervention. In

addition, the analysis includes new variables related to facilities distance from each other (outside a catchment area) and type of structure which have not been used in past studies.

This thesis is organized as follows: Section 2 reviews the existing literature and main findings. Section 3 describes the market characteristics in Lisbon. Section 4 explains the methodology, data sources and model. Section 5 discusses the results. Section 6 presents the main conclusions.

2. Literature review

The behaviour of drivers has been widely researched, starting from the decision of choosing a parking location to how price changes impact their behaviour. Teknomo and Hokao (1997) concludes that drivers in Surabaya, Indonesia, decide on a parking space based on the existence of vacancy spots, trip purpose, cruising time, walking distance from the facility to their destination, and price. This information allows for better administrative planning and effective allocation of parking spaces to parking demand. Regarding parking in Belgrade, city where off-street parking is profoundly insufficient, Simićević, et al. (2012), finds that if facilities prices increase then demand decreases, meaning people would change either parking location or method of transport. The study also concludes that drivers who cruised for a curbside parking space before looking for a parking facility, trying to reduce parking costs, are more sensitive to the price charged by the operator. This can have an impact when trying to achieve the right price differential, since as curb fees increase to close the gap, the less sensitive drivers are to parking facilities prices, which can help switching demand from the curb to parking facilities.

On the other hand, the market supply and management of parking facilities has not been extensively studied, focusing mainly on competition. Froeb et al. (2003), Choné and Linnemer (2012), De Nijs (2012) and Lin and Wang (2015), conclude that, because of walking costs, the appropriate market

is a small area and that competition affects prices in two ways: decreases the price level and increases price discrimination in relation to parking duration.

Froeb et al. (2003), Choné and Linnemer (2012) and De Nijs (2012) analyse the impact that mergers in the parking facilities market have on parking fees. Froeb et al. (2003) simulate the impact on prices for a merger where the participants are constrained by their capacity. By comparing capacity constrained firms in two different settings (merging and not merging), it concludes that the effect on price from a merger is weakened when capacity is a binding constraint, as firms safeguard against share-stealing quantity responses. For the city of Paris, Choné and Linnemer (2012) claim that Vinci buying GTM was followed by a 3% increase in public facilities price and De Nijs (2012), building on this work, concludes that the overall level of competition decreased leading to a 5% increase in price as well as more price discrimination, as more significant discounts were offered. In both studies, pricing schemes for 12 hours offered by the operators, previously and after merging, are analysed. However, parking facilities also compete with the curb, and this relation was not accounted for in these studies.

Lin and Wang (2015) and Gragera and Albalate (2016) study price determinants for parking facilities.

Lin and Wang (2015) study the Manhattan's parking facilities market, particularly the connection between competition and price discrimination, and concludes that the curvature degree of hourly pricing schemes decreases with competition, meaning a greater proportional drop in low-end prices than in high-end prices. Assuming the presence of walking costs, define the appropriate market as a limited area with a 0.3- or 0.5-mile radius, and use 602 facilities and the 1hour fee to estimate a price equation. To relate variables, namely features of the surrounding neighbourhood and competition measures, with prices, it proposes a log-linear relationship.

The main conclusion is that the overall price level is negatively related to competition, in particular, a unitary decrease in the HHI (that translates to an increase in competition) leads to a 95% price reduction, whereas a unitary increase in the owned share of competitors (meaning a decrease in competition) leads to a 53% price increase. Furthermore, they study the curvature of pricing schemes in relation to parking duration. It concludes that as competition accentuates, price discrimination decreases, meaning a sharper decline in prices for drivers parking for shorter periods of time compared to those with longer parking duration. It justifies these results with the different behaviour of drivers when cruising for a parking space, assuming the second will undergo a more thorough search and be more sensitive to price. These are in line with the current textbook theory by stressing that a firm's capacity to price discriminate is undermined by competition. Moreover, this paper concludes further that an efficient parking policy should incorporate local parking conditions, and so, it justifies the use of fixed effects accounting for parking facilities location, although this was not done in this paper.

Gragera and Albalate (2016) investigate price determinants for the Barcelona's market featuring the interaction of curbside parking availability with demand for parking facilities. It is concluded that these are not perfect substitutes as drivers prefer on-street parking, being willing to pay a premium for it. Kobus et al. (2013) reaches the same conclusion regarding parking in the Netherlands. Moreover, Gragera and Albalate (2016) also find that curbside regulation highly affects demand for parking facilities. By setting a 500-meters radius to define their relevant area, also due to walking costs, and using 391 facilities and the 1hour fee; they estimate the model by considering parking, facilities features illustrating operational costs and neighbourhood characteristics, competition measures, and curbside parking information, such as spaces available and prices charged.

Their results show that, in Barcelona, parking facilities prices are negatively correlated to on-street fees, as a €1/hour decrease in curbfees leads to an 11.5% price increase, showcasing the uneconomical and ineffective usage given to curbside parking. This argument is very relevant: curbside parking fees are being set too low, as authorities neglect that parking facilities and curbside parking are substitutes, even if not perfect, increasing cruising. Lower prices for on-street parking are associated with increased traffic levels in areas where the demand is high, (Shoup, 2016). In this case, the curb is being favoured over a facility, allowing the operators to expand their market power, deepening the distortion present. Furthermore, they claim that while curbside parking supply has no statistical significant, its level of scarcity has: the dominance of the facility over the curb leads, for each additional curbside space, to a price increase of 0.002%. According to their results, market concentration is not statistically significant, but the share of facilities owned by the same operator within its catchment area positively correlates with prices, since a 1% unitary increase in this share drives prices up by 0.57%. This makes sense, as the operator gains market power, it is able to increase prices.

Moreover, the authors claim that price variation is mostly due to operational costs and quality drivers, as for example, facilities with sophisticated technological payment systems charge 5.61% more. These differences can inform operators on marginal costs' heterogeneity and how to accommodate government intervention, such as the opening of more public facilities to increase competition and decrease off-street prices. Their final statement stresses the effects of imperfect information, specially how it limits the effectiveness of direct price regulation and public actions. For example, if drivers are unfamiliar with the price distributions being offered or alternative facilities in the area, parking facilities can once again increase their mark-up, worsening pre-existing distortions.

Lin and Wang (2015) and Gragera and Albalate (2016), more closely the latter, are the starting point for this thesis, namely for the use of a catchment area for the parking facilities, the variables and specification used in the model. This thesis will also account for new variables that incorporate location and the different types of parking facilities, expanding the existing analyses.

3. Parking market in Lisbon

This thesis focuses on the parking facilities market in the city of Lisbon where the main activity is off-street parking and the product, a parking facility, refers to a specific location for short- or long-term parking. According to the Portuguese Government's regulation (*Deliberação n.º 41/AM/2004*), parking facilities can be classified into three types: A, B and C, meaning respectively: parks that serve big commercial surfaces and public rotation, parks for residents only, and mixed parks for both public rotation and residents. The facilities can be on the surface, underground or structural, with different capacities and offer different features.

Our sample for the city of Lisbon includes 237 commercial parking facilities available for public access, owned by 92 companies, some with restricted use. From the existing companies, only five are public operators, being EMEL the one with the largest market share of 58 parks; there are eight multinational and national private parking operators such as Empark, SABA and Placegar with 71 parks combined; and the remaining 104 parks belong to private individual companies (usually one facility by company) with their primary market varying from hotels, shopping malls, universities and supermarkets.

Table 1: **Description of parking facilities ownership**

Parking Facilities Ownership			
State - Owned	**63**	**Private Companies**	**104**
EMEL	58	Airports	6
Municipalities	2	Auditoriums	5
State Facilities	3	Garages	16
Private Operators	**71**	Hospitals	10
APARC	2	Hotels	25
Braga Parques	3	Real Estate	6
Empark	39	Shopping Malls	11
Mundicenter	2	Supermarkets	17
Placegar	11	Universities	2
SABA	4	Others	6
SIENT	8		
SIERRA	2	**Total**	**237**

This industry is somehow regulated by the government, as in *Deliberação n.º 41/AM/2004*. However it does not create significant barriers to entry.

This market can be analysed using either the number of facilities owned or the total parking capacity of each operator. Note that not always a higher number of facilities owned by one individual company translates into a higher number of parking spaces. Regarding individual companies and their respective market share, EMEL and Empark are the largest firms under both measure definitions as seen in table 2 where the Top 4 biggest players are shown.

Table 2 – Biggest players present in the market

Biggest Players		
	Total	**Market Share**
Number of facilities owned		
EMEL	58	24.37%
EMPARK	39	16.37%
Pingo Doce, SA	14	5.88%
Placegar	11	4.62%
Parking capacity owned		
EMPARK	12922	18.06%
EMEL	9525	13.31%
SIERRA	9414	13.15%
SIENT	5149	7.19%

The Herfindahl–Hirschman Index and concentration ratios are widely used to measure concentration levels. In Lisbon, parking facilities operate in an overall competitive market, as presented in table 3, by the Herfindahl–Hirschman Index being less than 0.15, as this represents the accepted threshold in the economic theory for a competitive market. As to concentration, considering the market share for the 4 and 8 largest companies shown in table 4, this market can be recognized as relatively concentrated, likely an oligopoly, as the ratios are higher than 40%, again, being this the accepted threshold in the economic competition theory.

Table 3 – HHI for the parking market

Herfindahl–Hirschman Index	
Number of facilities owned	0.09621
Parking capacity owned	0.08483

Table 4 – Concentration ratios for the marking market

Concentration ratios	
Number of facilities owned	
CR4	51,3%
CR8	60,1%
Parking capacity owned	
CR4	51,7%
CR8	69,8%

It can then be concluded that the overall Lisbon parking market is characterized by large firms operating in a competitive market. However, it should be noted that the relevant market for a parking facility tends to be a much smaller area than the city level or even a civil parish level. The reason for this is related to the existence of walking costs. Drivers are not willing to search for parking alternatives far away from their final destination. Therefore, evaluating the type of market structure by focusing on the HHI and concentration ratios for the whole city of Lisbon can be misguided. On the other hand, when taking into account the previous features when defining the relevant market for a parking facility, one concludes that there is evidence of an oligopoly type of competition, and in some situations, even a monopoly or at least a dominant firm. Moreover, the average HHI per parking facility catchment area, a buffer with 500 meters radius, is 0.375.

According to the existing economic theory, a HHI above 0.25 is a highly concentrated market, and so, at a local level parking facilities can have market power.

Interestingly, EMEL parking facilities have oligopolies in most of its locations and several monopolies, possibly due to a first mover advantage: initially, being the only operator in the market allow it to be established in key areas of the city, which together with the current barriers to entry, makes it difficult for other operators to open new facilities where EMEL is already a dominant firm.

Price is an instrument that affects the individual's decision of using a car by increasing its cost, and can also influence parking spaces' usage (e.g. enhance public rotation) and impact the different types of users (e.g. favor residents with designated spaces or different pricing schemes, such as monthly passes).

Price can be charged as a flat fee or it can be discriminated (a progressive fee, for example, as drivers have different willingness to pay or even to discourage long-term parking, in the case of curbside parking). Additionally, prices can be discriminated by type of user. In Lisbon, the price charged by parking facilities for one hour varies between 0.0€ and 3.6€, the average being 1.21€. It should be noted that the same operator can charge different prices in different facilities, either due to the competition in that area or the different features offered at a specific location. Although there are public-owned operators (EMEL, municipalities and different public-owned facilities), the prices for the facilities they manage still react to market forces and are not regulated or fixed by the government. Prices can also differ according to the type of facility and location.

The presence of alternative parking options can also influence prices and, in the parking facilities market the main substitute is curbside parking. Curbside parking is controlled only by EMEL,

which sets fixed prices at a uniform hourly rate, contrasting with those set by parking facilities, and vary only according to the city zone, as described in table 5, which can be: Green, mostly for residential areas and far away from the city centre; Yellow, for transaction areas between green and red; or Red, mostly for commercial and service areas, in the city centre, served by a good network of public transportation and for a maximum of two hours.

Table 5 – Curbside parking fees in Lisbon, per zone

Pricing Scheme for curbside parking				
	0h15	1h00	2h00	4h00
Green Zone	0.25€	0.80€	1.60€	3.20€
Yellow Zone	0.30€	1.20€	2.40€	4.80€
Red Zone	0.50€	1.60€	3.20€	–

4. Methodology

4.1. The Model

In order to investigate the determinants of parking fees, a price equation for the first hour was estimated. It is hypothesized that price (p_i) set by each parking facility can be explained as function of its own features (o_i), the surrounding market structure characteristics (m_i), the curbside parking conditions (c_i), civil parish specific characteristics, captured through special fixed effects (s_i), and idiosyncratic error term (ε_i), within a buffer with D radius, being this the relevant market area around each parking facility.

This estimation will follow the Ordinary Least Squares method, using robust standard errors to control for possible heteroskedasticity. Lin and Wang (2015) show that, in relation to parking duration, total parking expense is an increasing concave function, as such, price does not behave in a linear form. For that reason, and following the existent literature, a Log-Linear form is used when estimating the model. Spatial fixed effects at the civil parish level are also incorporated in the specification to account for possible unobserved variables, eliminating the omitted variable

bias, with the case reference being the civil parish of *Ajuda*. Moreover, fixed effects are also included for the type of structure that the facility, with the case reference being structural parking.

$$p_i = f(o_i; m_i; c_i; a_i; \varepsilon_i) \quad (1)$$

$$\ln(p_i) = \beta_0 + \beta_1 * o_i + \beta_2 * m_i + \beta_3 * c_i + \beta_4 * s_i + \varepsilon_i \quad (2)$$

where,

o_i = matrix of parking facilities features (capacity, operating hours, type of structure, operational costs and quality drivers)

m_i = matrix of market structure characteristics (HHI, ownership share)

c_i = matrix of curbside parking conditions (parking spaces, zones and fees)

s_i = civil parishes specific characteristics

ε_i = idiosyncratic error term

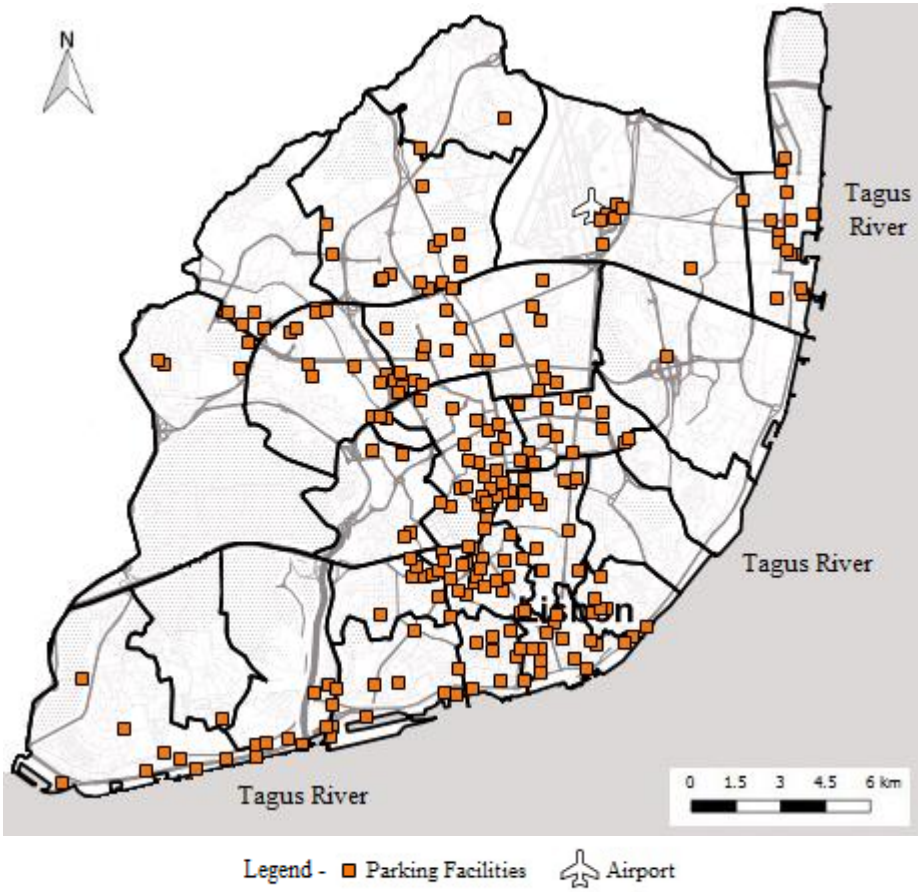
4.2. Data Sources

For this thesis, primary research was conducted regarding parking facilities features and prices, focusing on both private and public commercial parks located throughout Lisbon. Each facility was geo-coded through a georeferencing program, QGIS, in order to draw pinpointed maps and create competition variables, useful in the study of market structure, competition and impact of facilities location on prices. The map originated with this program is shown in figure 1, indicating each facility location.

Regarding curbside parking, EMEL is the only responsible operator, therefore, data relating to spaces density and prices was collected from their website.

All additional data presented in this study was collected from official records and government official websites, namely, INE (*Instituto Nacional de Estatística*) where data on population, car ownership rates, house selling prices was obtained; and *Câmara Municipal de Lisboa*, where data on civil parishes, such as area was retrieved, and also data on commercial and cultural spaces, transit options, and parking meters through *Lisboa Aberta*, an open data source website provided by the municipality.

Figure 1 – Map for the parking facilities analysed in this thesis



4.3. Variables

To estimate the price charged by parking facilities, measures representing the facilities features, measures accounting for market structure and measures related to curbside parking were used as explanatory variables. These variables will now be presented, and their expected impact discussed.

The three main characteristics used to account for operational and development costs are the facility capacity, the facility opening hours and the value of the land were the facility is located.

CAPACITY is the total number of parking spaces of each facility. This variable represents the pertinent investment costs incurred and demonstrates the shortage of the supply with respect to potential demand. The latter is also relevant when studying price determination, since the greater the gap between potential demand and available capacity, the stronger the power parking facilities can exercise. As such, the possible impact on prices is unpredictable.

HSPRC is the housing average selling price, in euros, per square meter, for the civil parish the facility is located in. This works as a surrogate for land value and is incorporated to reflect investment costs variability related with land acquisition.

Although CAPACITY and HSPRC are variables used to illustrate investment costs, they represent different perspectives of it, thus having a low correlation value (-0.04).

OHW is the number of opening hours, per week, for each facility. This allows consideration of operating costs (e.g. electricity) and personnel costs and is expected to have a positive relation to prices.

Moreover, through dummy variables, other features that might have an influence on prices were also taken into account: parking facility structure (surface, underground or structural); payment options (cash, card or Via Verde); if it has restrictions (height or GPL); if it has specific features (disabled spots, gated, light, overnight option, security camera, elevator or bathroom); and if it offers additional services (manned, car wash, valet). It is anticipated that some of these will impact prices, as they might increase investment and operating costs, decrease personnel costs or even affect drivers perceived quality.

COMDENSE accounts for the commercial density present in the relevant area. It is calculated as the total number of commercial places divided by the area, in hectares, within the buffer market. As the level of commercial density increases, price increase is also predictable, considering areas with a higher economic level have a higher parking demand.

Regarding, market structure, two aspects were covered for each parking facility in its relevant area: the Herfindahl-Hirschman Index and the presence of competitors owned by the same operator. Following the existing literature, to create the significant market for each parking facility a 500 meters radius buffer was used, due to the aforementioned walking costs.

HHI was calculated as the sum of the squared market share that each operator has within the pertinent area for a specific facility. This value ranges between 0 and 1, with the latter case representing a monopoly situation. It is expected to have a negative impact on prices since an increase in competition translates into price decrease.

SHARE was incorporated to assess the impact that the level of market power of each facility has on price. This was calculated as the share of competitors owned by the home operator within the relevant area, and varies between 0 and 1, where 1 represents the operator owning 100% of the parking facilities present in that confined area. Contrary to HHI, it is anticipated to have a positive relation on prices, because an increase in market power allows the operator to increase prices.

Following Albalate and Gragera (2016), to take into consideration the effect that curbside parking can have as a substitute for off-street parking facilities, the features of on-street parking were also included in this thesis through three explanatory variables.

CURBDENSE expresses the level of supply for curbside parking for the catchment market area, measured in spaces per hectare. To calculate this measure, the total number of existent curbside

spaces within the relevant area was divided by the buffer area, in hectares. It is expected to negatively influence prices, considering these spaces are a strong substitute for parking facilities.

CURBFEE is the weighted curbside price per hour of the curbside spaces existent in the relevant area, by the type of zone. Its predicted to have a positive relation with the prices set by the operators.

GRATIO is the ratio of the capacity of the home parking facility to the curbside spaces existent in the relevant market, allowing to measure the power of facilities over the curb. It is expected to have a positive impact on prices, as the stronger the power the facility has in relation to the curb, the higher the prices it can charge.

EMEL is a dummy variable with the purpose of accounting for the fact that some parking facilities are owned by the public operator. Even though the prices charged in these facilities follow an economic reasoning and are not fixed by the government, they were the first movers in this market.

OPTIONS comprehends other type of options for drivers to reach their destination - the number of metro and train stations within the significant pertinent area for each parking facility, as they can substitute the transportation mode altogether and not just the parking space.

Adding to the existent literature, this thesis proposes variables that relate distance between parking facilities with type of structure, to assess how prices from more distant facilities (outside the catchment area), which imply higher walking costs, impact the parking facility pricing scheme. This effect was studied having into account different types of structure of parking facilities, as these imply different cost structures. Besides the 500 metres buffer considered, it were also included "donuts" for intervals between 500 and 600 metres, 600 and 700 metres, and 700 and 800 metres. These variables were created through QGIS, and calculated as the average price per type of structure for each "donut" interval.

Table 6 characterizes the variables mentioned, except for the dummy variables.

Table 6 – Summary of descriptive statistics for the explanatory variables. Dummy variables are not included.

Variable	Obs	Mean	Std. Dev	Min	Max	Unit	Description
PRICE	237	1.21	0.05	0	3.60	price per hour	1h price
LNPRICE	237	0.19	0.03	-2.48	1.28	natural log of price per hor	1h price
CAPACITY	237	301.97	36.21	1	6850	number of spaces	capacity
OHW	237	148.90	2.16	50	168	number of hours per week	operating hours per week
HHI	237	0.38	0.02	0.06	1	index points	Herfindahl-Hirschman Index
SHARE	237	0.18	0.02	0	1	percentage	share of competitors owned by operator
COMDENSE	237	368.10	20.83	0	1639	density per hectare	commercial density
HSPRC	237	3082.48	38.65	1606	4133	price per squared meter	house average selling price
OPTIONS	237	1.20	0.06	0	4	number of options	train and metro options
CURBDENSE	237	2277.42	105.21	0	5551.32	density per hectare	curbside parking density
GRATIO	237	45.47	18.66	0	3693	number of spaces	ratio between facilities and curb capacity
CURBFEE	237	0.87	0.03	0	1.48	price per hour	curbside parking fees
PSURF500	237	0.77	0.05	0	3	price per hour	average price surface facilities within 500m
PUNDER500	237	1.21	0.05	0	3.40	price per hour	average price underground facilities within 500m

It should also be mentioned that before running the OLS model, the Gauss-Markov Assumptions were tested to ensure that the OLS results were the best possible estimate. The assumptions on random sampling and parameters' linearity are automatically checked. The no perfect collinearity assumption was tested through VIF, where no variable presented a value higher than 10 and where the mean VIF was 2.01 (please refer to Appendix 1). The assumption for zero conditional mean tested through a scatter plot of the errors was not satisfied, possibly due to the omitted variable bias, and so, to account for this, fixed effects regarding civil parishes were used. The last assumption, homoskedasticity, verified by the Breusch-Pagan Test, was also not satisfied, thus, robust standard errors were used, to control for the existing heteroskedasticity.

5. Results and Discussion

The model estimation results are presented in table 7[2]. Model 2 accounts for the fixed effects that arise from each civil parish and is the best model as it presents a higher adjusted R-squared. This model explains 29.8% of the parking price variation observed in Lisbon[3].

[2] Model estimations were done through Stata.

[3] It is interesting to note that the adjusted R-squared in this analysis is of the same magnitude as in Albalate and Gragera (2016) which equals 0.283.

Table 7 – Results.

Variables	Model 1		Model 2	
	Coeficient	P-value	Coeficient	P-value
SURF	.992224	0.413	.033757	0.818
UNDER	.2157866	0.091*	.1947019	0.186
SQOHW	-.0000103	0.030**	-8.48e-06	0.142
ONIGHT	.2210608	0.064*	.2294376	0.082*
BATH	.184122	0.012**	.1627641	0.040**
PVIA	.1962799	0.056*	.1877056	0.082*
HSPRC	.000098	0.201	-.0001519	0.704
COMDENSE	.043305	0.000***	.0472814	0.002***
HHI	-.3194704	0.095*	-.43519	0.048**
SQSHARE	.4328218	0.060*	.314689	0.234
CURBFEE	-.1664895	0.268	.1481164	0.282
CURBDENSE	-.0000285	0.099*	-.0000978	0.032**
EMEL	-.0597056	0.579	-.0332237	0.758
OPTIONS	-.0089447	0.776	-.0406117	0.275
PSURF500	.1146196	0.052*	.0364976	0.657
PUNDER500	-.0645652	0.355	-.1275623	0.033**
Constant	-.1878485	0.436	.5773285	0.574
Observations	237		237	
Adjusted R-squared	0.247		0.298	
Structure fixed effects	Yes		Yes	
Civil parish fixed effects	No		Yes	

, ** and * represent significance levels of 10%, 5% and 1%, respectively.*
Area-specific dummies are not reported.

Note that including civil parish fixed effects improved the model performance, and so, conclusions will be drawn from Model 2. However, these spatial fixed effects might not accurately capture the unobserved variation of the parking facility relevant market, as this tends to be a smaller catchment area than a civil parish.

The fixed effects accounting for the type of structure show that being an underground parking facility (UNDER), rather than a structural one, is not statistically significant.

The different operational cost measures used have different impacts on prices. While offering the overnight option (ONIGH) and having the presence of a bathroom (BATH) translates into an increase of the price charged by 22.9% e 16.3%, respectively, the operating hours (SQOHW) are not statistically significant. The possibility to pay with *Via Verde* (PVIA) increases the price

charged by 18.8%, ceteris paribus. The existence of such system implies not only increased installation costs but also increased perceived quality, and so parking facilities can charge a mark-up on their fee.

HSPRC, which attempts to capture land value and subsequent costs, is not statistically significant.

COMDENSE correlates positively to prices and is the most significant explanatory variable. It expresses the possible parking demand present within the relevant area, since high levels of economic activity create demand for parking in that area. Ceteris paribus, a unitary increase in commercial density per hectare leads to a 4.73% price increase.

Contrary to the parking facilities market in Barcelona, HHI is significant in the Lisbon's market, similarly to Lin and Wang (2015) results for the Manhattan's market. However these have opposite correlations: while in Lisbon, an index point unitary increase in the HHI decreases prices in 43.5%, ceteris paribus, in Manhattan a 4% decrease in the HHI (which corresponds to 1 standard deviation of their data) leads to a 12% price decrease. In Barcelona, Gragera and Albalate (2016) justify their result by the fact that imperfect information gives parking facilities no incentives to lower prices, as drivers would not be aware of prices changes or alternative parking facilities nearby, and so, parking facilities competition with each other, is not a significant variable. In Manhattan, competition drives prices down, as predicted by the economic theory. In Lisbon, this does not seem to be the case. A possible reason for this negative relation can be that the parking facilities catchment area characteristics have a strong influence on how these facilities set their prices, especially curb prices. Note that competing with curbside parking is more relevant than competing with each other, as the price differential between the two is low. So, even if the market has increased concentration from parking facilities, these will still react to on-street parking fees.

In addition, and also in contrast to Gragera and Albalate (2016) findings, CURBFEE is not statistically significant, but CURBDENSE is. This may be explained by the price differential between the curb and parking facilities being smaller in Lisbon (average price differential of €0.34), than in Barcelona (€0.72), and the availability of parking spaces being also an important driver of parking prices, although the impact of the latter may be overlooked, as a unitary increase in curbside parking density decreases prices in 0.0001%.

EMEL is not statistically relevant. Even though the parking facility is owned by the public operator, it behaves as a private operator and so this characteristic has no significant impact on how prices are set. OPTIONS is also not statistically significant.

The price for surface parking facilities within 500m (PSURF500) is not significant. However, price for underground parking facilities within 500m (PUNDER500) is. A unitary increase in this price will decrease the price estimation in 12.8%, ceteris paribus.

6. Conclusions

Lisbon, like most cities in the world, has a pricing gap between parking facilities and curbside parking. This leads to inefficiencies in the parking market due to cruising and traffic congestion (Shoup, 2016). The right price differential occurs when curb fees are close to parking facilities prices, allowing for rotation. In Lisbon, this differential is €0.34, nonetheless, not small enough to achieve efficiency.

In this thesis, the determinants of parking prices were studied, accounting for operational costs and quality forces as well as market structure characteristics, curbside parking features and by incorporating distance related variables. A Log-Linear specification was used to estimate the price

model using a cross-sectional database of 237 parking facilities located throughout the city of Lisbon.

As in Gragera and Albalate (2016) curbside features also influence the price charged by parking facilities in Lisbon and, like in the Barcelona case, curbside parking is also being used inefficiently. However, the gap between curb fees and the prices set by off-street commercial facilities is not as high in Lisbon compared to Barcelona, and therefore parking facilities cannot exploit their market power with the same strength as in the Barcelona case. This may explain why curb fees are not statistically significant in the Lisbon's market and why parking facilities charge, on average, lower prices compared to Barcelona. On the other hand, curbside parking density is significant and should be used as a policy instrument to overcome some of the parking issues and car usage in Lisbon.

Furthermore, and in line with the existent literature, variables that account for operational costs and quality drivers have the highest impact on parking prices, explaining most of the price variation in Lisbon's parking facilities market.

To get the right price differential that allows the elimination of cruising and the problems that arise with it, curb prices should be higher. This would in turn reduce the gap between the curb and off-street facilities prices and also cruising as shown in the Amsterdam case. However, some caution should be taken when considering the main conclusions from this study. Like in the case of Barcelona, it is possible that Lisbon drivers also do not have perfect information on the prices charged by parking facilities or about the location of neighbouring parking facilities. Parking facilities can take advantage of this and further exacerbate pre-existing distortions by exploiting their market power, even if the gap between curb fees and off-street prices is quite slim. Nonetheless, future research relating driver's information and behaviour could be taken to further underhand parking prices. Another avenue for future research would be to explore possible spatial

interactions between existing parking facilities which if not address may lead to spatial autocorrelation.

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Appendix

Table demonstrating VIFs results for the variables included in the model.

Variable	VIF
PRICE	1.62
SURF	2.36
UNDER	2.87
CAPACITY	1.16
OHW	1.66
PVIA	1.67
ONIGHT	1.75
BATH	1.47
COMDENSE	2.36
HSPRC	2.08
HHI	2.72
SHARE	2.34
EMEL	2.00
CURBDENSE	2.01
GRATIO	1.08
CURBFEE	4.12
OPTIONS	1.69
PSURF500	1.37
PUNDER500	1.82
Mean VIF	2.01