Parking policy in Arnhem: lowering off-street parking prices during the evening

Master thesis

Abstract - Cities all around the world deal with the problem of empty off-street parking spaces while the on-street parking spaces are full. Literature from Kobus et al. (2013) and Ostermeijer et al. (2022) suggest this might be because there is an on-street parking premium. In this research, we will estimate how a policy change in Arnhem in 2015 influences the decision to park on- or off-street. The policy change was to lower the off-street parking prices below the prices of on-street parking during the evening. To estimate this a linear probability model was used with a difference-in-difference estimator. The results indicate an increase in the probability of parking off-street equal to 7-9% on 'Koopavond' (the only evening when the shops are open) after the policy change. On other evenings people park more off-street as well when there are lower prices. The results imply that lowering the prices can lead to more people deciding to park off-street instead of on-street.

Vrije Universiteit Amsterdam, School of Business and Economics
Spatial, Transport and Environmental Economics (STREEM)
Annemiek van Loon (2647474), a.l.van.loon@student.vu.nl
Supervisor: Prof. J. van Ommeren
Date: 29/06/2023

Index

1 Introduction

Every car ride starts and ends with parking. But where are all the cars parked? In city centers there is often not enough parking space for all residents to park their cars on the street. The overcrowded streets lead to problems like double parked cars, but also to congestion, noise, and pollution. In Amsterdam, off-street parking facilities in the form of garages are built to reduce these problems. However, people still prefer to park on the street instead of off-street in the garage (Frederik, 2018). This results in busy streets with empty expensive garages underneath them. This is not only true for Amsterdam, cities around the world deal with similar problems (Shoup, 2005).

Literature on pricing parking suggests it is best to price curbside parking the same as garage parking. However, this is the case in Amsterdam and still the garages are empty. The literature finds that this might be caused by a premium for parking on the streets (Kobus, 2012; Kobus et al., 2013; Gragera, 2017; Ostermeijer et al, 2022). People prefer to park on-street and are willing to pay more for on-street parking than for off-street parking. This would suggest that parking problems could be solved by lowering the prices off-street or increasing the prices on-street. Arnhem dealt with the same problems as Amsterdam in its city center and decided to try and lower the prices to empty the curb and fill up the garage. Previous research on this premium has investigated the effect of having a price difference. We will add to this by investigate the effect of changing the policy by lowering the prices off-street in the evening in Arnhem in 2015. We will try to find if this has a positive effect on the probability to park off-street. This can contribute to the literature by showing how a change in policy through lowering the price off-street could lead to less empty garages and overcrowded streets.

To investigate this, we will try to answer the research question: *"How does a policy change of lowering off-street parking prices below on-street parking prices affect the decision to park on- or off-street?"* A policy change in 2015 made off-street parking on evenings approximately €2 cheaper compared to on-street parking. We are interested in how this affects the behavior of people choosing where to park. This study focuses mainly on the effect of the policy change on 'Koopavond'. 'Koopavond' is a Thursday evening when parking is cheaper, but the shops are open. Next to this, this study investigates the effect of Covid-19 on parking decisions.

The question will be answered using a linear probability model which includes a difference-in-difference estimator to capture the effect of the policy change on 'Koopavond'. This is done for the years 2014-2023. In here we will also be able to see the effect of Covid-19. After this, a similar linear probability model is used to investigate the effect on 'Koopavond' only. We hypothesize that more people will park off-street after the policy change in the evening. Next to this, we expect this effect to be larger on 'Koopavond'. Another expectation is that people with short durations will park on-street. The last hypothesis is that Covid-19 decreases the number of parked cars and increases the probability to park on-street.

The thesis will be structured as follows. Section 2 will describe the relevant literature on pricing parking. Thereafter, section 3 will explain the data and context, describe the trends in Arnhem with relation to parking, the methodology used to answer the research question, and possible limitations to this research. Section 4 will describe the results which will be discussed in section 5. Finally, section 6 will provide conclusions and recommendations for further research. After section 6, a reference list can be found and appendices regarding a map of Arnhem, and regression tables can be found.

2 Literature review

2.1 Pricing parking

With the arrival of the car questions about parking cars came to light[1]. In 1954 one of the first papers about pricing parking was written by Vickrey. According to Vickrey the most efficient way to regulate parking was to price parking. Price parking ensures parkers with the highest willingness to pay are the ones parked in the available spots. Without pricing, parkers are not distributed efficiently over space. This is because with free parking there is no spot available for the person with a higher willingness to pay compared to the people parked. But also, because more people will locate around in or the city center, while not having the highest willingness to pay. This leads to too many people wanting to park at the same place leading to cruising for parking. The parking spaces near the city center are full, while the parking spaces further away are empty (Anderson & De Palma, 2004). With setting the right prices, cruising for parking can be eliminated and parking can be distributed efficiently over space (Arnott et al., 1991). However, in the past, most parking policies focused on creating available parking spaces for everyone instead of pricing parking. Minimum parking requirements in off-street facilities were issued by governments to ensure parking space everywhere. Today in countries all over the world this is still the parking policy. However, this only leads to car dependency (Shoup, 1999). Next to this, off-street facilities can be empty, because people prefer parking on-street over parking off-street. To get people off the full curb and into the empty garage it is better to price on-street parking than create more off-street parking.

2.1.1 Pricing against congestion

Another reason to price parking is to use it as a type of road pricing. Pricing parking can be seen as a second-best alternative to road pricing since road pricing is hard to implement (Zhang et al, 2015). A car trip begins and ends with parking, and with paid parking in most cities each trip in the city this ends with paying a parking fee. In this way travelling for the city over the roads is paid for in the parking fee and can be seen as a way of road pricing. However, how

[1] Literature review based on research project Annemiek van Loon (2023)

much and how long car drivers use these roads is unknown. Still, most of the external costs of road use can be internalized with pricing parking (Verhoef et al., 1995). Studies into the patterns of evening and morning commutes of workers concerning road tolls and pricing parking, show that commutes are optimized by internalizing a toll into the parking fee (Fosgerau & De Palma, 2013; Zhang et al., 2015). A downside though is the fact that only people ending their trip in the city need to pay for parking, and not people driving through. Therefore, congestion will not be reduced enough for it to be an alternative against road pricing (Glazer & Niskanen, 1992). Congestion could even be increased with pricing parking as high prices would lead to lower durations of parking, which leads to higher turnover (Zakharenko, 2016). However, when people who arrive first are not priced, they will occupy a place as long as they want. In central business districts can be parked on a spot all day, which ensures that people with other purposes need to park somewhere else even though they might only be parked there for a short while.

2.1.2 Cruising for parking

It is said that free parking does not exist. With an inefficient distribution of parking, there will always be people searching for a parking spot. This search time takes time, which costs money. In addition, there are search costs such as extra fuel, and there are externalities imposed on others like noise, pollution, and congestion (Shoup, 2006). These are the so-called cruising costs. Next to this, people are further away from their destination, which makes that they need to walk longer, but also park at a space in front of somewhere someone else has to be. On hir or her turn, this person then also has to cruise to find a parking spot (Arnott & Rowse, 1999). Cruising also occurs when parking is priced differently at a certain location or on-street compared to off-street. In most countries, off-street parking is more expensive than on-street parking which leads to creasing because people try to find a cheaper on-street spot. Next to this, people cruise because they want to park near their destination even though it is more expensive in this place. With inefficient pricing, people will therefore continue to cruise (Calhtrop & Proost, 2006).

Estimates of cruising for parking for 11 cities around the world show how 8-74%, with an average of 30%, of cars has to cruise for parking (Shoup, 2005). Some caution needs to be taken, because some studies were performed in overcrowded and underpriced locations. Still it is important to see how since the arrival of the car cruising for parking is an issue (Shoup, 2021). Newer methods nowadays are used to measure cruising of parking. In San Fransisco and Ann

Arbor estimates were found of 5-6%, with a very strict definition of cruising (Weinberger et al., 2020). In Stuttgart estimates of 15% were found (Hampshire & Shoup, 2018). The question remaining is what the cruising costs are. There are the cruising costs for yourself, and the costs imposed on others. The latter can be researched by seeing how many people need to cruise because all spots are taken. In Istanbul, parking your car for an hour leads to marginal external costs equal to 15% of the hourly Istanbul wage (Inci et al., 2017). An improvement was made to the methodology of Inci et al and the study was reproduced in both Istanbul and Melbourne and found the same results (Van Ommeren et al., 2021). The private costs of cruising can be estimated by looking at the willingness to pay for a parking permit by residents in Amsterdam. The willingness to pay of residents is lower compared to that of non-residents. This leads to inefficient distribution of parking. And still residents must search for a spot, since it is not assigned. These private cruising costs are equal to €1 per day (Van Ommeren et al., 2014). When cruising time is known, private cruising costs are equal to external cruising costs (Arnott & Inci, 2006). Which in Amsterdam would mean €2 per day per resident, not including external noise or pollution costs.

2.2 Pricing on- and off-street parking

On- and off-street parking are related to each other. In this section, we will first look into how parking prices off-street are determined and what the optimal price for off-street parking is. Hereafter we will investigate the optimal price of on-street parking and how this relates to off-street parking prices.

2.2.1 Off-street parking

Parking in off-street facilities is determined by multiple factors. Garages and parking lots can be linked to other activities like going to the stores or to the theater, which can influence prices. Next to this, garage parking is connected to curb parking. For instance, expanding the supply of off-street parking in Barcelona does not affect the fee in garages. However, a change in the price of on-street parking does affect prices in off-street parking (Albalate & Gragera, 2017). When the prices of on-street parking go up, the garages fill up, there is a negative price elasticity. This is the case for frequent and infrequent parkers (Gragera & Albalate, 2016). Next to this, prices are determined by imperfect information. Price obfuscation in the off-street parking market is used to drive the prices up. In Barcelona the cheapest parking spot can only be found by experience or passive information, and not by an intensive search strategy (Albalate

& Gragera, 2018). Therefore, governments are needed to ensure perfect information on the parking market for efficient pricing.

Another determinant for off-street parking prices is the influence of market power. There is market power because parking garages and parking lots are discretely distributed over space. There is not always an off-street alternative close by another off-street facility. Prices are determined by the amount of competition there is and how much market power private off-street parking facilities can exert (Arnott, 2006). When market power can be exerted, higher prices than marginal costs can be charged. In New York this effect of market power is studied, and it is found prices go up with market power (Lin & Wang, 2015). This effect is studied even further by looking into a merger of garages in Paris. It finds that with a merger and thus less competition, prices go up (De Nijs, 2012). Private parking facilities do not internalize cruising costs, which makes pricing inefficient. Parking facilities owned by the government do internalize these externalities (Anderson & De Palma, 2004). This can be one of the reasons why in most cities in the world off-street parking is regulated by the government and only a share is publicly owned (Kobus et al., 2013).

2.2.2 On-street parking

The on-street parking fee is connected to the off-street one. People will try to maximize their utility by choosing the best parking spot. Prices are a big determinant in this utility. The curb is currently underpriced. In Barcelona the efficiency gap comes down to €0.45-€1.05 (Gragera & Albalate, 2016). This efficiency gap is the result of cruising for parking. The full price of parking on-street consists of the price for parking paid and the cruising costs together. With a lower on-street parking price people will try to find a spot on the street which causes cruising costs. When the prices of on-street parking go up people will decide to park off-street when there is no place on-street and this will go on until the parking prices of both options will be equal and cruising is almost eliminated (Arnott, 2006). It is therefore best to have curb parking priced in such a way that cruising is eliminated, but parking is not unsaturated (Arnott & Inci, 2006). This is true when assuming prices are the main determinant for choosing where to park, which is true according to Golias et al. (2002). Next to the private cruising costs, external cruising costs are now also accounted for, and the government no longer needs distortionary taxing against externalities. Next to this, overcrowding on streets will diminish and empty garages will be filled up again.

Arnott & Inci (2006) assumed sensitive demand for parking, Arnott & Rowse (2009) use the same concept model but assume insensitive demand. Meaning a higher price will not directly affect parking decisions. An increase in prices on-street will lead to the same full price, but search and cruising costs are now included in the fee. This leads to an increase of the social surplus equal to $3.20 for each $1 increase in the parking price. Market power of private garages can be a problem in trying to achieve efficient pricing. With a monopoly on off-street parking facilities the prices should not be equal but just under or over the price of off-street parking. This is in the extreme case of a monopoly on off-street parking (Calthrop & Proost, 2006).

Another solution for an efficient parking market is to optimize capacity. However, distortions in the parking market make it hard to find optimal capacity. From the literature one general conclusion is found. With very high demand all capacity should be off-street and with very low demand on-street (Arnott & Inci, 2015). This happens in some downtown cities with very high demand (Arnott et al., 2015). Yet, the difficulty lies in determining optimal capacity in between the extremes. The optimal capacity can be created by optimal pricing. In this way capacity is self-supplied (Van Ommeren et al., 2021).

The effect of decreasing the gap between of- and on-street prices is studies in Amsterdam, by looking into the big parking policy changes with relation to parking prices in 2019. Prices on-street went up with an average of 66%, off-street parking prices went up by less than this, decreasing the gap. The increase in prices led to 14% less demand on-street and 17% less demand on- and off-street. This again decreased traffic in Amsterdam with 2-3%. In the evening this effect is greater than in the morning (Ostermeijer et al., 2022). Another study into the effect of pricing was done by a simulation using a Wardropian traffic model. This study showed that higher fees on-street increase welfare. However, the study also showed that poor individuals benefit less since their value of time and thus cruising costs are lower compared to richer individuals (Van Nieuwkoop et al., 2016).

2.3 Premium for on-street parking

The studies mentioned in section 2.2 concluded that on- and off-street parking should be priced the same. However, this is only true when people attach the same value to parking on-street as to parking off-street while this is not always the case. Some people value on-street parking more because they can park as close to the destination as possible and walking time is minimized or because parking garages have small designs which makes parking more difficult (Arnott et al., 1991). Other reasons for parking on-street can be cheap fuel prices, which makes cruising less expensive, a low value of time and being alone, which makes the travel costs to the destination smaller (Shoup, 2006).

The willingness to pay extra for parking on-street is measured in recent studies. In Barcelona estimates for the extra willingness to pay for on-street parking are equal to €0.55 an hour. These estimates are even higher when comparing on-street parking with private off-street parking. This is because private garages only interact with on-street prices and not with other garages when determining their prices (Gragera, 2017). Another study into the premium of parking on the curb is performed in Almere. In Almere there is almost no cruising for parking and on-street parking is more expensive than off-street parking. In this study a premium of €0.35-€0.58 per hour for parking on-street is found (Kobus, 2012). With an improved model (Kobus et al., 2013) find similar estimates of a premium of €0.37-€0.60 an hour for parking on the curb. The demand for on-street parking depends on the duration of parking and is more elastic when people park for longer periods. The premium for on-street parking is thus higher with shorter parking durations. Individuals who want to park for longer periods are more likely to park off-street and walk longer. Individuals who park for shorter periods have to walk less. This decreases the total costs concerning walking. These studies show how setting the price of on-street parking can be welfare improving by decreasing cruising for parking, preventing too busy streets, and increasing the occupancy rates in the off-street parking facilities.

2.4 Parking trends and Covid-19

With the arrival of possibilities to use data and mobile phones, parking behavior and parking policy changed. Making use of data makes it easier to find free parking spots in garages and makes analyzing pricing policies easier. Intelligent parking systems can reduce congestion, pollution, parking times, and even accidents (Yang & Lam, 2019). This same conclusion is drawn by Caicedo (2010), who also states that search costs decrease when using intelligent parking systems such as real-time parking information. At the same time parking apps become more and more popular. Paying with cash is disappearing as more and more people opt to use parking apps (Trendboek Mobiliteit, p. 88-89, 2023). The use of parking apps has a positive influence on the utilization of parking spaces, which makes parking more efficient and decreases cruising for parking (Ahad et al., 2016). This leads to lower on-street parking costs. Next to this, parking with apps makes you pay for the real time you park instead of the time you entered at the parking meter. It makes parking on-street less stressful which makes it more attractive (Trendboek Mobiliteit, p. 58-59, 2023)

During Covid-19 parking behavior changed drastically. Because of the lockdowns, city centers were empty and so were the parking spots in these cities. The Google Mobility Index measures the number of people and their purpose in a certain place by analyzing phone movements. From this it is known how many people are in the city center. This is compared with the hours parked of short-term parkers around the city center. It is found that the two follow the same pattern. In April 2020 there was 67.3% less parking than in January 2020. In the following months it seemed that with making the lockdowns less strict people return to their old ways. This is not the case however for business parking, with more people working from home there is less demand for parking from workers (Monit, 2021). Studies in Australia also showed how presence of cars decreased with 12.6%-56.4% during the first lockdown (Mesfin et al., 2022). Until now, no literature has been found on the effect on parking post Covid-19 to see if there are permanent changes in behavior.

3 Methodology

3.1 Context

3.1.1 The municipality of Arnhem

The data used for this research is open data from the municipality of Arnhem. This data has been made publicly available with authorization of Arnhem via Monit, an IT company focused on data driven research into parking. The city of Arnhem is located in the province of Gelderland in the Netherlands. The city has around 165,770 inhabitants (CBS, 2023). During the Second World War Arnhem was heavily bombed and ruined. After the Second World War a period of rebuilding started, and Arnhem was modernized. Nowadays Arnhem is an important traffic node for traffic over roads, rails, and waterways. The city center of Arnhem is known for its shopping possibilities, museums, theaters, concert building and places to go out during the evening (Buurtmonitor 2018, 2018). Unlike other evenings where stores are closed after 18:00, stores in the city center of Arnhem are open on Thursday evenings between 18:00-21:00. This concept is widely known as “Koopavond”.

3.1.2 Parking policy in Arnhem

Arnhem has 2715 paid parking spaces on-street and around 3200 parking spaces off-street depending on the day. There are differences in parking spaces per day because some off-street parking places are only open on Thursday evenings, Saturdays, and Sundays. In the city center there are 1411 parking spaces on street and 2300 in garages, which are regulated by the municipality (Gemeente Arnhem, 2023). The municipality has three municipal parking garages called “Rozet”, “Musis”, and “Centraal”. On-street parking is divided into 22 different parking zones. Parking can be paid online or at one of the 125 parking meters, which are connected to the 22 parking zones. Appendix 1 shows where the zones and three municipal parking garages are located. There are expensive zones, which are in the city center, consisting of zone 26001, 26031, 26033, 26041, 26075, 26092, 26093, 26094, 26095, 26096, 26097. And the less expensive zones consisting of 26011, 26034, 26051, 26052, 26061, 26071, 26073, 26082, 26099, which are outside the city center.

The parking policy in Arnhem has changed in 2015 and 2023. Before 2015 parking on the street was free between 18:00-09:00, except on Thursday evenings between 18:00-23:00 when parking was charged because each Thursday evening is ‘Koopavond’. During the day parking on-street was priced at €2.80 per hour. Off-street parking between 06:00-23:00 was charged at €2.52 per hour. From January 2015 onwards, street parking between 18:00-23:00 is charged for all days where before January 2015 only Thursday evenings were priced. Next to this, prices went up to €2.90 in expensive parking zones and to €1.75 in less expensive parking zones. Off-street prices got up to €2.52 an hour. However, to get people off the streets and into the off-street parking facilities, off-street parking prices went down to €0.50 per hour between 18:00-06:00. This change was made, because the streets were full in the evenings, while the garages were empty. The goal of the municipality was to change this around (Parkeervisie Binnenstad, 2016). In 2023 the prices of parking went up again. Street parking in 2023 is now charged at €3.40 in the expensive parking zones and at €2.25 per hour in the less expensive parking zones. Garage parking went up to €3.00 per hour during the day, and to €1.00 during the evening and night. Parking subscriptions are also possible in Arnhem for residents and cost €141 per year.

3.2 Data

3.2.1 Data description and selection

The dataset of Arnhem contains parking data on the parking transaction per month between January 2014 until April 2023. It shows for each observation when a parking session starts and ends. The dataset consists of 336 different csv files, which are merged into one dataset. The dataset has 27,018,336 observations and the data consists of three different types of parking options. Off-street parking, on-street parking paid through an app online, and on-street parking paid at a parking meter. For each different option it shows at which location an individual parks. For off-street this is one of the three municipal parking garages. For on-street paid online this is in one of the 22 parking zones. For on-street paid at a parking meter at which parking meter someone has paid, this parking meter is connected to one of the 22 parking zones.

After obtaining the full dataset the data was cleaned. Observations from the year 2014 before August were dropped, because 50% of the data on street parking was missing. Data was also dropped when the start or end time of the parking session was unknown. Next to this, observations with a duration smaller than five minutes and bigger than a week were dropped. Data from two parking meters with an unknown location and data from one unknown zone were also dropped. This dropped data is thought of as a human or computer error. Besides, holidays like Eastern, Whitsunday, Christmas and New Years' Eve were dropped. Because parking prices and times differ on these holidays.

Since Stata cannot work properly with more than 3,000,000 observations, a sample needed to be taken to handle this big dataset. A sample of 10% was taken and 2,421,051 observations were left in the dataset. This is still a big dataset and therefore it is possible to draw statistically significant conclusions even though a sample is taken. However, the standard error will be $\sqrt{10}$ times as big. This is something to be wary of when performing regressions. In Table 1 the descriptive statistics of mean, standard deviation, minimum, and maximum of the variables are visible. The zones, start- and ending times, and other time variables are left out, because they are not numbers but names.

Table 1 Descriptive Statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
Off-street	2,421,051	0.504	0.500	0	1
On-street	2,421,051	0.496	0.500	0	1
On-street online	2,421,051	0.534	0.153	0.297	0.817
On-street machine	2,421,051	0.466	0.154	0.163	0.703
Duration	2,421,051	3.577	7.426	0.083	168
Year	2,421,051	2018.448	2.545	2014	2023
Temperature in °C	2,421,051	10.631	6.272	-7.2	30.3
Precipitation in mm	2,421,051	2.464	4.882	0	68.5
During day	2,421,051	0.728	0.445	0	1
Evening	2,421,051	0.206	0.405	0	1
Koopavond	2,421,051	0.040	0.197	0	1
Parking price in €	2,421,051	2.171	0.907	0	3.4
Subscription	2,421,051	0.080	0.271	0	1

From the descriptive statistics we can find some general information about parking in Arnhem. Over the years, 50.4% of the people parks off-street and 49.6% on-street. Of this people who park on-street 46.6% pays at the meter, 53.4% online. The average duration of parking is 3.6 hours. Most parking sessions are during the day, with 72.8%. And 0.040% of the observations is on Koopavond, which is equal to 96,842 observations.

3.2.2 Creation of new variables

New variables were created to work with the dataset. Firstly, duration was derived from the start and ending times of the parking sessions. Secondly, dummy variables were created. For on- and off-street parking, for the way of paying when parking on-street in the form of online or at the meter. A dummy for being during the day and during the evening was created, for parking being on Koopavond, for having a subscription or not, and for being in a certain zone. All parking meters were matched to their zone. After this, parking prices were included and matched to the zone, year, and time. Next to this, weather data from the Royal Netherlands Meteorological Institute (KNMI) is merged into the dataset. This data comes from the nearest weather station in Deelen, 10 kilometers away from the city center of Arnhem. The total precipitation in millimeters and average temperature for each day is matched to each observation with the same date in the already existing dataset to be able to control for weather.

3.3 Trends in data

3.3.1 On- versus off-street parking

Where the descriptive statistics showed the average share of street and garage parking the trends in this section will show how this develops over time instead of an average over the years. Some caution when interpreting the number of parked cars is needed, the dataset is a 10% sample. Therefore, this is a 10% sample of the total number of parked cars per month. Still, the trend line shows how parking behavior changes over time.

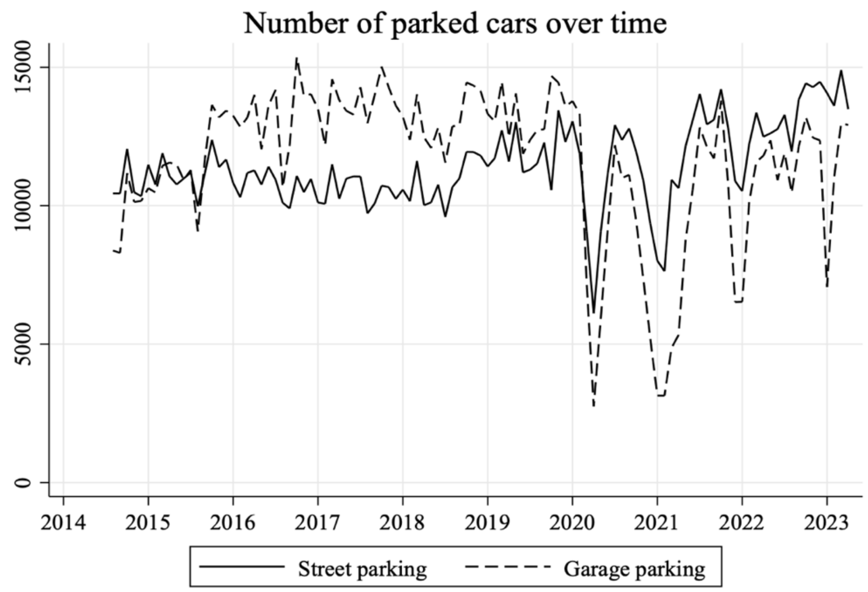


Figure 1 Graph number of parked cars per month over the years

In 2015 the local authorities of Arnhem changed the parking policy with the goal for more people parking off-street and less on-street. From Figure 1 we can see street parking stayed stable, however street parking relative to garage parking did decrease. From the second half of 2015 we can see the policy seemed to work. More people park on-street than off-street. However, in 2020 a sharp disruption can be seen. Covid-19 struck, and people had to stay at home. The number of parked cars decreases and mainly during the lockdowns. Next to this, more people choose to park on-street instead of off-street from this moment on. This behavioral change also exists after the Covid-19 pandemic and lockdowns.

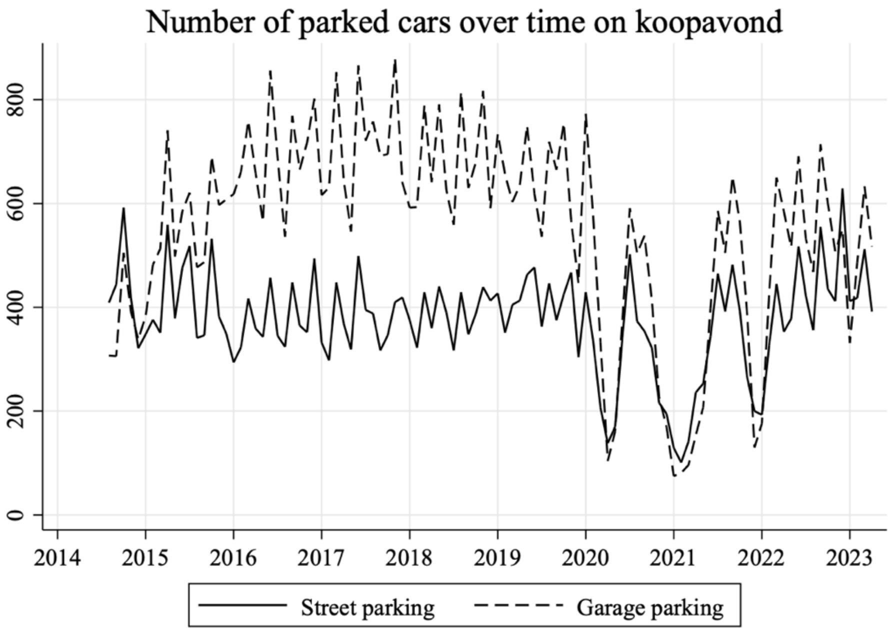


Figure 2 Graph number of parked cars per month over the years on Koopavond

In Figure 2 we can see the trend of parking on Koopavond. The price on-street in the evening was already €2.80, so the only change in 2015 is the lowering of the price in the garage. It is visible that many people decide to park at the garages from this moment on. However, also in this case people’s behavior seems to change a bit after Covid-19. Less people park during Koopavond and the difference between on- and off-street parking is less visible. The difference with Figure 1 however is there is still relatively more off-street parking during Koopavond.

3.3.2 Duration of parking

When looking at the effects of duration on parking decisions it is important to see if duration has changed over time. In Figure 3, we can see how there seems to be a small upward trend in duration on the street, however from 2019 on this is not visible anymore. For garage the upward trend is better visible, especially when looking at subscripted parkers. These are mainly residents of Arnhem. With working more from home more people are parked than before.

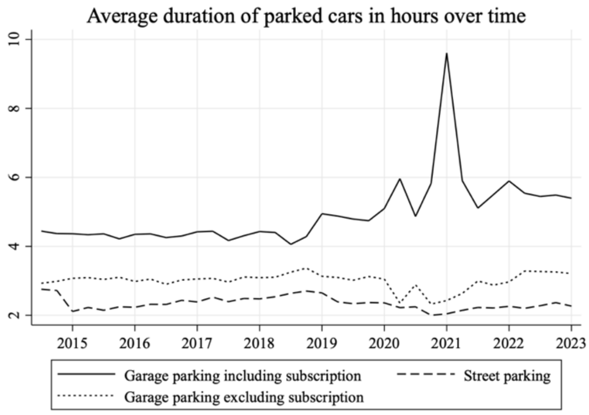


Figure 3 Graph duration of parking over the years

3.3.3 Parking at a parking meter or online

In Figure 4 we can see how the share of paying online via an app when parking on-street has increased, while paying at the parking meter has decreased. There was already a trend going on over the years since 2014, Covid-19 seems to not have changed this trend. However, it is visible that if this trend goes on, in a few years paying at a parking meter might disappear completely.

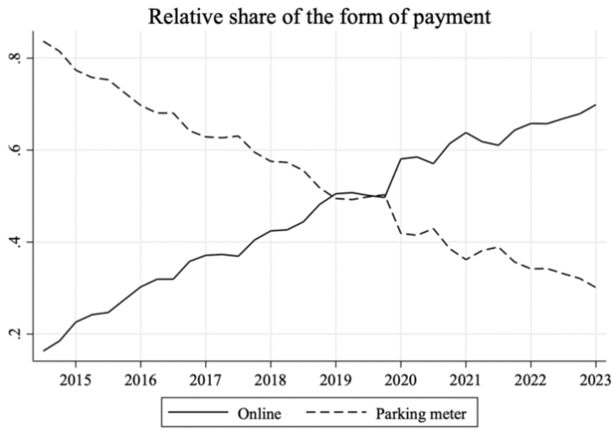


Figure 4 Graph type of parking payment in shares

3.4 Model

To research if the hypotheses drawn can be rejected or not, we first look at the relationship between parking on Koopavond and the probability of parking off-street or not. When individuals do not park off-street, they decide to park on-street, since it is a given that they want to park. This research is performed with a linear probability model, which is an Ordinary Least Squares method. In the model the dependent variable is *offstreet,* which is a binary variable, taking the value of either 0 or 1. And the independent variable is *koopavond* which is also a binary variable. A linear probability model is chosen instead of other binary models like logit and probit models because the linear probability model is easier to understand and thus easier to conclude from making it suitable for this research.

However, there are also downsides to linear probability models (Greene, 2007). Firstly, the non-normality of the error term, this can increase standard errors, which can lead to wrong conclusions. We already have a problem of higher standard errors because of the sample taken. However, there are still enough observations in the data for this downside not to be a problem. Secondly, there is the problem of heteroskedasticity of the standard errors. This problem can be fixed using robust standard errors, therefore robust standard errors will be used in all the models. Thirdly and lastly, there is the problem of expected values outside the 0-1 interval. A negative probability of parking on- or off-street is not possible, so this would be a problem. However, in this case this is not a problem since we are interested in the effect of *koopavond,* the effect over time, of Covid-19, and in the effect of duration, but not in the result of the probability of parking off-street when adding all these variables. Next to this, when we look at the results of our models a probability lower than 0 or higher than 1 is not likely to occur.

We will also perform an event study which measures a difference-in-difference. Which will be used to extract the effect of lowering the price in 2015 relative to 2014 in the parking garages on Thursday evenings. One problem with this is that we only have data from August 2014 on, which makes it harder to validate the equal trends assumption, since the new policy started in 2015. Next to this, we do not have data on similar cities and the parking behavior in these cities. However, there seems to be no reason to believe there was a specific trend in parking on Koopavond before 2015.

3.4.1 Model specifications Table 2

The first model will investigate what the effect of *koopavond* is on the decision to park on- or off street. In this case *offstreet* is the dependent variable and the variable *koopavond* is the independent variable. To do this a selection of data is taken, observations with a duration bigger than 8 hours are dropped, since these observations are not people comparable to people who park on Thursday evenings, but park for other purposes. Next to this, observations with starting times from 16:00-18:00 are dropped, to distinguish if someone parks during the day or the evening and not during both. Next to this, we will look at an area with three parking garages and parking zones are dropped if they are more than 10 minutes walking away from a parking garage. This is the maximum distance non-weekly shoppers are willing to walk (Van der Waerden et al., 2017).

First a baseline model is created, to which the other models can be compared. In the following models, we will add monthly dummies to control for time fixed effects, we will add control variables, like duration, evening, and weather, and a difference-in-difference estimator will be added to investigate the price change in 2015 on Koopavond. Robust standard errors are used in all the models to make sure there is no heteroskedasticity. This is done by clustering the standard error by the date, since some of the variables in the dataset are the same for each date. In the first model we will define Y_{it} as the dependent variable *offstreet* which is equal to 1 when someone parks off-street, K_t as the *koopavond* variable, which is equal to 1 during Thursday evenings, and ε_{it} as the error term.

$$(1)\ Y_{it} = \beta_0 + \beta_1 K_t + \varepsilon_{it}$$

The second specification adds *duration* in hours as an independent variable for the decision to park on- or off-street. It is defined as D_i. Duration has a big impact on the decision to park on- or off-street. Especially for short durations people are expected to park on-street. It is expected that when duration increases, people will start to park less on-street and more off-street. A problem however can be the endogeneity of the duration variable (Kobus et al., 2013).

$$(2)\ Y_{it} = \beta_0 + \beta_1 K_t + \beta_2 D_i + \varepsilon_{it}$$

After this, a variable for *evening* is added. This is done because on all other evenings, parking is priced lower in garages as well, compared to the rest of the day and the street. When only including koopavond we see the effect of koopavond but are not able to define how koopavond might differ from other evenings. Next to this, it is useful to see how the parking policy affects non koopavond evenings as well.

$$(3)\ Y_{it} = \beta_0 + \beta_1 K_t + \beta_2 D_i + \beta_3 E_t + \varepsilon_{it}$$

After this, the weather control variables are added, first the average *temperature* of the day in °C specified by T_t and total *precipitation* of the day in millimeters specified by P_t . Temperature and precipitation are added since weather can influence the decision to park off-street or not. It is found that more people park off-street when there is rain and cold weather (Kobus et al., 2013). Next to this, weather can influence duration, because people do not want to be outside for long and park for shorter durations.

$$(4)\ Y_{it} = \beta_0 + \beta_1 K_t + \beta_2 D_i + \beta_3 E_t + \beta_4 T_t + \beta_5 P_t + \varepsilon_{it}$$

Hereafter, monthly dummies are added denoted by $\gamma_t$to control for time fixed effects. This is extra important since Covid-19 should be controlled for and with these dummies we can control for this. The monthly dummies will be studied to see how the policy change in 2015 impacted parking, how Covid-19 impacted parking, and if the new regulation of 2023 has an impact on parking.

$$(5)\ Y_{it} = \beta_0 + \beta_1 K_t + \beta_2 D_i + \beta_3 E_t + \beta_4 T_t + \beta_5 P_t + \gamma_t + \varepsilon_{it}$$

To measure the effect of the policy change in 2015 a difference-in-difference estimator is added, which is denoted by $K_t PC_t$. The dummy variable *policychange* is created which is equal to zero in 2014 before the policy change, and 1 after the policy change in 2015. This is interacted with *koopavond* to see how off-street parking might have changed after the policy change.

$$(6)\ Y_{it} = \beta_0 + \beta_1 K_t + \beta_2 D_i + \beta_3 E_t + \beta_4 T_t + \beta_5 P_t + \beta_6 PC_t + \beta_7 K_t PC_t + \gamma_t + \varepsilon_{it}$$

As mentioned before there is reason to believe duration is endogenous. Firstly, because garages are often further away from the desired location people want to go, this increases their walking time to the destination, which increases their duration. Secondly, because people know the prices of on-and off-street parking. Off-street parking is cheaper and people who want to park long will probably choose the cheaper option than people who park for a short while and choose the most convenient option. This can cause a bias the duration coefficient (Kobus et al., 2013). Therefore, duration is instrumented. The instrument used is the average duration per hour for everyone, this is correlated with the endogenous duration, but not with the decision to park on- or off-street. It is denoted by Z_i. This is done with a constant π_0 and an error term ν_i. The predicted values for duration from 7) are used as duration variable in 8).

$$7)\ D_i = \pi_0 + \pi_1 Z_i + \nu_i$$

$$8)\ Y_{it} = \beta_0 + \beta_1 K_t + \beta_2 \widehat{D}_i + \beta_3 E_t + \beta_4 T_t + \beta_5 P_t + \beta_6 PC_t + \beta_7 K_t PC_t + \gamma_t + \varepsilon_{it}$$

The results will be shown in Table 2 in section 4.2 Results Table 2. The monthly dummies will be shown in Appendix 2.

3.4.2 Model specifications Table 3

To investigate the policy change from the year 2015 we will perform an event study in which a regression is performed for Thursday nights only in the last five months of each year from 2014 till 2019. For 2014 we only have data for the last five months, since people can have different parking behavior at different times we compare similar months, with seasonal fixed effects. The last five months of 2014 can be compared to the last five months of 2015, this change can be compared to how it differs between 2015 and 2016, and between 2016 and 2017 and so on. Again, observations between 16:00-18:00 and with a duration longer than eight hours are dropped. Next to this, the same zones are selected.

Again, at first a baseline model is created. In this model a dummy is included to see what the effect is for being before or after the policy. The dummy is equal to 0 in 2014 before the policy change, and 1 after the policy change in 2015. We will define Y_{it} as the dependent variable *offstreet* which is equal to 1 when someone parks off-street*,* PC_t as the *policychange* variable, which is equal to 1 for the years after 2014, and ε_{it} as the error term. In (2), (3) and (5) the same steps as in section 3.4.1 were followed adding duration, weather controls, and instrumenting duration with average duration.

$$(1)\ Y_{it} = \beta_0 + \beta_1 PC_t + \varepsilon_{it}$$

$$(2)\ Y_{it} = \beta_0 + \beta_1 PC_t + \beta_2 D_i + \varepsilon_{it}$$

$$(3)\ Y_{it} = \beta_0 + \beta_1 PC_t + \beta_2 D_i + \beta_3 T_t + \beta_4 P_t + \varepsilon_{it}$$

To control for seasonal fixed effects, monthly dummies are included in the model denoted by γ_t. These dummies indicate whether an observation belongs to a certain month. So, to the month of August, September, October, November, or December. With these dummies we can compare the same months in different years and can control for patterns in specific months such as the summer vacation in August or shopping for Christmas and Sinterklaas in November and December.

$$(4)\ Y_{it} = \beta_0 + \beta_1 PC_t + \beta_2 D_i + \beta_3 T_t + \beta_4 P_t + \gamma_t + \varepsilon_{it}$$

$$5)\ D_i = \pi_0 + \pi_1 Z_i + \nu_i$$

$$(6)\ Y_{it} = \beta_0 + \beta_1 PC_t + \beta_2 \widehat{D}_i + \beta_3 T_t + \beta_4 P_t + \gamma_t + \varepsilon_{it}$$

3.5 Model limitations

Some limitations need to be considered before looking into the results to make sure they are interpreted correctly and for careful conclusions to be drawn. First, we will discuss the limitation of only having data from Arnhem from 2014 on, which can only be used from the month August on. Because of the interesting policy change in 2015 it would have been valuable to have data from more years before 2015. Now, we must assume the situation in 2014 is like that in the years before 2014 and there has not been a major behavior change. Besides, it would have been interesting to control for other cities who had similar policies in 2014 but did not change their policy in 2015. In this way, it would have been possible to see if the policy reason is the cause of a change in behavior, instead of only assuming it is because of the policy change.

Next to this, is the fact we do not have very specific data of Arnhem. The data is subdivided in parking zones, but the exact location is unknown. It makes it harder to distinguish which zone is still an alternative for garage parking. Large zones which on one location are close to a garage cannot be used, because at the other side of the zone there is no garage close by. Besides, there is the problem of only having the municipal parking garages in the dataset while there are also other parking garages in the city center.

Another limitation lies is the duration variable. As explained before this variable might be endogenous. With the IV approach we accounted for this endogeneity. In Appendix 3 we try to build a model to see if duration follows a certain trend. This is done by performing a linear regression model. First for on-street parking and thereafter for off-street parking. In the model Y_{it} is the dependent variable duration, YT_t the yearly trend, C_t a dummy for the lockdowns, T_t and P_t weather controls, $\mu_{i,s}$ zone fixed effects in case of on-street parking.

$$Y_{it} = \beta_0 + \beta_1 YT_t + \beta_2 C_t + \beta_3 T_t + \beta_4 P_t + \mu_{i,s} + \varepsilon_{it}$$

In Appendix 3 we can see the duration of parking on-street has increased with 0.006 hours each year and dropped with 0.16 hours during the lockdowns. For garage parking the effect is bigger. It grows with 0.16 hours per year, and Covid-19 lockdowns increased parking duration on average with almost 1 hour. This effect is also visible in Figure 3. This trend in duration might be the reason for more people to choose off-street parking since the duration of parking increases over time, and the price in garages is lower. However, we see the opposite in the trend over the years with more people parking on-street. It is important to be aware of this since duration is such an important factor in the probability to park on- or off-street. Besides, we use the average duration as an instrument.

The last limitation is the fact that there is not enough information about the effect of Covid-19 or the recent price increase. This is the case because these events happened not long ago. The results can change on the long term. However, it is still possible for now to see if there is effect on parking choices because of Covid-19. And if immediately after the price change of 2013, behavior changes.

4 Results

The results should be interpreted as follows when looking at Table 2. We have a linear probability model indicating that when it is Koopavond the probability of parking off-street goes up with around 0.0232-0.119 percentage point. With an average off-street parking probability over the years of 50.4% this comes down to a new probability which is 2.32%-11.9% higher. This would indicate an increase of 4.60%-23.61% in the probability of parking off-street at Koopavond. The other dummy variables can be interpreted in the same way. For precipitation, temperature, and duration it can be interpreted that when there is a one unit increase this leads to given percentage point increase. In case of the duration variable this would mean an increase in duration of one hour leads to a percentage point increase of 0.102-0.0914. this is also the case for precipitation and temperature. The R-squared from the variables is not that high. However, we are using a binary variable. Therefore, this is not a problem. The significance of each of the results found is denoted with asterisks. There are either one, two or three asterisks which means significance at respectively 10, 5, or 1 percent. When there are no asterisks, this means the result is not statistically significant.

4.1 Results Table 2

Table 2 shows the results from model specifications (1), (2), (3), (4), (5), (6), (7) as described in section 3.4.1. From this model we will try to see if there is reason to believe that lower prices in garages in the evenings, and especially on Koopavond, lead to more people choosing to park in garages during the evening. A difference-in-difference approach is used in which the interaction term is the interaction between *koopavond* and *policychange.* In (7) we will try and account for the endogeneity problem by using an IV approach. The instrument appears to be strong with an F-stat of 96.01 which is bigger than the value of 10 at which an instrument appears to be strong.

We will start by investigating what the effect of Koopavond is on the probability of parking on- or off-street. At first, in (1) and (2) the effect seems to be very big with a percentage point increase of 0.111-0.119. If we assume the average share of off-street parking to be 50.4% as in the descriptive statistics in Table 2 this would mean an increase in the probability to park off-street of 22.02%-23.61%. This changes however when including the other evenings into the model as can be seen in (3). The effect of Koopavond being in the evening is now captured into the evening variable as well. Next to this, the same price difference is present on all evenings hence the fact the probability to park off-street is also bigger on the other evenings. After including the evening variable, the effect of it being Koopavond is smaller, but still significant. The effect in (3), (4), and (5) is now equal to 4.60%-5.24%. The effect of it being evening is now captured into the evening variable. This variable is statistically significant at the 1% level in all the model specifications. The effect of it being evening is a 0.111-0.116 percentage point increase on the probability to park off-street. This is an increase of 22.02%-23.02%.

To investigate the effect of the policy change in 2015 a difference-in-difference estimator is used. This can be seen in (6) and (7). It shows how before the policy change when prices were almost equal on- and off-street on Koopavond there is no significant difference in the probability on parking off-street because it is Koopavond. However, after 2015 there is an increase in the probability of 0.0361-0.0380 percentage points. Meaning that the effect of the policy suggests a 7.16%-7.54% increase in off-street parking relative to on-street parking significant at the 5% level. On the other hand, the policy change variable shows a decrease in off-street parking probability overall. This is equal to a 0.0317-0.0377 percentage points decrease.

The effect of precipitation on the probability to park off-street is small, but for (5), (6), and (7) it is significant at the 5% level. There seems to be a positive effect of precipitation on the probability to park off-street. From the results we can see this effect is around 0.000469-0.000478 percentage point. Meaning an increase of 0.09% per millimeter rain. The effect of temperature is at least significant at the 5% level for (4), (5), (6), and (7) however shows results that are negative and positive.

Duration seems to affect the probability quite a lot. With values ranging from 0.989-0.102 before instrumenting. After instrumenting the effect is a bit smaller which would imply there is a bias after instrumenting, because duration is exogenous. The value is now equal to 0.0914. This means that with an increase in duration of an hour the probability to park off-street will go up by around 19%.

We are also able to look at the monthly dummies which are included in Appendix 2. The constant is the month August of 2014. With the dummies we can see if there is an impact for it being Covid-19 and if there is a change in behavior over the years and because of the price increase in 2023. What is visible is that in time of lockdowns the probability of parking off-street goes down by a lot. This suggests street parking is preferred over garage parking. During the first lockdown in April 2020, the dummy variable is equal to -0.144 to -0.176 and statistically significant at the 1% level. For January 2021 this effect is even bigger and equal to -0.206 to -0.239. This would come down to a decrease in the probability of parking off-street of 40.87%-47.4%. Next to this, we see the trend in the dummies we already saw in Figure 1, where from 2020 on street parking becomes more popular than garage parking. From (6) and (7) we find significant results from April 2015 on, suggesting higher probabilities of parking off-street. These dummies could off-set the negative results of the policy change dummy in the difference-in-difference models (6) and (7).

Table 2 Effect of policy change on parking off-street on Koopavond

VARIABLES	(1) Baseline	(2) Extended duration	(3) Extended evening	(4) Weather controls	(5) Month FE	(6) DiD	(7) IV Duration
Koopavond	0.111***	0.119***	0.0264***	0.0261***	0.0232***	-0.0117	-0.0153
	(0.00367)	(0.00341)	(0.00368)	(0.00369)	(0.00270)	(0.00937)	(0.00944)
Policy change						-0.0337***	-0.0317**
						(0.0127)	(0.0127)
Interaction term						0.0361***	0.0380***
						(0.00966)	(0.00971)
Duration		0.102***	0.101***	0.101***	0.0989***	0.0989***	0.0914***
		(0.000347)	(0.000323)	(0.000323)	(0.000344)	(0.000343)	(0.000823)
Evening			0.116***	0.116***	0.111***	0.111***	0.113***
			(0.00155)	(0.00155)	(0.00152)	(0.00152)	(0.00156)
Precipitation				0.000285	0.000473**	0.000469**	0.000478**
				(0.000251)	(0.000213)	(0.000213)	(0.000215)
Temperature				0.000595***	-0.00067**	-0.00067**	-0.00069**
				(0.000210)	(0.000328)	(0.000328)	(0.000330)
Constant	0.497***	0.276***	0.256***	0.249***	0.275***	0.276***	0.290***
	(0.00156)	(0.00133)	(0.00136)	(0.00292)	(0.00944)	(0.00939)	(0.00956)
Observations	1,818,946	1,818,946	1,818,946	1,818,946	1,818,946	1,818,946	1,818,946
R-squared	0.002	0.117	0.125	0.126	0.136	0.136	0.135
Adjusted for S.E.	YES	YES	YES	YES	YES	YES	YES
Control variables	NO	NO	NO	YES	YES	YES	YES
Time fixed effects	NO	NO	NO	NO	YES	YES	YES
DiD	NO	NO	NO	NO	NO	YES	YES
Duration instrumented	NO	NO	NO	NO	NO	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2 Results Table 3

In Table 3 we can see the results of the model specifications as described in section 3.4.2. The main variable of interest is the variable policy change. This variable shows how much higher the probability of parking off-street is on Koopavond. Table 3 indicates that only the policy change and duration variables are statistically significant at the 1% level. The weather controls and the seasonal dummies are not significant. For the seasonal dummies this suggests there is no change from year to year for similar months except for the effect of the policy change.

The effect of the policy change is much higher compared to the other model specifications when we do not control for duration. However, we see again the statistical significance of duration and so this effect captures some of the effects of duration on the probability to park off-street. The effect of the policy on Koopavond ranges from 0.0409-0.546 percentage points. On Koopavond an average of 58.24% parks off-street. This implies an increase in parking on Koopavond in the garage of 7.03%-9.38%, which is statistically significant at the 1% level.

For duration we see a similar effect as before in Table 2. The effect of a one hour increase in duration on the probability to park off-street is equal to 0.130-0.156 percentage points. This comes down to 22.32%-26.79%, which is also statistically significant and shows the importance of duration on the choice to park on- or off-street.

Table 3 Effect of policy at Koopavond on parking off-street

VARIABLES	(1) Baseline	(2) Duration included	(3) Weather controls	(4) Month FE	(5) IV Duration
Policy Change	0.110***	0.0546***	0.0535***	0.0519***	0.0409***
	(0.0134)	(0.0108)	(0.0108)	(0.0117)	(0.0117)
Duration		0.130***	0.130***	0.130***	0.156***
		(0.00287)	(0.00287)	(0.00287)	(0.0113)
Precipitation			0.000968	0.000973	0.000949
			(0.00131)	(0.00129)	(0.00127)
Temperature			0.000361	0.000169	0.000219
			(0.000740)	(0.000966)	(0.000959)
August				-0.00609	-0.00419
				(0.0131)	(0.0131)
September				-0.00395	-0.00294
				(0.0141)	(0.0138)
October				-0.0165	-0.0169
				(0.0130)	(0.0130)
November				0.00254	-0.000755
				(0.0143)	(0.0144)
December				-0.0152	-0.0171
				(0.0137)	(0.0140)
Constant	0.544***	0.321***	0.316***	0.326***	0.282***
	(0.0124)	(0.0112)	(0.0145)	(0.0188)	(0.0274)
Observations	20,419	20,419	20,419	20,419	20,419
R-squared	0.007	0.123	0.123	0.123	0.118
Adjusted for S.E.	YES	YES	YES	YES	YES
Control variables	NO	NO	YES	YES	YES
Time fixed effects	NO	NO	NO	YES	YES
Duration instrumented	NO	NO	NO	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5 Discussion

From the literature we learn how pricing parking can lead to an efficient distribution of parking spaces (Vickrey, 1954; Shoup, 2005). Underpricing parking can lead to cruising for parking, which causes negative externalities such as noise, pollution, and congestion (Shoup 2005; Inci et al., 2017; Hampshire & Shoup, 2018; Weinberger et al., 2020; Van Ommeren et al., 2021). Next to this, pricing parking can be used to reduce congestion as a type of road pricing (Verhoef et al., 1995; Fogerau & De Palma, 2013; Zhang et al., 2015). To make sure parking is priced efficiently, studies suggest that it is best to fully eliminate cruising for parking (Arnott & Inci, 2006). The solution to this would be to make parking off-street the same price as on-street (Shoup, 2006, Arnott & Inci, 2015, Van Nieuwkoop et al., 2016). However, these studies are based on a situation where on-street parking is underpriced. In the Netherlands parking on-street is usually more expensive than off-street. This is also the case in Arnhem. Besides, before the policy change in Arnhem, the price of parking on-street was already higher than parking off-street. Still, Arnhem had a problem with too many people wanting to park on-street. (Parkeervisie Binnenstad, 2016).

This can be because it there seems to be an extra willingness, a premium, to park on-street. This premium ranges from €0.35-0.60 (Kobus, 2012; Kobus et al., 2013; Gragera, 2017; Ostermeijer et al, 2022). In Arnhem in 2014, on-street parking costs €0.28 more than off-street and in 2014 there is more on- than off-street parking. This is in line with the literature about the premium, because the on-street premium is higher than the actual price difference. This suggests that there would still be cruising for parking on busy moments. This changes when the premium on the evenings becomes €2. When this happened, off-street parking becomes more popular than on-street parking. However, although off-street parking goes up after the policy change there are still people parking on-street. This can be the case because they are not aware of the prices (Albalate & Gragera, 2018). Or because people have such a high premium for parking on-street. This can be the case because you can park as close as possible to your destination (Arnott et al., 1991) Or when you have a low value of time, on-street parking is relatively cheap, costs for fuel are low, and you are alone (Shoup, 2006). From Figure 1 we can see how in 2014 on-street parking was preferred over off-street parking.

The effect of the policy is also visible in Figure 1 and Figure 2. Mid 2015 the policy seemed to work, and people decided to park more off-street than on-street. When Covid-19 struck this effect disappears, while the price difference stays the same. This might suggest the premium for parking on-street was a lot higher during Covid-19. This can be because people did not want to be inside of a garage but in outside in the fresh air. After all, the goals of people going to the city center changed, and people wanted to be closer to their destination. This is also visible in the monthly dummies in Appendix 2 which show enormous drops in the probability to park off-street during the lockdowns.

To research the effect of a lower price at 'Koopavond' and evenings on the probability to park off-street regression analyses were performed, which are visible in Table 2 and Table 3. We first look at the effect of 'Koopavond'. It is visible that evenings play a big role into the choice to park on- or off-street as well, besides it being 'Koopavond'. When including for evenings the effects of it being 'Koopavond' go down by a lot. This makes sense since on other evenings there are also lower prices and people will park more off-street too. This effect comes down to 22%-23% more garage parking, with a price that is €2 lower than on the street. When it is also 'Koopavond' this effect is even bigger with 4.6%-5.2%. This can be the case because there is a different public on 'Koopavond'. Normally the people parking in the evening are the residents of the city center. They have their routine behavior, and some people will value parking near their house more than having to walk to the garage each morning and walking back each evening after work. However, on 'Koopavond' there are people parked who go shopping. When people go out for an evening shopping and the garages are still in walking distance, they will choose to park off-street where it is less expensive (Van der Waerden et al., 2017).

Another important take-away from Table 2 and Table 3 is that after the policy change around 7.5% more people seem to park off-street on 'Koopavond'. This is statistically significant at the 5% level in Table 2 which includes all dates, and significant at the 1% level in Table 3 which only includes 'Koopavond'. This indicates having a €2 lower price off-street leads to 7.5% more off-street parking compared to the situation where on- and off-street parking were almost charged the same. This again would make sense since people who go shopping are willing to walk longer to their destination and will therefore change to off-street parking.

However, we find a negative effect of the policy change on the probability to park off-street on all other moments than 'Koopavond'. This can be because there is the limitation of not having enough data for parking on-street in the evening before the policy change in 2015, since there were no transactions before this moment due to parking being free. This change can therefore be because suddenly there are more observations for parking on-street in the evenings after 2015. The effect of the policy change could therefore be influenced by missing data on parking before 2015 on moments when parking was free.

The results found for the weather controls are really small. They are significant at the 5% level in Table 2. The positive coefficient for precipitation suggests that rain leads to more people parking off-street which would make sense because parking garages offer shelter. The weather control is positive and negative at the same time for temperature. This change is because we use monthly dummies, they might capture the average temperature effect. The controls are not significant in Table 2, this can be the case because there are not enough observations, since 'Koopavond' only happens four times a month. Therefore, we compare four evenings each month. The same goes for seasonal time trend. Too little observation can lead to not enough statistical power.

In Table 2 and 3 the effect of duration on the probability to park off-street is around 20%. This effect is statistically significant at the 1% level. This can be explained by the fact that people who only want to be parked for a little while do not want to walk long to their destination and will therefore park on-street. A potential issue in the interpretation of the duration coefficient is that the effect of a price decrease differs over time blocks (Kobus et al., 2013). The duration coefficient implies an increase of around 0.10 percentage points in the probability to park off-street for each extra hour of parking. Only 25% of the people park off-street for duration shorter than an hour. Parking for an extra hour leads to a growth equal to 0.09 percentage points in the probability of parking. Which is true since average parking for a duration shorter than two hours is equal to 34%. However, the difference between parking for less than three or four hours is only equal to respectively 41% to 44%. The effect of duration becomes smaller after a certain duration and might therefore not be linear. Otherwise, this would imply parking for more than eight hours would only happen in the garage which is not the case.

Next to this more people seem to pay via parking apps instead of at the parking meter as visible in Figure 3. This can also be because less people want to touch the parking meter and prefer using their phone. Besides, they do not have to walk to the parking meter. Lately, an interesting trend in parking is perceived. People seem to pay via parking apps instead of at the parking meter as visible in Figure 4. This is an interesting concept, because a change in preferences can be a reason for more people parking on- or off-street. The determinants for choosing between garage and street parking are related to time saved and parking prices (Golias et al., 2002; Kobus et al., 2013). However, the conveniency of paying at the curb with an app and receiving a notification each five minutes if you are still parked might become an influence as well. This can influence the results in preferences where to park and where this preference change comes from. We follow the assumption of Golias et al. (2022) by explaining that more people parking off-street during 'Koopavond' because of the lower price. In Appendix 4 a regression is performed to show this change in preferences over the years. The model looks as follows. Y_{it} a dummy variable for paying at the meter, YT_t is the yearly trend, C_t a dummy for the Covid- 19 lockdowns, T_t and P_t weather controls, $\mu_{i,s}$ zone fixed effects.

$$Y_{it} = \beta_0 + \beta_1 YT_t + \beta_2 C_t + \beta_3 T_t + \beta_4 P_t + \mu_{i,s} + \varepsilon_{it}$$

In this model we see how there is a significant negative trend in choosing to pay at the meter. Each year it decreases with around 3 percentage points, which is significant at the 1% level. During the lockdowns 2 percentage point less people chose to pay at the meter, this effect is also significant. Next to this, when it rains there is a small preference for paying online. This also makes sense since you can pay inside your car instead of outside where it rains at the meter. For future research it would be interesting to research the effect of the type of payment on on-street parking.

We were not able to include an occupancy rate into the research. However, it is interesting to see how the policy change impacts the occupancy rate as well. Therefore, it would be useful to include an occupancy rate in further research. Another improvement could be to look at the price change in 2023, for now we were not able to really investigate this. There was only data on three months and these months could not be compared with similar months in 2021 or 2022, because there were lockdowns at that time. Next to this, we mentioned some limitations to the dataset. It would be interesting to use other cities as controls for how people behave on 'Koopavond' when there is not this big price difference. Additionally, future studies can research how a premium affects parking behavior in these cities. Besides, having a dataset which includes all coordinates of locations where to park would be interesting to have more information about if a parking spot is an alternative and if people would want to walk from this place to their destination and what the maximum distance people are willing to walk is.

6 Conclusion

This research aimed at finding how a lower parking price in the garages on evenings, and especially on ‘Koopavond’, impacts the probability to park off-street. This was done by using data on the city of Arnhem, who changed its policy in 2015 by lowering the prices of off-street parking in the evenings, which made off-street prices €2 lower than parking on-street prices. A linear probability model was used including a difference-in-difference estimator to account for the effect of the change in policy on ‘Koopavond’, next to the other evenings. Our study has found that having lower prices off-street compared to on-street, has a positive effect of approximately 20% on the choice to park off-street. This effect is with 5% even bigger on ‘Koopavond’ than on other evenings. When looking at the change in behavior we see that after the policy change 7.5% more people park off-street. This suggests that lowering the off-street prices below the level of on-street prices leads to relatively more people parking off-street. However, during Covid-19 this was not the case and lower prices off-street did not lead to more people parking off-street on all days and only a slightly during ‘Koopavond’. Next to this, we found that a shorter duration leads to more on-street parking.

The literature suggests that having equal prices will lead to an efficient distribution of parking. However, other studies found that there might be a premium for parking on the street. This premium is an argument for charging the curb higher than the garage. This is done in Arnhem and this study shows that people will change their parking behavior. This has implications for other municipalities struggling with too much demand for on-street parking during the evening. They can lower off-street prices to tackle this problem. This study adds to the literature by researching how higher prices on-street can get people off the streets and into the garages. Next to this, this study adds to the literature since not much research into the effect of a premium for on-street parking has been done before. Further research into the premium by including control cities, investigating behavior after Covid-19, investigating lowering prices on other moments of the day, and investigating the effect of paying with apps will be very interesting.

Prices, duration, and the premium for on-street parking seem to be the main determinants in the decision to park on- or off-street. Lower prices on evenings in the garage lead to more people parking in garages on ‘Koopavond’ and other evenings.

Reference list

Ahad, A., Khan, Z. R., & Ahmad, S. A. (2016). Intelligent parking system. *World Journal of Engineering and Technology*, *4*(2), 160-167.

Albalate, D., & Gragera, A. (2017). The determinants of garage prices and their interaction with curbside regulation. *Transportation Research Part A: Policy and Practice*, *101*, 86-97.

Albalate, D., & Gragera, A. (2018). Empirical evidence on imperfect information in the parking market. *Journal of Transport Economics and Policy (JTEP)*, *52*(3), 322-342.

Anderson, S. P., & De Palma, A. (2004). The economics of pricing parking. *Journal of urban economics*, *55*(1), 1-20.

ArcGIS Web Application. (2023). *Zelf combineren van Open Data op kaart*. [Map] https://arnhem.maps.arcgis.com/apps/webappviewer/index.html?id=ccc471b8ef5c45afb8f91bc7f486c6cc

Arnott, R. (2006). Spatial competition between parking garages and downtown parking policy. *Transport Policy*, *13*(6), 458-469.

Arnott, R., & Inci, E. (2006). An integrated model of downtown parking and traffic congestion. *Journal of Urban Economics*, *60*(3), 418-442.

Arnott, R., & Rowse, J. (1999). Modeling parking. *Journal of urban economics*, *45*(1), 97-124.

Arnott, R., & Rowse, J. (2009). Downtown parking in auto city. *Regional Science and Urban Economics*, *39*(1), 1-14.

Arnott, R., De Palma, A., & Lindsey, R. (1991). A temporal and spatial equilibrium analysis of commuter parking. *Journal of public economics*, *45*(3), 301-335.

Arnott, R., Inci, E., & Rowse, J. (2015). Downtown curbside parking capacity. *Journal of Urban Economics*, *86*, 83-97.

Caicedo, F. (2010). Real-time parking information management to reduce search time, vehicle displacement and emissions. *Transportation Research Part D: Transport and Environment*, *15*(4), 228-234.

Calthrop, E., & Proost, S. (2006). Regulating on-street parking. *Regional Science and Urban Economics*, *36*(1), 29-48.

CBS. (2023, June 15*). Regionale kerncijfers Nederland*. [Dataset] Retrieved June 29, 2023, from https://opendata.cbs.nl/statline/#/CBS/nl/dataset/70072NED/table?fromstatweb

Conceptnota PARKEERVISIE BINNENSTAD. (2011). Retrieved June 29, 2023, from https://www.arnhem6811.nl/wp-content/uploads/2016/08/PARKEERVISIE-BINNENSTAD.pdf

De Nijs, R. (2012). The price discrimination effect of a large merger of parking garages. *Economics Letters*, *117*(3), 928-931.

Fosgerau, M., & De Palma, A. (2013). The dynamics of urban traffic congestion and the price of parking. *Journal of Public Economics*, *105*, 106-115.

Frederik, J. (2018, September 22). *De oplossing voor bijna alles: duurder parkeren*. De Correspondent. https://decorrespondent.nl/8716/de-oplossing-voor-bijna-alles-duurder-parkeren/524365882084-012b1d1e

Gemeente Arnhem. (2018). *Betaald parkeerzone*. [Dataset]. https://opendata.arnhem.nl/datasets/Arnhem::betaald-parkeerzone/explore?location=51.981596%2C5.910851%2C14.62&showTable=true

Gemeente Arnhem. (2018). *Parkeerautomaten*. [Dataset]. https://hub.arcgis.com/datasets/Arnhem::parkeerautomaten/explore?showTable=true

Glazer, A., & Niskanen, E. (1992). Parking fees and congestion. *Regional Science and Urban Economics*, *22*(1), 123-132.

Golias, J., Yannis, G., & Harvatis, M. (2002). Off-street parking choice sensitivity. *Transportation Planning and Technology*, *25*(4), 333-348.

Gragera, A. (2017). The Economics of Parking: Essays on Regulation, Competition and Information Frictions.

Gragera, A., & Albalate, D. (2016). The impact of curbside parking regulation on garage demand. *Transport Policy*, *47*, 160-168.

Greene, W. (2007). Discrete Choice Modeling. New York University, Leonard N. Stern.

Hampshire, R. C., & Shoup, D. (2018). What share of traffic is cruising for parking?. *Journal of Transport Economics and Policy (JTEP)*, *52*(3), 184-201.

Heijting, D. (2022, December 2). *Parkeertarieven Arnhem verhoogd: dit zijn de nieuwe prijzen*. Indebuurt Arnhem. Retrieved June 29, 2023, from https://indebuurt.nl/arnhem/gemeente/parkeren-in-arnhem-wordt-duurder-dit-zijn-de-nieuwe-parkeertarieven~216231/#slide-5

Inci, E. (2015). A review of the economics of parking. *Economics of Transportation*, *4*(1-2), 50-63.

Inci, E., & Lindsey, R. (2015). Garage and curbside parking competition with search congestion. *Regional Science and Urban Economics*, *54*, 49-59.

Inci, E., Ommeren, J. V., & Kobus, M. (2017). The external cruising costs of parking. *Journal of Economic Geography*, *17*(6), 1301-1323.

KNMI. (2023). *Dagwaarden van weerstations.* [Dataset]. Retrieved June 15, 2023, from https://daggegevens.knmi.nl/klimatologie/daggegevens

Kobus, M. B., Gutiérrez-i-Puigarnau, E., Rietveld, P., & Van Ommeren, J. N. (2013). The on-street parking premium and car drivers' choice between street and garage parking. *Regional Science and Urban Economics*, *43*(2), 395-403.

Kobus, M., Gutiérrez-i-Puigarnau, E., Rietveld, P., & Ommeren, J. V. (2012). Drivers' willingness to pay for curb parking (rather than in a garage).

Lin, H., & Wang, I. Y. (2015). Competition and price discrimination: evidence from the parking garage industry. *The Journal of Industrial Economics*, *63*(3), 522-548.

Mesfin, B. G., Sun, D., & Peng, B. (2022). Impact of COVID-19 on Urban Mobility and Parking Demand Distribution: A Global Review with Case Study in Melbourne, Australia. *International Journal of Environmental Research and Public Health*, *19*(13), 7665.

Milosavljević, N., & Simićević, J. (2014, April). Revealed preference off-street parking price elasticity. In *Proceedings of 5th Annual Meeting of the Transportation Research Arena* (pp. 1-10).

Monit (2023). *Open parkeerdata Arnhem*. [Dataset]. https://arnhem.maps.arcgis.com/apps/webappviewer/index.html?id=ccc471b8ef5c45afb8f91bc7f486c6cc

Mukhija, V., & Shoup, D. (2006). Quantity versus quality in off-street parking requirements. *Journal of the American Planning Association*, *72*(3), 296-308.

Ostermeijer, F., Koster, H., Nunes, L., & van Ommeren, J. (2022). Citywide parking policy and traffic: Evidence from Amsterdam. *Journal of Urban Economics*, *128*, 103418.

Pierce, G., Willson, H., & Shoup, D. (2015). Optimizing the use of public garages: Pricing parking by demand. *Transport Policy*, *44*, 89-95.

Razenberg, J. (2019). *Parking policy Arnhem: an on-street parking premium* [MA thesis]. Vrije Universiteit Amsterdam.

Riemslag, M., & Fousert, M. (2021, December 7). *Parkeren en het "nieuwe normaal" - Een data analyse - Monit.* Monit. Retrieved June 26, 2023, from https://monitdata.com/parkeren-en-het-nieuwe-normaal/.

School of Business, Department of Economics, Working Papers.

Shoup, D. C. (1999). The trouble with minimum parking requirements. *Transportation research part A: policy and practice*, *33*(7-8), 549-574.

Shoup, D. C. (2005). *The high cost of free parking*. Chicago: Planners Press.

Shoup, D. C. (2006). Cruising for parking. *Transport policy*, *13*(6), 479-486.

Shoup, D. C. (2021). Pricing curb parking. *Transportation Research Part A: Policy and Practice*, *154*, 399-412.

Trendboek Mobiliteit 2023 (12). (2022). Acquire Publishing. https://bieb.acquire.nl/mobiliteit/trendboek-mobiliteit-2023

Van der Waerden, P., Timmermans, H., & de Bruin-Verhoeven, M. (2017). Car drivers' characteristics and the maximum walking distance between parking facility and final destination. *Journal of transport and land use*, 10(1), 1-11.

van Nieuwkoop, R. H., Axhausen, K. W., & Rutherford, T. F. (2016). A traffic equilibrium model with paid-parking search. *Journal of Transport Economics and Policy (JTEP)*, *50*(3), 262-286.

Van Ommeren, J., de Groote, J., & Mingardo, G. (2014). Residential parking permits and parking supply. *Regional Science and Urban Economics*, *45*, 33-44.

Van Ommeren, J., McIvor, M., Mulalic, I., & Inci, E. (2021). A novel methodology to estimate cruising for parking and related external costs. *Transportation Research Part B: Methodological*, *145*, 247-269.

Van Ommeren, J., Wentink, D., & Dekkers, J. (2011). The real price of parking policy. *Journal of Urban Economics*, *70*(1), 25-31.

Verhoef, E., Nijkamp, P., & Rietveld, P. (1995). The economics of regulatory parking policies: the (im) possibilities of parking policies in traffic regulation. *Transportation research part A: policy and practice*, *29*(2), 141-156.

Vickrey, W. (1954). The economizing of curb parking space. *Traffic engineering*, *29*(1), 62-67.

Weinberger, R. R., Millard-Ball, A., & Hampshire, R. C. (2020). Parking search caused congestion: Where's all the fuss?. *Transportation Research Part C: Emerging Technologies*, *120*, 102781.

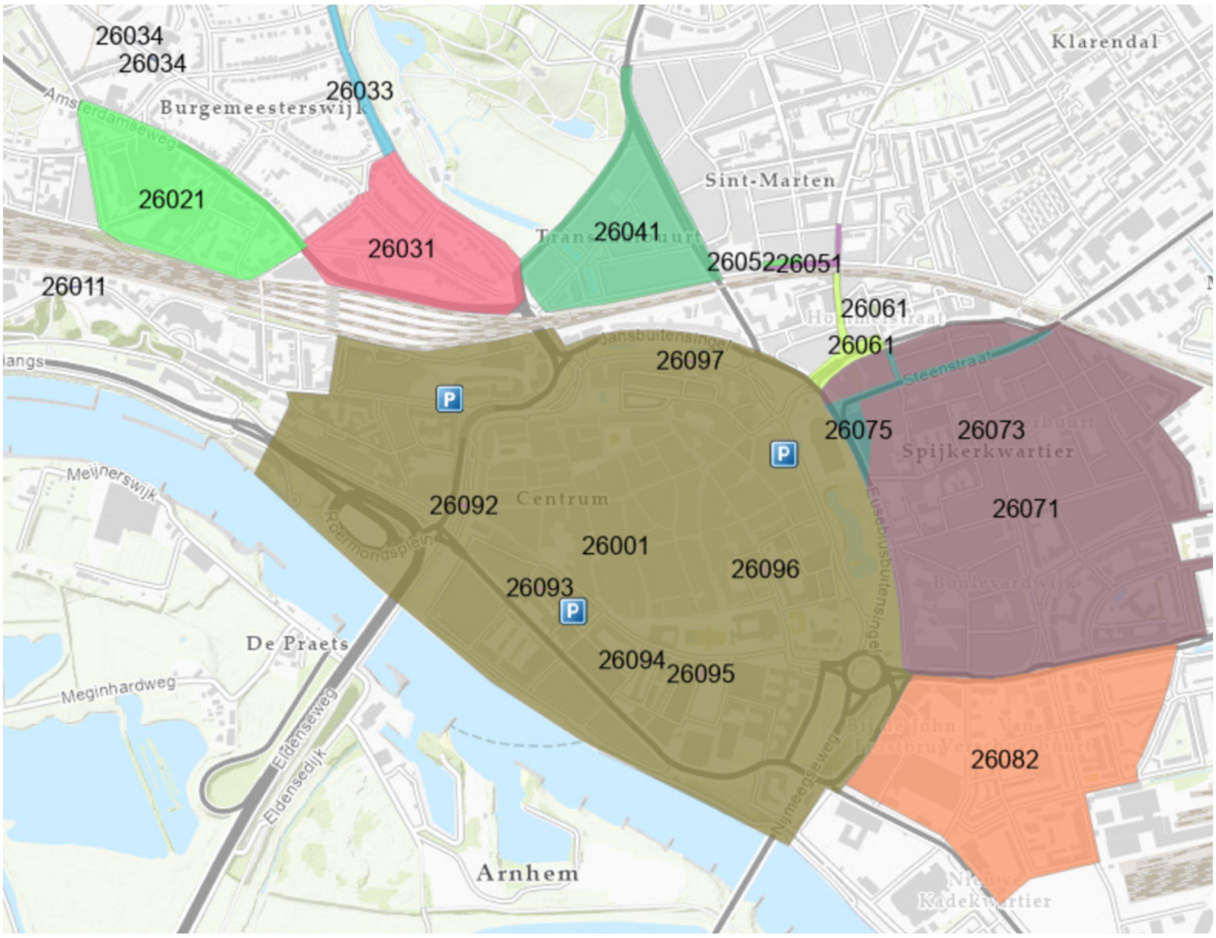
Yang, W., & Lam, P. T. (2019). Evaluation of drivers' benefits accruing from an intelligent parking information system. *Journal of cleaner production*, *231*, 783-793.

Zakharenko, R. (2016). The time dimension of parking economics. *Transportation Research Part B: Methodological*, *91*, 211-228.

Zhang, X., Huang, H. J., & Zhang, H. M. (2008). Integrated daily commuting patterns and optimal road tolls and parking fees in a linear city. *Transportation Research Part B: Methodological*, *42*(1), 38-56.

Appendices

Appendix 1



Appendix 2

Appendix 2 Table 2 including monthly dummies

VARIABLES	(5) Month FE	(6) DiD	(7) IV Duration
Koopavond	0.0232***	-0.0117	-0.0153
	(0.00270)	(0.00937)	(0.00944)
Policychange		-0.0337***	-0.0317**
		(0.0127)	(0.0127)
Koopavond*PolicyChange		0.0361***	0.0380***
		(0.00966)	(0.00971)
Duration	0.0989***	0.0989***	0.0914***
	(0.000344)	(0.000343)	(0.000823)
Evening	0.111***	0.111***	0.113***
	(0.00152)	(0.00152)	(0.00156)
Precipitation	0.000473**	0.000469**	0.000478**
	(0.000213)	(0.000213)	(0.000215)
Temperature	-0.000665**	-0.000665**	-0.000689**
	(0.000328)	(0.000328)	(0.000330)
2014 Sep	-0.0212	-0.0212	-0.0205
	(0.0133)	(0.0131)	(0.0132)
2014 Oct	0.0118	0.0121	0.0135
	(0.0106)	(0.0104)	(0.0104)
2014 Nov	0.0148	0.0148	0.0164
	(0.0153)	(0.0151)	(0.0152)
2014 Dec	0.0239**	0.0236**	0.0248**
	(0.0117)	(0.0115)	(0.0116)
2015 Jan	-0.0250**	0.00732	0.00626
	(0.0120)	(0.0127)	(0.0128)
2015 Feb	-0.0163	0.0160	0.0153
	(0.0115)	(0.0122)	(0.0123)
2015 Mar	-0.0205*	0.0118	0.0111
	(0.0117)	(0.0126)	(0.0126)
2015 Apr	0.00275	0.0350***	0.0348***
	(0.0111)	(0.0122)	(0.0123)
2015 May	0.0129	0.0452***	0.0450***
	(0.0104)	(0.0119)	(0.0120)
2015 Jun	-0.00259	0.0297**	0.0294**
	(0.0106)	(0.0123)	(0.0124)
2015 Jul	0.00594	0.0382***	0.0377***
	(0.0102)	(0.0122)	(0.0123)
2015 Aug	-0.0149	0.0174	0.0166
	(0.0165)	(0.0178)	(0.0179)
2015 Sep	0.00455	0.0369***	0.0367***
	(0.0114)	(0.0129)	(0.0129)
2015 Oct	0.0127	0.0450***	0.0453***
	(0.0111)	(0.0124)	(0.0124)

2015 Nov	0.0122	0.0446***	0.0449***
	(0.0128)	(0.0138)	(0.0139)
2015 Dec	0.0210*	0.0533***	0.0535***
	(0.0115)	(0.0127)	(0.0128)
2016 Jan	0.0306**	0.0629***	0.0628***
	(0.0138)	(0.0145)	(0.0146)
2016 Feb	0.0308**	0.0632***	0.0631***
	(0.0133)	(0.0139)	(0.0140)
2016 Mar	0.0137	0.0460***	0.0461***
	(0.0123)	(0.0132)	(0.0132)
2016 Apr	0.0336***	0.0659***	0.0663***
	(0.0116)	(0.0127)	(0.0128)
2016 May	0.0159	0.0482***	0.0485***
	(0.0126)	(0.0140)	(0.0140)
2016 Jun	0.0353***	0.0676***	0.0677***
	(0.0112)	(0.0130)	(0.0130)
2016 Jul	0.0629***	0.0952***	0.0955***
	(0.0107)	(0.0126)	(0.0127)
2016 Aug	0.0170	0.0493***	0.0492***
	(0.0113)	(0.0130)	(0.0131)
2016 Sep	0.0477***	0.0800***	0.0801***
	(0.0125)	(0.0141)	(0.0142)
2016 Oct	0.0611***	0.0934***	0.0946***
	(0.0105)	(0.0118)	(0.0119)
2016 Nov	0.0449***	0.0773***	0.0779***
	(0.0128)	(0.0136)	(0.0137)
2016 Dec	0.0390***	0.0713***	0.0716***
	(0.0117)	(0.0125)	(0.0126)
2017 Jan	0.0391***	0.0714***	0.0719***
	(0.0138)	(0.0143)	(0.0144)
2017 Feb	0.0244	0.0567***	0.0572***
	(0.0161)	(0.0165)	(0.0166)
2017 Mar	0.0354***	0.0677***	0.0685***
	(0.0122)	(0.0132)	(0.0133)
2017 Apr	0.0500***	0.0823***	0.0833***
	(0.0124)	(0.0135)	(0.0136)
2017 May	0.0367***	0.0690***	0.0696***
	(0.0128)	(0.0141)	(0.0142)
2017 Jun	0.0344***	0.0667***	0.0672***
	(0.0113)	(0.0130)	(0.0131)
2017 Jul	0.0539***	0.0863***	0.0866***
	(0.0109)	(0.0127)	(0.0128)
2017 Aug	0.0632***	0.0955***	0.0957***
	(0.0106)	(0.0124)	(0.0125)
2017 Sep	0.0635***	0.0958***	0.0965***
	(0.0113)	(0.0128)	(0.0129)
2017 Oct	0.0620***	0.0943***	0.0954***
	(0.0113)	(0.0127)	(0.0128)

2017 Nov	0.0414***	0.0737***	0.0747***
	(0.0128)	(0.0138)	(0.0138)
2017 Dec	0.0435***	0.0758***	0.0764***
	(0.0123)	(0.0130)	(0.0131)
2018 Jan	0.0284**	0.0608***	0.0612***
	(0.0138)	(0.0146)	(0.0147)
2018 Feb	0.0231*	0.0554***	0.0557***
	(0.0131)	(0.0136)	(0.0137)
2018 Mar	0.0229*	0.0552***	0.0556***
	(0.0130)	(0.0138)	(0.0139)
2018 Apr	0.0340***	0.0663***	0.0671***
	(0.0125)	(0.0138)	(0.0139)
2018 May	0.0308***	0.0631***	0.0637***
	(0.0113)	(0.0130)	(0.0130)
2018 Jun	0.0360***	0.0683***	0.0688***
	(0.0138)	(0.0153)	(0.0154)
2018 Jul	0.0489***	0.0812***	0.0817***
	(0.0113)	(0.0133)	(0.0133)
2018 Aug	0.0432***	0.0755***	0.0759***
	(0.0110)	(0.0128)	(0.0129)
2018 Sep	0.0273**	0.0597***	0.0603***
	(0.0135)	(0.0149)	(0.0150)
2018 Oct	0.0273**	0.0597***	0.0607***
	(0.0119)	(0.0132)	(0.0133)
2018 Nov	0.0153	0.0476***	0.0487***
	(0.0139)	(0.0148)	(0.0148)
2018 Dec	0.0176	0.0499***	0.0504***
	(0.0140)	(0.0147)	(0.0148)
2019 Jan	0.00303	0.0353**	0.0359**
	(0.0140)	(0.0145)	(0.0145)
2019 Feb	-0.000828	0.0315**	0.0319**
	(0.0138)	(0.0147)	(0.0147)
2019 Mar	0.000902	0.0332***	0.0338***
	(0.0116)	(0.0126)	(0.0127)
2019 Apr	-0.00877	0.0235*	0.0241*
	(0.0121)	(0.0133)	(0.0134)
2019 May	-0.00288	0.0294**	0.0298**
	(0.0122)	(0.0134)	(0.0134)
2019 Jun	-0.000908	0.0314**	0.0315**
	(0.0141)	(0.0155)	(0.0156)
2019 Jul	0.0108	0.0431***	0.0432***
	(0.0116)	(0.0135)	(0.0135)
2019 Aug	0.00742	0.0397***	0.0399***
	(0.0113)	(0.0131)	(0.0132)
2019 Sep	-0.0147	0.0176	0.0179
	(0.0120)	(0.0135)	(0.0136)
2019 Oct	0.0462***	0.0785***	0.0795***
	(0.0174)	(0.0183)	(0.0185)

2019 Nov	-0.0152	0.0171	0.0176
	(0.0137)	(0.0145)	(0.0145)
2019 Dec	0.00128	0.0336**	0.0337**
	(0.0142)	(0.0149)	(0.0150)
2020 Jan	-0.0193	0.0130	0.0134
	(0.0139)	(0.0147)	(0.0148)
2020 Feb	-0.00312	0.0292**	0.0296**
	(0.0131)	(0.0139)	(0.0140)
2020 Mar	-0.0715***	-0.0392**	-0.0406**
	(0.0188)	(0.0194)	(0.0196)
2020 Apr	-0.176***	-0.144***	-0.148***
	(0.0119)	(0.0132)	(0.0131)
2020 May	-0.0498***	-0.0175	-0.0211
	(0.0124)	(0.0137)	(0.0138)
2020 Jun	-0.0346**	-0.00224	-0.00360
	(0.0136)	(0.0151)	(0.0152)
2020 Jul	-0.00866	0.0236*	0.0229*
	(0.0109)	(0.0126)	(0.0127)
2020 Aug	-0.0199*	0.0124	0.0113
	(0.0109)	(0.0129)	(0.0130)
2020 Sep	-0.0400***	-0.00772	-0.00867
	(0.0116)	(0.0131)	(0.0133)
2020 Oct	-0.0393***	-0.00700	-0.00939
	(0.0113)	(0.0126)	(0.0127)
2020 Nov	-0.0611***	-0.0287*	-0.0322**
	(0.0148)	(0.0157)	(0.0157)
2020 Dec	-0.121***	-0.0886***	-0.0927***
	(0.0204)	(0.0209)	(0.0209)
2021 Jan	-0.239***	-0.206***	-0.210***
	(0.0102)	(0.0110)	(0.0110)
2021 Feb	-0.215***	-0.183***	-0.187***
	(0.0106)	(0.0116)	(0.0117)
2021 Mar	-0.173***	-0.141***	-0.145***
	(0.0109)	(0.0119)	(0.0119)
2021 Apr	-0.141***	-0.108***	-0.112***
	(0.0123)	(0.0133)	(0.0133)
2021 May	-0.0552***	-0.0228*	-0.0248*
	(0.0115)	(0.0128)	(0.0129)
2021 Jun	-0.0537***	-0.0213	-0.0227*
	(0.0111)	(0.0130)	(0.0131)
2021 Jul	-0.0256**	0.00671	0.00599
	(0.00998)	(0.0119)	(0.0120)
2021 Aug	-0.0213*	0.0110	0.0103
	(0.0113)	(0.0130)	(0.0131)
2021 Sep	-0.0380***	-0.00567	-0.00645
	(0.0120)	(0.0136)	(0.0136)
2021 Oct	-0.0212**	0.0111	0.0111
	(0.0106)	(0.0120)	(0.0121)

2021 Nov	-0.0537***	-0.0213	-0.0225
	(0.0128)	(0.0137)	(0.0138)
2021 Dec	-0.0976***	-0.0653***	-0.0682***
	(0.0147)	(0.0154)	(0.0157)
2022 Jan	-0.113***	-0.0806***	-0.0835***
	(0.0184)	(0.0189)	(0.0191)
2022 Feb	-0.0718***	-0.0394***	-0.0404***
	(0.0125)	(0.0134)	(0.0135)
2022 Mar	-0.0645***	-0.0322**	-0.0325**
	(0.0122)	(0.0132)	(0.0133)
2022 Apr	-0.0423***	-0.00998	-0.00987
	(0.0129)	(0.0139)	(0.0140)
2022 May	-0.0292**	0.00307	0.00331
	(0.0149)	(0.0162)	(0.0163)
2022 Jun	-0.0627***	-0.0304**	-0.0307**
	(0.0109)	(0.0127)	(0.0128)
2022 Jul	-0.0401***	-0.00777	-0.00811
	(0.0117)	(0.0134)	(0.0135)
2022 Aug	-0.0454***	-0.0131	-0.0135
	(0.0101)	(0.0123)	(0.0123)
2022 Sep	-0.0536***	-0.0213	-0.0216*
	(0.0114)	(0.0130)	(0.0130)
2022 Oct	-0.0483***	-0.0160	-0.0156
	(0.0106)	(0.0121)	(0.0122)
2022 Nov	-0.0630***	-0.0307**	-0.0307**
	(0.0112)	(0.0124)	(0.0125)
2022 Dec	-0.0654***	-0.0331***	-0.0335***
	(0.0119)	(0.0126)	(0.0127)
2023 Jan	-0.177***	-0.145***	-0.146***
	(0.0328)	(0.0334)	(0.0337)
2023 Feb	-0.0782***	-0.0458***	-0.0463***
	(0.0143)	(0.0152)	(0.0154)
2023 Mar	-0.0658***	-0.0335***	-0.0337***
	(0.0111)	(0.0121)	(0.0122)
Constant	0.275***	0.276***	0.290***
	(0.00944)	(0.00939)	(0.00956)
Observations	1,818,946	1,818,946	1,818,946
R-squared	0.136	0.136	0.135
Adjusted for S.E.	YES	YES	YES
Control variables	YES	YES	YES
Time fixed effects	YES	YES	YES
DiD	NO	YES	YES
Duration instrumented	NO	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix 3

Table 4 Trend in duration

VARIABLES	(1) On-street	(2) Off-street
Yearly trend	0.00601***	0.168***
	(0.00155)	(0.00382)
Covid-19 lockdowns	-0.166***	0.995***
	(0.0103)	(0.0414)
Precipitation	-0.000289	-0.00121
	(0.000723)	(0.00175)
Temperature	-0.000915	-0.0121***
	(0.000583)	(0.00138)
Constant	2.351***	4.106***
	(0.0102)	(0.0211)
Observations	1,200,826	1,220,225
R-squared	0.028	0.004
Adjusted for S.E.	YES	YES
Control variables	YES	YES
Zone fixed effects	YES	NO

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix 4

Table 5 Trend in choosing the form of payment

VARIABLES	(1) OLS
Yearly trend	-0.0293***
	(0.000128)
Duration	-0.00307***
	(8.26e-05)
Covid-19	-0.0204***
	(0.00103)
Precipitation	-0.000383***
	(6.22e-05)
Temperature	5.96e-06
	(4.82e-05)
Constant	0.670***
	(0.000846)
Observations	1,200,826
R-squared	0.558
Adjusted for S.E.	YES
Control variables	YES
Zone fixed effects	YES

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$