ERASMUS UNIVERSITY ROTTERDAM
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Effects of Underground Waste Containers on neighbourhood attractiveness and the Utrecht housing market: the case of 'Het Nieuwe Inzamelen'

Master Thesis Urban, Port & Transport Economics

Abstract: In 2015, the municipality of Utrecht introduced a new method of collecting household waste in which underground waste containers were placed in the neighbourhoods. These containers provide both advantages and disadvantages, and the reception was twofold. Utilising data containing the characteristics of real estate and their transaction price from 2011 to 2020, this paper concerns the impact of these containers on the valuation of properties. A multilevel hedonic pricing model, difference-in-differences statistical technique and joint significance tests are employed that explains residential property prices based on property-specific housing attributes and neighbourhood specific location attributes. The results suggest that there is a positive relationship between having a container close to a home and its transaction price, while the containers have an overall negative effect on transaction prices on the neighbourhood level. In addition, the possible relationship between the percentage of rental homes in a neighbourhood and the magnitude of the effect of underground waste containers on transaction prices are investigated, yet no evidence is found supporting this interrelation. The results shed new light on the effects of real estate and location characteristics in estimating transaction prices within the Utrecht housing market and can be of importance to policymakers, urban planners, and real estate appraisers.

Keywords: Neighbourhood attractiveness, real estate, amenities, underground waste containers, hedonic pricing method, difference-in-differences, ANOVA

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Date final version: 15 July 2

Preface

In front of you lies my thesis written for the Master of Science 'Urban, Port & Transport'. With this thesis, I hope to be able to contribute to the body of knowledge on urban economics and real estate.

Partly thanks to the COVID-19 pandemic, I discovered a new hobby: walking. Every Sunday morning, I would go for a walk through the streets of Utrecht. And every time I would walk around the corner, my eyes shift to the pile of garbage bags lying on the sidewalk, as can be seen in Figure 1. This waste disposal location is right next to a food catering and several residential houses, located in a charming neighbourhood. This is not a one-time occurrence and never do I appreciate the sight of this agglomeration of trash. I was curious as to whether this frustration is worse for the residents living nearby, who are confronted with this daily. I asked myself if these containers and their characteristics influence the neighbourhood attractiveness. In particular, I was curious whether the adjoining houses are economically affected by these underground waste containers. Thanks to this negative externality, I knew what the subject for this thesis would be.

I would like to thank my supervisors Jeroen van Haaren and Susan Vermeulen for the support and constructive feedback throughout the research project. Also, I could not have written this thesis without the databases of the NVM realtors and the municipality of Utrecht. Therefore, I thank Ruben Frank and Michiel Gerritse for helping me access these databases.

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Chapter 1. Introduction

In 2015, the municipality of Utrecht has begun a new method of collecting household waste, called "Het Nieuwe Inzamelen", which roughly translates to "the New Collecting" (Gemeente Utrecht, 2014). Instead of garbage collectors retrieving the waste off every household individually, citizens are now required to carry over their waste into a communal underground waste container (abbreviation: UWC), conveniently located in every neighbourhood. The municipality of Utrecht discusses these locations of UWCs with the citizens of the affected neighbourhood. Several factors regarding these locations are considered, such as traffic, the streetscape, and the preservation of greenery. According to the municipality of Utrecht, these factors are not always easy to combine, and therefore, compromises are made.

Whilst these containers solve many problems, they also caused new complications. Hence, there exists both praise and criticism against the placement of UWCs in citizen's neighbourhoods. For example, the advantages of a UWC nearby is that citizens do not need to walk far to dump their waste, it helps with improving the streetscape by removing aboveground containers, or they are environmentally more friendly because of improved efficiency (Pieterbas, 2020). The downside is that the UWC is experienced as a source of frustration. Citizens throw away their trash at unconventional times, or if the container is at its maximum capacity, dump their waste next to the container, see Figure 1. Litter piles up, resulting in odour-, vermin- and noise pollution for the citizens living near these UWCs.

Figure 1: Underground waste containers at above full capacity. Location: Wittevrouwen, Utrecht.

Citizens of several neighbourhoods have signed petitions where they advocate the removal of certain UWCs (H. Cammeraat, 2021). There have been various lawsuits against some locations of the UWCs in Utrecht, where the prosecutors claim they live next to a dumping ground, and that it reduces the value of their property (Raad van State, 2018). The municipality of Utrecht is aware of the problem of possible property value reduction but unfortunately are restricted in studying this aspect (Stadsbedrijven, 2020). This shows that there is a need to fill this research gap.

In this study, the central research question is as follows:

> *What is the impact of underground waste containers on the neighbourhood attractiveness, reflected by the transaction prices of owner-occupied homes?*

To help answer this question, three hypotheses are formulated. The first hypothesis is:

> ***Hypothesis 1:*** *The transaction price of real estate is negatively affected by underground waste containers in proximity to their homes.*

A multilevel hedonic pricing methodology is employed that explains residential property prices based on property-specific housing attributes and neighbourhood specific location attributes. The traditional hedonic model is estimated using Ordinary Least Squares regression with robust and cluster options to include the spatial perspective.

The second hypothesis is as follows:

> ***Hypothesis 2**: The attractiveness of a neighbourhood is positively affected by the availability of underground waste containers.*

This hypothesis differentiates itself from the first hypothesis by not exclusively looking at the impact of UWCs in proximity to real estate, but by studying the overall change in price levels in the neighbourhood where UWCs are installed. To test for this, a difference-in-differences statistical technique is used. What exactly the term 'proximity' entails is discussed in the next chapter.

For the third hypothesis, the interest is in whether the share of rental properties in a neighbourhood has any joint significance with the magnitude of the effect of a UWC. Therefore, the third hypothesis is:

> ***Hypothesis 3**: The magnitude of the effect of underground waste containers on transaction prices on the neighbourhood level decreases with an increase in rental properties.*

The statistical approach to this question uses a combination of the two-way Analysis-of-Variance (ANOVA) statistical test and including interaction effects in the hedonic pricing model while using fixed effects for the neighbourhood level.

The scope of this research is the city of Utrecht. Utrecht is the fourth-largest city of the Netherlands, located in the eastern corner of the Randstad conurbation. The data used is a combination of latitude and longitude data of UWCs in Utrecht received from the municipality itself, and the data provided by the Nederlandse Coöperatieve Vereniging van Makelaars en Taxateurs (NVM), the Dutch Association of Real Estate Brokers and Valuers. The data used is from the years 2011 to 2020. Besides, neighbourhood data is collected from the Dutch Central Bureau of Statistics (CBS) and Utrecht Monitor.

The remainder of this paper is structured as follows. First, the theoretical framework is discussed. Here, the relationship between neighbourhood attractiveness and house prices, the role of amenities, UWCs as an amenity, and the aforementioned hypotheses are explained and clarified. After these introductory parts, the data and the methodology are presented. The results are shown and discussed in the chapter afterwards. The paper ends with a conclusion, limitations, and recommendations for further research.

Chapter 2. Theoretical Framework

In economics, the urban housing market is distinctive in that the market is completely product-differentiated. That means, every product in the market (house or land) is unique (A. Piasecka, 2017). This is the foremost reason why the housing market is not perfect. Furthermore, a lack of transparency of the mechanism influencing the prices exists, and obtaining complete information is difficult (Manganelli, 2015). Besides these characteristics of the housing market, there are more factors influencing house prices. Such factors can be divided into macro-, meso- and microeconomic levels. Examples of macroeconomic factors regarding the housing market are socio-demographic (population), socio-economic (GDP), political (housing policy), or financial (availability of mortgage loans) (O. Ruza, O. Lavrinenko, R. Zelcs, 2014). Mesoeconomic factors refer to location -and therefore neighbourhood- specific characteristics, or in other words, amenities. Examples of amenities are the availability of a local park or a good-quality school nearby. Lastly, microeconomic factors regarding the housing market refer to the physical characteristics of the dwelling, such as the number of bedrooms, or the construction period (Visser & van Dam, 2006). This study is mostly interested in the mesoeconomic factors since underground waste containers fall under this category. This is further elaborated in section 2.2.

2.1 The role of amenities in house prices

The relationship between amenities and property value has been extensively researched, and to a great extent derived from the work of von Thünen (1826), Weber (1929), Alonso (1964) and Muth (1966), where they laid down the fundamentals of location theory in economics. Lancaster (1966) in his study of consumer theory noted how a consumer values a dwelling is based on its characteristics or properties, and the widely cited paper of Rosen (1974) for his influential work on hedonic price modelling is based on this work. Freeman (1979) in his book noted that the price of a dwelling is composed of its characteristics: structural, environmental, and locational.

The definition according to the South Gloucestershire Council (2016) in the context of property and land use planning of an amenity is something to be considered to benefit a location, contribute to its enjoyment, and thereby increase its value. These amenities are thus of geographic nature and consist of a broad range of different features. In their working paper 'Consumer City', Glaeser, Kolko, and Saiz (2000) have divided these different features into four types of amenities, which composes a useful framework. These types of amenities are explained below because they act as relevant control variables in the models used in this study. It is important to include all types of amenities to minimize the effect of omitted variable bias and account for all factors that could influence transaction prices.

The first type of amenity is the presence of a rich variety of services and consumer goods. Examples are restaurants, hotels, or theatres: these are hard to transport and therefore local goods. The research on this type of amenities is relatively low but has been growing in the past years. An example of this is by Kung and Proserpio (2020) and Segú (2018) who studied the effects of an active Airbnb listing on house prices and rents, or the work of Öner (2013), in which he studied the relationship of the role of retail as an amenity in Sweden.

The second type of amenity is aesthetics and physical setting. Glaeser et al. (2000) noted that there is little evidence on the role of architectural beauty, but recent experiments by Cetintahra, Eksioglu, Cbucktu (2015) showed that economic values of properties increased with increased aesthetics of the street. According to Glaeser et al. (2000), the most important determinant of aesthetics and physical setting regarding increasing house prices is that of weather, measured by the January temperature or rainfall. Recent research however showed that no evidence that temperature alone has an impact on housing values, and it depends on a combination of multiple factors (Gourley, 2021).

The third type of amenity is good public services. Public services span from education to healthcare to infrastructure. The research regarding this type of amenity on house prices has been extensive, especially school quality and crime levels have received much attention. Haurin & Brasington (1996), Davidoff & Leigh (2008), and Turnbull & Zahirovic-Herbert (2018) found that high-quality public school has a positive impact on house prices, however, this relation is not always linear (Chiodo, Hernández-Murillo & Owyang, 2010). Regarding crime, Thaler (1978) and Hellman & Naroff (1979) were some of the first to study this impact on house prices and found that it had a negative impact. However, Tita, Petras & Greenbaum (2006) indicated that the average impact of crime rates on house prices is misleading. Crime is capitalized at different rates for poor, middle class, and wealthy neighbourhoods and does not have a uniform impact on the housing market, since it is related to multiple factors, such as the property type or the type of crime (McIlhatton, McGreal, Paz, & Adair, 2016, Lynch & Rasmussen, 2001, Ceccato & Wilhelmsson, 2020).

Finally, the fourth type of critical urban amenity is speed. The authors explain this type of amenity as the ease with which individuals can move around, and the range of services and jobs available in the metropolitan area. As the saying goes "time is money", residents value locations where the transport time is low and therefore not costly (Chen & Rosenthal, 2018). This amenity is closely related to the availability of transport & infrastructure and studied extensively. Gibbons & Machin (2005), Klaiber & Smith (2010), and Levkovich, Rouwendal & Marwijk (2016) have found evidence in their studies that transport infrastructure in proximity to the house increases its transaction price. Efthymiou & Antoniou (2012) show that proximity to infrastructure has a positive or negative impact on house prices, depending on the type of the transportation system. Transportation such as national rail stations and airports have a negative effect due to externalities such as noise pollution. Furthermore, Glaeser et al. (2000) highlight that the distance to the central business district (CBD) plays an important role in house prices. The monocentric city model equilibrium (based on the work of Alonso (1964), Muth (1969), and Mills (1972)) explains this phenomenon: residents exchange more commuting time for lower land prices. Living close to the CBD, therefore, increases house prices.

2.2 Underground waste containers and their role as an amenity

Waste collection systems are implemented worldwide primarily for public health reasons. Secondary reasons are to recover materials so that they can be reused and recycled (Rodrigues, Martinho, Pires, 2016). While waste management is a widely studied topic, no literature exists regarding a possible relationship between specifically UWCs and house prices. There does exist a vast amount of literature regarding landfills/waste transfer/ incineration/other waste treatment sites and house prices, but these amenities are not comparable to a UWC due to the difference in size, purpose, and frequency (see Eshet, Baron, Shechter Ayalon (2006), Zou, Tai, Chen, Che, (2020), Casado, Serafini, Glen, Angus, (2016)). In this section, elaboration is given on what the characteristics of UWCs are, and their role as an amenity in the neighbourhood.

Waste management is viewed as part of a generation, collection, and disposal system, requiring a systematic approach to understand all the components and their interactions (Seadon, 2010). Waste collections exist of five different features: container type, vehicle type, collection method, waste streams, and type of service (Rodrigues et al, 2016). The container type is the most important feature of the UWC since this is the most relevant and innovative feature. Underground containers are a relatively new type of container, and first investigated by ISWAWGCTT (2004), Nilsson & Christensen (2011), and Greco, Allegrini, Lungo, Savellini, & Gabellini (2014). As for the size of the container, underground containers are relatively large. Secondly, the vehicle type feature refers to the vehicles designed to empty the containers, and regarding UWCs, the municipality of Utrecht uses container-lifting devices that are hoisted over the container by the truck. As for the collection method, the containers are emptied once a week by the aforementioned trucks. Some UWCs in Utrecht are replaced by ‘smart’ UWCs, which contain a computer chip that can send signals when the container is almost at full capacity (Gemeente Utrecht, n.d.). Fourthly, the waste stream type refers to the source of the waste, which for UWCs are of residential/household origin. And finally, the type of service refers to either a pick-up system, where residents put their waste on the street or a drop-off system, where residents bring their waste to a communal container. Underground waste containers use the drop-off system.

As mentioned before, UWCs are a mesoeconomic factor, and regarding the type of amenities classified by Glaeser et al. (2000), it falls under the third type, which means it is a public good. One of the attributes of a UWC is that it can be considered both an amenity and disamenity (see chapter 1). Due to the use of UWCs, above-ground waste containers, loose garbage bags, or garbage bins are removed from the streetscape. In addition, residents are no longer bound to certain days for the disposal of household waste. But the households near UWCs experience the downsides relatively more, e.g., noise-, odour- and vermin nuisance, despite the measures undertaken by the municipality of Utrecht, such as fines. Therefore, this study assumes that households close to a UWC weigh the negative externalities more than the positive externalities and experience the UWC as a disamenity. This contradicting nature leads to the first two hypotheses:

> ***Hypothesis 1:*** *The transaction price of real estate is negatively affected by underground waste containers in proximity to their homes.*
>
> ***Hypothesis 2****: The attractiveness of a neighbourhood is positively affected by the availability of underground waste containers.*

Hypothesis 1, therefore, investigates the transaction price of real estate of owner-occupied homes near the containers, while the second hypothesis enlarges the scope and investigates the transaction prices of all owner-occupied homes at the neighbourhood level. 'Proximity' is a vague concept and demands an explanation. Therefore, in this study proximity is defined as the property is within 20 metres (Euclidean distance) to a UWC. This distance is chosen because the municipality of Utrecht uses this distance in their maps regarding the location of UWCs and their radius; see Figure B2 in Appendix B. Further explanation is given in section 3.4.

2.3 Characteristics of the neighbourhood

Households are segregated by geographical areas, which represents a neighbourhood. Households within a neighbourhood show similarities in socio-economic characteristics and preferences, such as household income or family size (A. Islam, 2012). The definition of the neighbourhood according to Galster (2001, p. 2112) is as follows: "The neighbourhood is the bundle of spatially based attributes associated with clusters of residences, sometimes in conjunction with other land uses". These spatially based attributes which are shared can be for example the number of natural areas, crime levels, or mobility for cars. Tiebout (1956) was one of the first who recognized these inter-neighbourhood differences and intra-neighbourhood similarities with his theory of local expenditure. He predicted that households with similar interests form practically homogeneous neighbourhoods. Residents in the same neighbourhood show similar demand for the social, economic, and physical environment, and share the same abilities to pay for their demand of services. There exists a notion of 'keeping up with the Joneses' (Ioannides & Zabel, 2003). This means that residents feel pressure to keep up with the neighbourhood, further altering behaviour and increasing the homogenization of the neighbourhood. Further research by Lynch and Rasmussen (2004) shows that there is a fiscal fragmentation between neighbourhoods. High-income households demand high-quality services and prefer to exclude low-income households from their neighbourhood. Low-income households in a neighbourhood are associated with social annoyance and less demand for a better neighbourhood environment. Hence, neighbourhoods have different characteristics and demands, therefore amenities can play different roles and have non-identical impacts.

Now that the characteristics of neighbourhoods are discussed, it is possible to go further in-depth about neighbourhood effects. Neighbourhood effects are the concept which hypothesizes that neighbourhoods have an (in)direct effect on the behaviour of individuals and their characteristics. The concept of the neighbourhood influencing behaviour has long been known (see Park, Burgess, Roderick, & McKenzie, 1925), but it has still received considerable attention in the last 30 years (Ham, Manley, Bailey, Simpson, & Maclennan, 2012). However, the work of Wilson (1987) 'The Truly Disadvantaged" is widely regarded as the most influential work on neighbourhood effects. In his theory, Wilson suggests that living in a poor neighbourhood has detrimental consequences on resident outcomes, such as drug use, low birth weight, and economic self-sufficiency. Since Wilson's work, a substantial amount of literature has been written on neighbourhood effects, such as Jencks & Mayer (1990), Galster & Killen (1995), and Dietz (2002). Manski (1993, 2000) has categorized neighbourhood effects into three types, which are discussed next.

The first type is that the endogenous neighbourhood effect, also known as peer effects. This effect occurs when the behaviour of an individual is influenced by the behaviour of other individuals in the same neighbourhood. This is associated with "social multipliers": that if only one individual is affected, e.g., by a new policy, the individual's behaviour influences the behaviour of others, and after a while, the whole neighbourhood is affected. This could be a possible explanation for the agglomeration of trash around UWCs. In this case, if one individual puts their waste next to the UWC, more residents will follow this behaviour. This is the only effect that has this social multiplier. Secondly, the exogenous effect, also known as the contextual effect, occurs when the behaviour of an individual is affected by the exogenous characteristics of the group. Examples of exogenous characteristics in the neighbourhood context are the religious background or ethnicity of neighbours. Lastly, the third category is the correlated neighbourhood effect. This effect is related to the theory that neighbourhoods are homogeneous. The effect occurs when individuals in a neighbourhood tend to behave similarly because they have similar individual characteristics or face similar institutional environments. An example given by Manski (1999) is that youths in the same school tend to achieve similarly because they have similar family backgrounds or because they are taught by the same tutors. It is important to note that these effects are not mutually exclusive and thus can happen simultaneously. For example, assuming that homeownership rates affect juvenile delinquency (exogenous), if these activities of a minor cause other minors to participate in unlawful behaviour, then an endogenous effect is also present (Haurin, Dietz, & Weinberg, 2002). In the next section, further elaboration is given on the neighbourhood effect of homeownership rates.

2.4 Homeownership and the neighbourhood

In this section, further elaboration is given on how homeownership and specifically rental- and social housing affects the neighbourhood. What makes homeownership different from rental housing, is that homeownership is characterized by high transaction costs of disposing of the property and the right to the capital gains in the homeowner's property value. Because of this right, there exists an incentive for homeowners to invest in their property, and have it well maintained (Haurin et al., 2002). Moreover, homeownership alters social behaviour through two mechanisms according to Cox (1982). The first one is the "interest theory", which entails that homeowners have a financial stake in local affairs because these affairs have an impact on the price of their property. Secondly, homeowners are less mobile than renters and are more likely to remain in a neighbourhood (see Hammnett, 1991; Rohe et al., 1996; Lundborg & Skedinger, 1999). Due to this immobility and the fact that undesirable changes in the neighbourhood reduce the value of the property, homeowners are incentivized to participate in local political- and social activities.

Furthermore, the effects of homeownership on several (socio)economic measures in the neighbourhood have been studied extensively. These measures range from the performance of children in school (Harkness & Newman, 2003; Barker & Miller, 2009; Holupka & Newman, 2012), to life satisfaction and increase in social interactions (Rose & Basolo, 1997; Manturuk, Lindblad, & Quercia, 2010; Engelhardt, Eriksen, Gale, & Mills, 2010), to improved property maintenance and longer lengths of tenure (Rohe & Stewart, 1996). In this study, the interest is in how homeownership rates affect the quality of local public goods, since UWCs fall under this category. As already mentioned before, Cox argues that homeowners are incentivized to participate in local activities and have well-maintained houses. Lyons & Lowery (1989) show that homeowners are more likely to express dissatisfaction about their neighbourhoods to the local government. Guterbock (1980) claims that homeownership leads to greater demands on local government services and public goods. With these research results available, Dietz et al. (2003) claim that the quantity and quality of local public goods and amenities – thus UWCs – should be greater in areas with more homeowners.

The relationship between rental- and social housing and anti-social behaviour in the neighbourhood is discussed in this section. Since the 1980s, the rental housing market in Australia has increasingly become the tenure for individuals with limited incomes and high levels of social need (Flint, 2006). The poorest sections of the community are concentrated in certain neighbourhoods and are associated with poverty, stress, and anti-social behaviour (Arthurson & Jacobs, 2004). This is not only limited to Australia since policymakers and legislators have identified anti-social behaviour primarily with tenants from the social housing- and private rental market in the UK as well (Hunter, Nixon, Slatter, 2005). Bannister and Scott (1997) identified a spectrum of anti-social behaviour comprising three distinct but potentially interrelated phenomena: neighbour problems (disputes arising from nuisance), neighbourhood problems (rubbish in public places), and crime problems (housebreaking). The most frequent source of complaint is noise, with a 2003 MORI survey in the UK reporting one in three residents being annoyed by neighbour noise. The study also revealed differential experiences of neighbour noise by residential tenure, where rental housing tenants were found to be noisier than owner-occupiers. Neighbourhood complaints come from the so-called risk areas, with the risk factors including high-density housing and rented accommodation (DEFRA, 2006). In the Netherlands, the liveability of the neighbourhood (the sum of the factors that add up to a community's quality of life) is increased by the sale of rental accommodations (RIGO, 2017), further reinforcing that rental housing lowers the quality of the neighbourhood.

Given the research and literature in this section, it can be deduced that an increase in the percentage of rental housing, and therefore a decrease of homeownership, is linked to a decrease in liveability in a neighbourhood and is regarded as an underperforming neighbourhood. An underperforming neighbourhood has less demand for high-quality amenities and the residents in these neighbourhoods care less about the nuisance caused by UWCs. In addition, according to Dietz et al. (2003), the quality of UWCs should be lower in areas with more rental owners. Quality here means that residents will use a UWC properly and minimize nuisance. Therefore, the assumption is made that the magnitude of the nuisance caused by UWCs decreases with an increase in rental housing. The last hypothesis is as follows:

> ***Hypothesis 3:*** *The magnitude of the effect of underground waste containers on transaction prices on the neighbourhood level decreases with an increase in rental properties.*

Chapter 3. Data and methodology

In this chapter, the methodology and methods used in this study are discussed. The process of acquiring and transforming the data is explained, followed by an elaboration on the theory of hedonic pricing models, and further detail is given on how certain variables are used to represent the different types of amenities. In addition, the statistical methods are introduced, and the corresponding assumptions are addressed.

3.1 Data collection

The pooled cross-section dataset used in this paper originates from multiple sources. The first dataset is provided by the Nederlandse Vereniging van Makelaars (NVM): the largest association of real estate agents and appraisers in the Netherlands. The NVM provided data regarding the transaction and structural attributes of real estate in Utrecht and ranges from 2011 to 2020 (n=37.373). It consists of price, property type, number of rooms, total square metres, and many more relevant variables.

The second dataset used is provided by the municipality of Utrecht and includes information regarding the UWCs in Utrecht. It consists of the postal code and street address, type of container, and the coordinates of the UWCs. GIS techniques are applied to match the proximity of a UWC to the neighbouring properties. Also, the year in which the container was placed is added to this database; this information is derived from multiple reports published by the municipality of Utrecht. Unfortunately, this information is not available for all UWCs, however, it is still sufficient. The missing data originates for the majority from observations in the most recently built district Leidsche Rijn. The observations with missing years equal 16% of the total observations.

Finally, the third and fourth datasets are provided by the Dutch Central Bureau of Statistics and Utrecht Monitor. Both datasets include the characteristics of all neighbourhoods in Utrecht. These characteristics are, among other things, the percentage of rental properties, the origin of residents, or safety. Every neighbourhood has a unique district code consisting of several postal codes. Every property from the NVM database is matched with the corresponding neighbourhood. For an overview of all the districts and (sub)neighbourhoods, see Figure B1 in Appendix B. Here, the same data modification methods are used for the NVM dataset.

The postal codes of the first dataset (NVM) are geocoded. This is done with the help of the PDOK LocatieServer (Publieke Dienstverlening Op de Kaart, 2021) and the PDOK Geocodeer spreadsheet developed by Baltussen, Tadema, and Michel (2021). This translates postal codes and house numbers to coordinates from the Basisregistratie Adressen en Gebouwen (BAG). A total of 382 (1,08%) errors occurred, and these observations are deleted. Finally, with the help of the statistical computing software R, the latitude and longitude data are linked to the right postal code, changed to a spatial data frame, and exported to a geopackage. The data is merged on location, which allows for multi-level analysis. The first level is on a structural level similar to the hedonic pricing model. The second level is that on the neighbourhood level.

3.2 The hedonic pricing method

Since the characteristics of the housing market and amenities have been discussed in chapter two, it is of importance to find the right econometric approach concerning the first hypothesis, *the transaction price of real estate is negatively affected by underground waste containers in proximity to their homes.* Rosen's widely cited theory about hedonic prices and implicit markets (1974) acts as the fundamentals of housing price research and is based on the work of A. Court (1939), who was the first to coin the term hedonic. The main idea of this hedonic regression framework is to decompose the characteristics of similar heterogeneous assets and give them separate values (Goodman, 1998). While Court applied the framework to the automotive industry, the most common example of the hedonic pricing method is in real estate. The housing market is a natural fit for the framework since the price of a property is determined by its attributes, such as the physical and locational variables. Housing is therefore not a homogeneous good (Malpezzi, 2002). Thanks to the hedonic pricing model, an estimation to which extent each factor of a property affects the transaction price is possible. Now, the monetary (dis)value of a UWC in proximity to a property can be derived because proximity to UWCs acts as a locational characteristic. The exact property characteristics used in the hedonic regression models, as well as the application of the hedonic pricing model, are discussed in the next two sections.

3.3 The hedonic pricing model

This section introduces the model used in this study. In their paper 'The Value of Housing Characteristics', Sirmans, MacDonald, Macpherson, and Zietz (2006) conducted a meta-analysis regarding the value of housing characteristics, and found that the hedonic pricing model has the following general form:

$$\textit{Transaction Price} = \alpha_0 + \beta_i X_i + \varepsilon$$

Where the transaction price is either in linear or logged form, the β_i is the estimated regression coefficient for the ith housing characteristic, X_i is the set of i housing characteristics, and ε is the residual error term. Sirmans et al. mentioned that across studies, hedonic models have differed in model specification. Hence, this general model is slightly modified so that it is the most suitable for this study.

First, this study uses the logarithmic transformation of transaction price instead of the transaction price. Logarithmic regression is the logical choice here since this causes the interpretation of the independent variables to be in percentages instead of absolute values. Comparing the impact of dependent variables is now possible since they are measured in the same unit. But most importantly, logarithmic transformation regression transforms the data to a normal distribution (a bell curve). This is important due to the central limit theorem which is one of the key concepts in probability theory, which states that the average of many observations of a random variable with finite mean and variance is itself a random variable—whose distribution converges to a normal distribution as the number of samples increases (Lyon, 2014). Further exploration of the dependent variable and its corresponding histograms is given in section 3.5. Secondly, the model does not consider the locational attributes linked to the property in their general form (aside from (inter)cardinal points). These locational attributes are included in the models of this study.

Considering these changes to the general model, the hedonic pricing model in this paper is structured as follows:

$$Log\ (P_i) = \alpha_o + \beta S_i + \gamma L_i + \varepsilon$$

Where $Log\ (P_i)$ is logarithmic of the transaction price for property i, α_o is the constant, β and γ are the corresponding coefficients, S_i are the relevant variables regarding the structural attributes of property i, L_i are the relevant variables regarding the locational attributes of property i, and finally, ε is the error term. Which variables the structural and locational attributes entail can be seen in Tables 1 and 2.

Finally, two regressions are using the same model, but each with a different dataset. The first regression uses the entire (cleaned) dataset, but the second regression only uses the observations of transaction prices between the 25% and 75% quantiles. As mentioned before, real estate is a very heterogeneous product, hence there are divergent transaction prices and as a result, there are several submarkets within the total real estate market (Kauko, Hooimeijer, & Hakfoort, 2002). The pricing mechanics in these submarkets may differ. Limiting the observations to a certain range allows the regressions to capture a single submarket and be more robust. This process of dropping variables results in a dataset with n=18261. For the detailed descriptive statistics, see Table E1 in Appendix E. As for why the values 25% and 75% are chosen, this is because this captures the middle-class household submarket the best. According to the cautious approach of CBS, middle-income is defined as earning between the 25% and 75% quantile of gross income in the Netherlands (Schreurs, 2021), assuming that the income of households is positively correlated to their willingness to pay for real estate. An official definition of middle-income, unfortunately, does not exist.

3.4 The relevant variables

Regarding Table 1, these variables are all provided by the NVM. The variables are chosen based on past work on the application of hedonic modelling to the housing market (see Malpezzi, 2002) and on the literature discussed in chapter 2. To do multiple linear regression, the variables with three or more categories and which are non-hierarchical (ordinal) are transformed into dichotomous variables. For this process, see Table A1 in Appendix A.

Table 1: Structural attributes

Variable	Definition of Variable	Measurement level/values
m2	Square footage	Numerical
Monument	If the property is a monument	Dummy: No monument (0), monument (1)
Newly_constructed	If the property is newly constructed	Dummy: Not new (0), new (1)
House_category	House or apartment	Dummy: House (0), Apartment, (1)
NRooms	Number of rooms	Numerical
NToilet	Number of toilets, multiplied by 3	Numerical
NBalcony	Number of balconies	Numerical
NKitchen	Number of kitchens	Numerical
Attic	Attic availability	Dummy: No attic (0), attic (1)
Elevator	Elevator availability	Dummy: No elevator (0), elevator (1)
Parking	Parking availability	Dummy: No parking (0), parking (1)
Garden	Availability of garden	Dummy: No garden (0), garden (1)
Good_condition_inside	Condition inside	Dummy: Not good (0), good (1)
Good_condition_outside	Condition outside	Dummy: Not good (0), good (1)
Centre	Location of the house in the city centre	Dummy: No centre (0), in the centre (1)
Busy_road	Location of the house concerning the road	Dummy: Quiet road (0), Busy road (1)
UWC_transaction	In proximity to a UWC (<20 metres) at the time of transaction	Dummy: No(0), yes (1)

As for the *UWC_transaction* variable, this study's interest is in the relationship between a property transaction price near a UWC, and the relationship between property transaction prices and UWCs on the neighbourhood level. To capture the first relationship, a dummy variable is created whether a property is in close proximity to a UWC (1) or is not (0). As already mentioned before, close proximity is a vague concept. Therefore, to make it concrete, this is defined as the property is within 20 metres of a UWC. To be more precise, the PDOK Location Server translates addresses to latitude and longitude of the dwelling; these coordinates correspond to the front door of a property, with negligible deviations. Hence, the dummy variable includes all the properties with its front door within a 20-metre radius (the Euclidean distance) of a UWC and is included in structural attributes Table 1. Regarding the 20-metre radius, there is an inevitable degree of arbitrariness in setting this distance. For this study, the 20-metre buffer distance is chosen because the municipality of Utrecht uses this distance in their maps regarding the location of UWCs; for such a map, see Figure B2 in Appendix B. Furthermore, a UWC must have been built or be in the process of being built at the time when the transaction took place. Otherwise, the UWC had no impact on the transaction price since it did not exist yet.

The exact creation of the UWC variable -whether the individual property is within 20 metres of a UWC- is as follows. First of all, this is done with the software QGIS version 3.12 București, and the coordinate reference system (CRS) used is WGS 84 / Pseudo-Mercator, EPSG: 3857. This CRS is used because the WGS 84 is the de facto standard for mapping applications and is sufficient for small-scale maps. Two vector layers are added, which are respectively the geopackages of the transactions and container databases. Now, for all individual transactions, a circular buffer of 20 metres is added with the help of the MMQGIS plugin. Then, the analysis tool Count Points in Polygon is used. Now, a count is added to its attribute list to every transaction if a container is insides its buffer area. This count variable is exported and converted to a dummy variable (0 if no containers, 1 if 0> containers). For visualization of these buffers, see Figure 2.

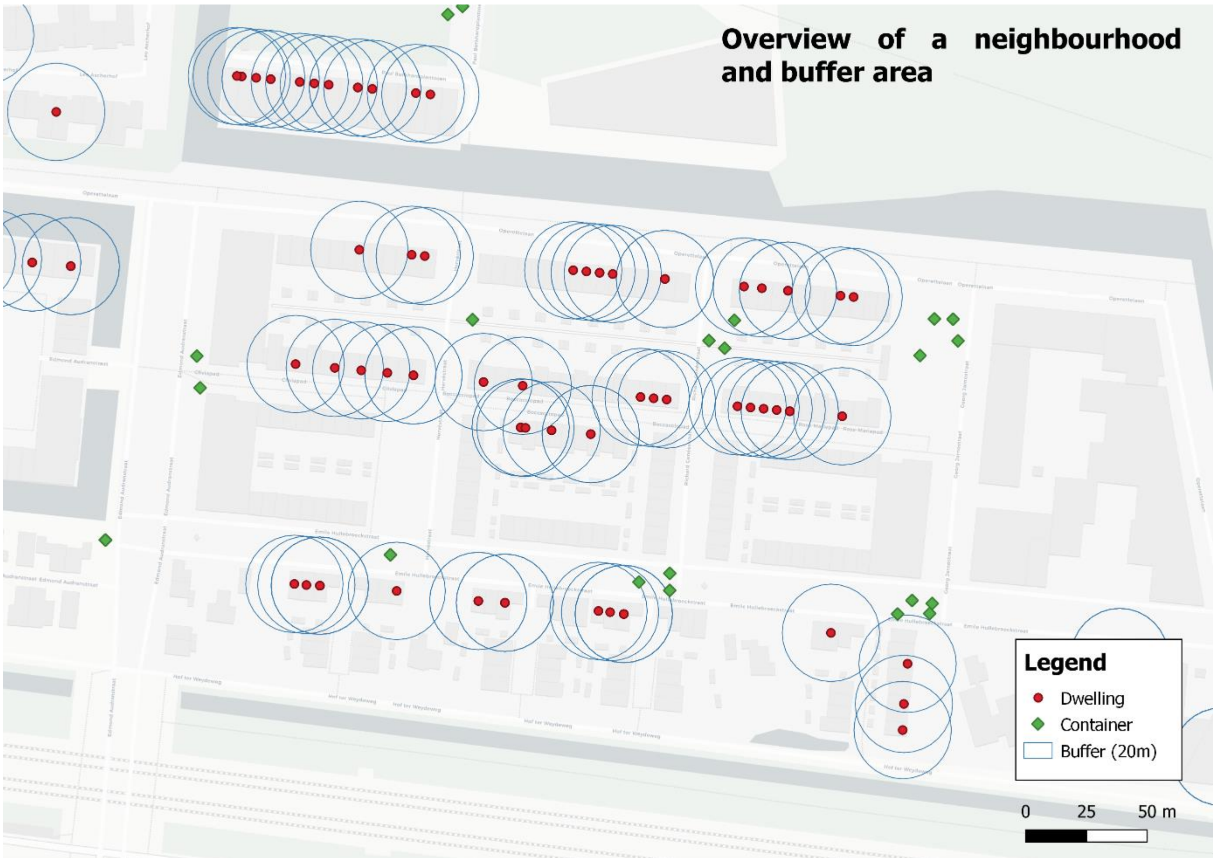

Figure 2: Overview of a neighbourhood and buffer area

As for the locational attributes, the databases of the NVM, CBS, and Utrecht Monitor are used. This includes information on the environment of the property. Specifically, all the data from the CBS is on the neighbourhood level. These neighbourhood level data are all from 2019, and therefore not all neighbourhood data of the observations are linked with the appropriate transaction year. While this increases estimation bias, the databases of other years besides 2019 of the CBS were incomplete or insufficient. Therefore, the choice is made for convenience and consistency purposes to use all the data of 2019, since this database is the most complete. The variables chosen are based on the amenity types discussed in the literature section, which are: a rich variety of services and consumer goods, aesthetics and physical setting, public services, and speed & accessibility. For an overview of the variables, see Table 2. All these variables are applied at the neighbourhood level.

Table 2: Locational Attributes

Variable	Definition of variable	Measurement level/values
Pop_dens	Number of inhabitants per km2	Numerical
Non_w	Number of inhabitants with a migration background	Numerical
P_rent	Percentage of rental properties	Numerical (0 to 100)
Income	Average income per income recipient x1000	Numerical
Unsafety	Percentage of residents who have felt unsafe	Numerical (0 to 100)
Culture	Number of cultural establishments	Numerical
Catering	Number of catering establishments	Numerical
D_supermarket	Average distance to supermarket	Numerical
D_health	Average distance to health establishment	Numerical
D_daycare	Average distance to day-care	Numerical
Water	Percentage water land use	Numerical
School	The average number of schools within 3 kilometres	Numerical

3.5 Econometric issues

There are some concerns regarding the statistical approach which is discussed in this section. First of all, transactions in the same neighbourhood share the same locational attributes, such as the parameters income, number of schools, or population density. This causes high autoregressive correlation, due to spatial dependence and spatial heterogeneity (Tse, 2002). This causes the estimated standard errors to be incorrect, and the model is less precise. Therefore, to correct this spatial dependence and heterogeneity, the neighbourhood effects must be fixed. This is done by clustering the transactions in the neighbourhood in the hedonic pricing model, with regression commands in the software Stata. The models, therefore, includes fixed effects on the neighbourhood level.

There is also the concern of the data not following a normal distribution and having outliers. This interferes with the statistical robustness of the models (Dixon & Yuen, 1974). As already mentioned before, to partly combat this concern the logarithmic transformation regression is used, but outliers may persist. There are several ways to deal with outliers, and in this research, winsorization is applied. Winsorization is the process of setting the outliers to predetermined percentiles, in this case to 1% and 99%. A new variable is generated, *price_w*, which is winsorized from the dependent variable *price*. Also, the logarithmic transformation for *price_w* is generated, which is *logprice_w*. For an overview of the histograms of these variables, see Figures C1 and C2 in Appendix C. These visualizations show that the winsorized logarithmic transformation variable is normally distributed. The sudden increase in density in both tails of the winsorized variables are to be expected since the outliers are moved to these values. The winsorized variables have an improved degree of normality of their distribution and will therefore be used in this study.

Furthermore, there is the concern of endogeneity. One of the explanatory variables could be related to the error term. There are three main sources of endogeneity: omitted variable bias (OVB), reverse causality, and measurement error. For this research, omitted variable bias is of most concern. As no instrumental variable is available, it is difficult to formally test for the presence of OVB (Koning, Vliet, & Wit, 2021). The same reasoning holds for reverse causality: without an instrumental variable, a Durbin-Wu- Hausman endogeneity test cannot be performed. The data is collected from several sources and not by the author of this paper, therefore there are limitations to checking for measurement errors of the data.

3.6 Descriptive Statistics

In this section, a summary of the data is presented. Further modifications and cleansing are done to the data to reduce errors and allow for higher quality information. First, the variables which the NVM did not clarify what they imply are deleted. Then, the variables with one value for all observations are deleted, such as municipality- or province number. Afterwards, several variables imply the same and are therefore deleted. Finally, the variables are deleted which will not be used in the regressions in this study. Moreover, if any variables had missing values, or physically impossible values (such as square metre being equal to 0, or on the contrary, equal to an abnormal big number), these were dropped from the datasets. In addition, two new variables are generated, which are the price per square metre, and its logarithmic transformation. See Figure C3 in Appendix C for the corresponding histograms. These graphs show that there are some extreme outliers; after manually checking these variables, it became clear that these were coding errors. Therefore, regarding the robustness of the models used, these outliers are also deleted from the database. This resulted in a total of 1402 (3,8%) dropped observations, including the dropped observations with incorrect geocodes.

Now, as one can see in Table 3, it becomes clear why it is important to winsorize the transaction price. Without winsorization, the minimum price of a transaction is equal to 54000. This is highly unlikely and is presumably the result of a data measure error. The winsorized price variable, *price_w*, shows much more believable statistics. As a result, the range of the logarithmic transformation decreased significantly, to a more normal distribution. For the structural and locational attributes statistics, see Tables 4 and 5. Furthermore, GIS techniques are used to illustrate the locations of the UWCs and to show the transaction prices per m^2 and their corresponding neighbourhoods, see Figures 3 and 4. The first map shows that the containers are consistently spread out and present in all neighbourhoods. Also, these maps show that the relatively newly build neighbourhoods of Leidsche Rijn (West of the Amsterdam–Rhine Canal) has a comparably lower price per m^2 than the neighbourhoods in and around the city centre. Furthermore, some small noticeable neighbourhoods such as Wittevrouwen and Vogelenbuurt demonstrate high transaction prices per m^2.

The average transaction price per year (see Figure 5) shows the fluctuation of the housing market in Utrecht. The decreasing prices are a result of the financial crisis of 2008 and are visible until 2013. After this year, the transaction prices started increasing again in record time. These trends are in line with the total real estate market in the Netherlands according to the Centraal Bureau voor de Statistiek (2019), therefore the Utrecht housing market is not exceptional, and the results of this study can be applied to other cases within the Netherlands.

Table 3: Statistics Dependent Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Price	35973	310227.78	168895.84	54000	2562500
logprice	35973	12.529	.468	10.897	14.756
price w	35973	308735.4	159657.38	105000	1035000
logprice w	35973	12.529	.462	11.562	13.85

Table 4: Statistics Structural Attributes

Variable	Obs	Mean	Std. Dev.	Min	Max
m2	35973	102.915	39.403	26	527
Monument	35973	.118	.322	0	1
Newly constructed	35973	.184	.388	0	1
House category	35973	.479	.5	0	1
Nrooms	35973	4.056	1.464	1	18
Ntoilet	35973	3.668	1.716	0	19
Nbalcony	35973	.359	.504	0	3
Nkitchen	35973	.88	.374	0	5
Attic	35973	.088	.284	0	1
Elevator	35973	.111	.315	0	1
Parking	35973	.167	.373	0	1
Garden	35973	.578	.494	0	1
Good condition ins~e	35973	.877	.329	0	1
Good condition out~e	35973	.939	.239	0	1
Centre	35973	.044	.205	0	1
Busy road	35973	.024	.153	0	1
UWC transaction	35974	.062	5.892	0	1117

Table 5: Statistics Locational Attributes

Variable	Obs	Mean	Std. Dev.	Min	Max
pop dens	35973	9742.374	4384.676	24	20225
non w	35973	947.343	937.473	10	5765
p rent	35973	48.306	16.927	2	99
Income	35971	33.8	7.235	11.8	56
unsafety	35973	29.167	9.917	0	50
Culture	35973	84.162	41.035	5	180
Catering	35973	56.744	35.969	5	340
d supermarket	35973	.566	.314	.2	2.7
d health	35973	.572	.268	.1	2.6
d daycare	35973	.383	.168	.2	2.2
water	35973	2.97	4.387	0	54
School	35973	23.629	8.399	3.7	39

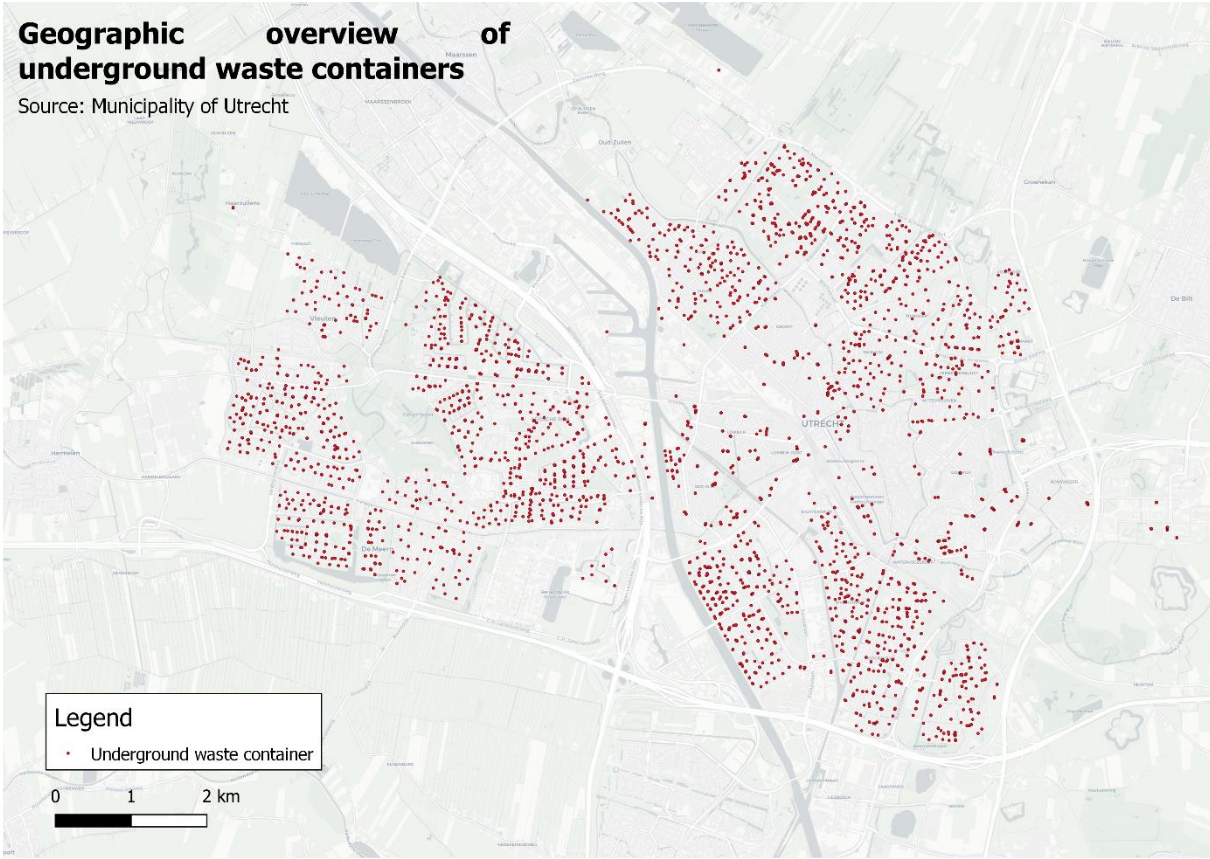

Figure 3: Locations of underground waste containers, Utrecht

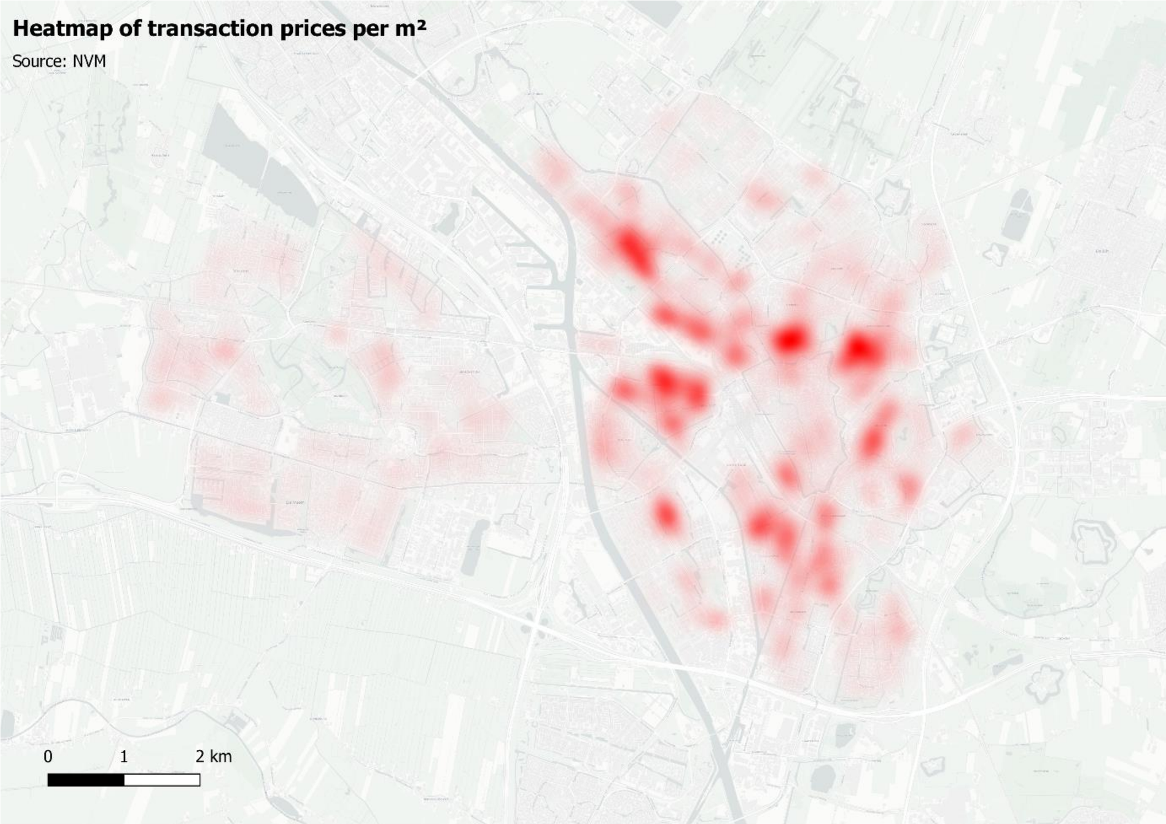

Figure 4: Heatmap of transaction price per m2 of real estate, Utrecht

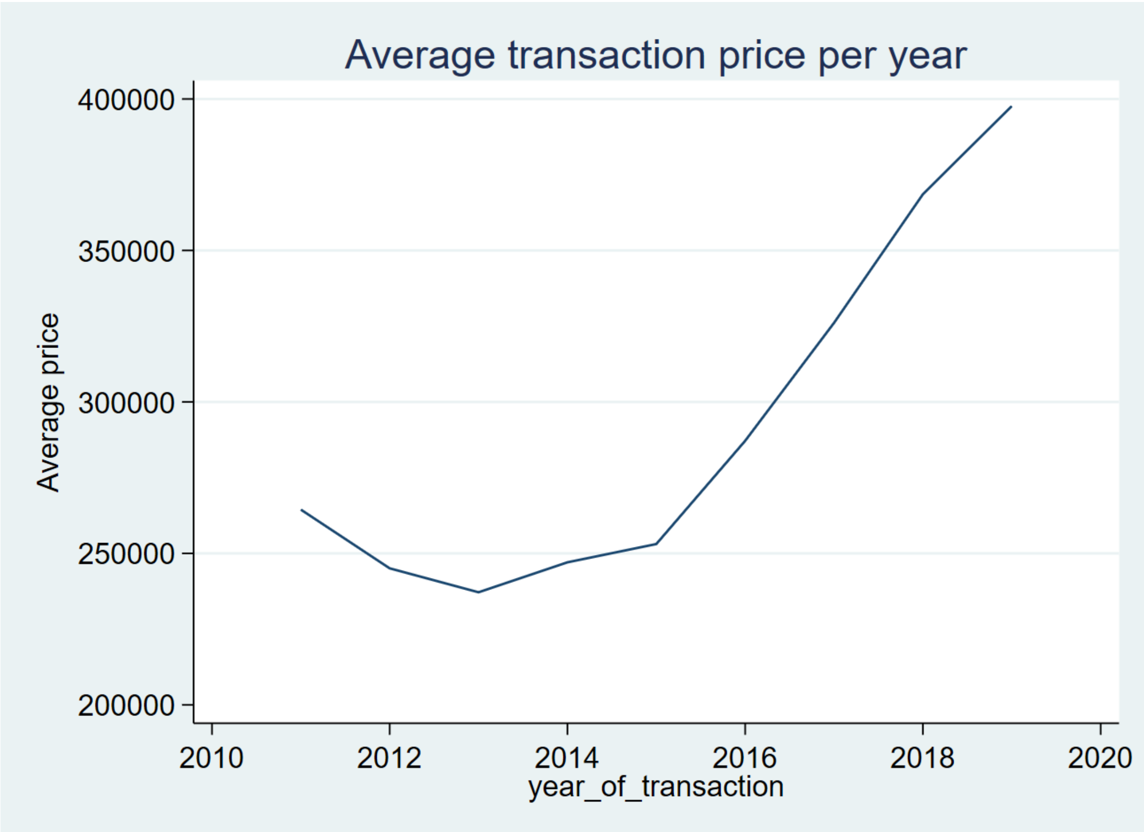

Figure 5: Average transaction price per year, Utrecht

3.7 Difference-in-differences

The previous parts of this chapter concern primarily the first hypothesis. Now, the approach to the second hypothesis is discussed. The second hypothesis, *the attractiveness of a neighbourhood is positively affected by the availability of underground waste containers*, enlarges the scope from the property level to the neighbourhood level. The interest is in evaluating the effects of UWCs on the attractiveness of a neighbourhood, reflected by the transaction prices. This situation translates itself to a difference-in-differences (DiD) statistical approach. DiD is a research design for estimating causal effects, and is popular in empirical economics (Lechner, 2011). DiD can be used when there is a need to evaluate a program or treatment, there are treatment and control groups, and there is the possibility to observe the groups before and after the implementation of the program. However, there are also some requirements: the treatment is not random, other things were happening while the program was in effect, and there is no possibility of controlling for all the potential confounders. Fortunately, 'Het Nieuwe Inzamelen' sufficiently fits all these criteria. The control group is the neighbourhood where UWCs have not yet been implemented, and the treatment group is the neighbourhood where UWCs are installed.

The DiD in a regression in this study has the following form:

$$Price = \beta_0 + \beta_1 D^{Post} + \beta_2 D^{Tr} + \beta_3 D^{Post} D^{Tr} \, [+ \beta_4 X_i] + \varepsilon$$

D^{Post} is the time dummy for whether the transaction was before or after the year of the program. D^{Tr} is the dummy variable for whether the transaction was in the treatment group, thus in a neighbourhood with UWCs. $D^{Post}D^{Tr}$ is the interaction of the time times the treatment. The coefficient of β_3 is the DiD estimate. X_i is the vector for the control variables, and ε the residual error term.

For the treatment group, the districts which received UWCs in 2015 in the neighbourhood of Overvecht is used, which are the sub-divisions Taag- en Rubicondreef, Wolga- en Donaudreef, Zamenhofdreef, Neckardreef, Vechtzoom-zuid, Vechtzoom-noord, Klopvaart Bedrijventerrein, Zambesidreef, Tigrisdreef, Poldergebied Overvecht, and surrundings. Overvecht was one of the first neighbourhoods to utilise the UWCs, and here the process of installing the containers was almost simultaneously. In addition, the year of implementation was in 2015. Since the range of the transaction data is from 2011 to 2020, there is sufficient data from multiple periods before and after the introduction of UWCs. Chabé-Ferret (2010) showed that having equal time distances to the treatment year is consistent with using just the most recent period. Besides, in other neighbourhoods, the installation of UWCs was spread over multiple periods, or in certain sub-neighbourhoods, it is unclear when the UWC was installed. Therefore, Overvecht is the best fit neighbourhood to act as the treatment group.

As for the control group, the neighbourhood of Utrecht Noord-West are used, which are the subdivisions Pijlsweerd-Zuid, Pijlsweerd-Noord, Nijenoord. Hoogstraat, Ondiep, 2e Daalsebuurt, Egelantierstraat, Mariëndaalstraat, Julianapark, Elinkwijk, Prins Bernhardplein, Geuzenwijk, Schaakbuurt, en Zuilen-Noord and surroundings. The reason for this is that Noord-West is similar in size to Overvecht and lay adjacent to each other. Moreover, Noord-West has only recently received UWCs in its neighbourhood in 2020, therefore all the transactions in the years 2011 to 2019 can be used in the regression.

One important aspect of DiD, in this case, is that the neighbourhoods should not differ in transaction price trends, otherwise the results will not be reliable. Unfortunately, there does not exist a direct test for this assumption. To validate that these neighbourhoods developed similar real estate prices and follow parallel trends, it is important to look at the trends in the transaction prices before the implementation of the UWCs. Therefore, a line graph is plotted: see Figure D1 in Appendix D. These visuals help demonstrate that the transaction prices underwent the same trends in the years from 2011 to 2019. Both neighbourhoods experienced decreasing transaction prices until 2013, and rapidly increasing transaction prices from the year 2015. In conclusion, the DiD is still sufficient as a statistical approach, and the parallel trend assumption holds.

3.8 Joint significance tests

Now the approach to the third and final hypothesis is discussed: *the magnitude of the effect of underground waste containers on transaction prices on the neighbourhood level decreases with an increase in rental properties.* Put another way, differs the effect level of a UWC on transaction prices for neighbourhoods with different levels of rental properties? The appropriate statistical approach for this question is the two-way analysis of variance (ANOVA). This is an extension of the one-way ANOVA, and the primary purpose of the two-way is to understand if there is an interaction between the two independent variables on the dependent variable. In this case, the two independent variables are whether the property is in proximity to a UWC at the year of the transaction, and the percentage of rental properties in the neighbourhood. The dependent variable is the logarithmic transformation of the winsorized price levels. The different groups are the different neighbourhoods. However, before this method can be applied, following the work of Gelman (2005), multiple assumptions of ANOVA analysis must be met, otherwise the results will not be valid.

The first three assumptions are related to the study design. The first assumption is that of the dependent variable, which should be measured at the continuous level. This is the case for this study. The second assumption is that the two independent variables should each consists of two or more categorical independent groups. Here, some adjustments to the variable must be made. The first independent dummy variable —proximity to a UWC— is sufficient, however, the second independent variable, the percentage of rental properties, is not. Therefore, a new variable is created which categorizes the percentage of rental properties in a neighbourhood. For this process, see Table A1 in Appendix A. The third assumption is that there should be independence of observations. This means that every transaction is only counted as one observation, and not in multiple groups. Since this study uses a cross-sectional dataset and thus not time-series, this is the case.

The fourth assumption is that there should not be any significant outliers. This can harm the two-way ANOVA and reduce the accuracy of the results. To account for this problem, the winsorized price levels is used, removing the significant outliers. The fifth assumption is that the dependent variable should approximately follow a normal distribution for each combination of the groups of the two independent variables. This is confirmed by the histograms in Figure C4 in Appendix C. And finally, the last assumption holds that there needs to be homogeneity of variance for each combination of the groups of the two independent variables. Here, Levene's test for homogeneity of variance is used, see Tables H1 and H12 in Appendix H.

After the results of the ANOVA are clear, new hedonic regressions are performed. This regression uses a variation of the model used in section 3.3 (the hedonic pricing model) but with an added interaction term. With the interaction term, it is possible to study the combined effect, rather than the simultaneous effect. Therefore, the results of these regression models must be carefully interpreted, as is always the case when working with interaction terms, since this changes the nature of the variables. Moreover, this hedonic model uses clustering per neighbourhood as well. The relation between the variables is shown with the help of interaction plots and is further analysed in the next chapter.

Chapter 4. Results and discussion

In this chapter, the results of the statistical tests for the three hypotheses are presented. In addition, these results are interpreted, placed in the right context, and discussed why they matter or not. Moreover, the limitations of the approaches to the hypotheses are discussed.

4.1 Hedonic pricing models

As discussed in section 3.3, the first hypothesis uses a hedonic pricing regression model. Applying the complete dataset, Table 6 shows the most important regression results with the logarithmic transformation winsorized price levels as the dependent variable. Model 1 excludes the control variables while model 2 includes them. As for the reason why the control variables are in- and excluded, this is done to check for the robustness of the findings. Adding control variables reduces omitted-variable bias, and there is interest in checking whether the inclusion of other covariates reduces or eliminates the impact estimated in the simple model. For an overview of the results of all the independent variables, see Table F1 in Appendix F.

Table 6: Regression results

VARIABLES	logprice_w (Model 1)	logprice_w (Model 2)
UWC_transaction	-.016	.065***
	(.05)	(.024)
_cons	12.529***	11.166***
	(.03)	(.082)
Observations	35973	35973
R-squared	0	.681
Fixed Effects Neighbourhood level	Yes	Yes
Control variables	No	Yes

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

First of all, the fit to the data is sufficient, with an R^2 of 68.1% explaining the variation for the models including the control variables. A sufficient number of coefficients across the two models are of the expected sign and most are statistically significant at the 95% level. The variables and their (un)expected results are discussed next.

See Table F1. An interesting result is that of the *Monument* and *Newly_constructed* variable. The former shows a positive sign and the latter a negative albeit statistically insignificant sign. This is to be expected since these variables are of contradicting nature. The *Monument* variable shows that dwellings built before 1905 are valued higher, while the *Newly_constructed* variable shows that dwellings built after 2001 are valued lower. These results can be linked to Figure 4: heatmap of transaction price per m^2 of real estate, Utrecht. In this map, the neighbourhoods in the West have a relatively lower price per square metre than the neighbourhoods in the East. The neighbourhoods in the West fall under the overarching neighbourhood Leidsche Rijn, which has only begun constructing houses since 1998: Leidsche Rijn is a Vinex-Wijk (Vierde Nota Ruimtelijke Ordening Extra). While the goal of Vinex-Wijken was to attract high-income households to more expensive dwellings than their current dwelling, the data used in this study suggests that this has not happened (Ministerie van VROM, 2005). Possible explanations for this could be trends affecting house prices positively which only occurred in the relatively older parts of Utrecht city (East of the Amsterdam–Rhine Canal).

The variables *m2, Nrooms, Ntoilet,* and *Nkitchen* all show the expected positive signs and are all significant at the 95% level. The last three of these variables have in common that they may all relate to the total square metre of a dwelling. Therefore, a pairwise correlation matrix is constructed to investigate this correlation, see Table E2 in Appendix E. As expected, the variables *m2* and *Nrooms* show a relatively high correlation of 0.770. To test whether this is an issue of collinearity, a Variance Inflation Factor (VIF) test is performed. Mathematically, the VIF for a regression model variable is equal to the ratio of the overall model variance to the variance of a model that includes only that single independent variable. This ratio is calculated for each independent variable. A high VIF indicates that the associated independent variable is highly collinear with the other variables in the model. Fortunately, the VIF test confirms that there is no collinearity since the values are all below the threshold of 5, see Tables E3 and E4.

Some structural control variables have unexpected results. Whether a dwelling has an available attic has a significant and negative effect on transaction prices. Perhaps an attic is seen as a liability since if it is not properly designed and maintained, many problems can occur—such as ice build-up or water damage, which would explain the negative sign. Furthermore, the variables *Garden, Elevator,* and *good_condition_outside* are not significant in model 2. The data is insufficient to make a conclusion.

As for the locational attributes, whether the dwelling is near the city centre or adjacent to a busy road, they have respectively positive and negative signs. The population density is significant although with a near-zero magnitude, therefore the effect of the population density can be considered negligible. The number of inhabitants with a migration background, the variable *non_w*, is negatively influencing transaction price, albeit also with a near-zero magnitude. This negative sign is to be expected since immigrants with a non-western background generally have lower income and education, therefore cannot afford dwellings with high transaction prices and settle in neighbourhoods with lower prices. This falls in line with the theory of the homogenization of neighbourhoods.

The percentage of rental properties has a positive coefficient in model 2 but is insignificant. Therefore, with the data given in this study, it is not sufficient to make a conclusion. According to the theoretical framework, the expectation was that it should negatively affect transaction prices.

This variable receives more attention in section 4.4, where possible interaction effects are investigated.

Income, unsafety, and *Culture* and *school* have the expected signs and are statistically significant. Overall, neighbourhoods with higher income are deemed to be of higher quality, therefore the transaction prices will increase according to the literature. *Unsafety* has a negative influence on transaction prices, which is to be expected: people do not want to feel unsafe in their neighbourhoods. *Culture* has a positive effect, although small in magnitude. It falls under the first type of amenity: the presence of a rich variety of services and consumer goods. A possible explanation for the positive effect is because cultural establishments are lower in priority in neighbourhoods compared to schools or supermarkets. Therefore, it can be deduced that neighbourhoods with additional cultural establishments already have the other amenities covered and are of higher quality. Finally, the average number of schools within 3 kilometres, *School,* has the expected positive sign. Schools fall under public services and according to the data an increase in quantity increases transaction prices. A possible explanation could be due that an increase in quantity means that there is an increasingly diverse choice of schools for parents, which can be considered a luxury position. Hence, this increases the quality of the neighbourhood and thus transaction prices.

While these locational attributes were in line with the literature, the variables *Catering, d_supermarket, d_health, d_daycare* and *water* are insignificant in model 2. The expectations were that it should have a positive significant effect on house prices. The data used in this study is not sufficient to make a conclusion in this case for these variables.

Finally, the independent variable of interest *UWC_transaction* is discussed. The definition of this variable is that the individual dwelling is in proximity, that is within 20 metres, to a UWC at the time of transaction. In model 1 where the control variables are excluded, this variable has the expected negative sign. This is the result of what the theoretical framework suggested. However, it is insignificant. In model 2 with the control variables included, the variable is statistically significant at the 99% level and has a positive sign. To be precise, if the dwelling is within 20 metres of an underground waste container at the transaction date, this is expected to increase the transaction price by 6,5% than if the property does not have an underground waste container in proximity at its transaction date, ceteris paribus. This suggests that there is a positive relationship between UWCs in proximity and transaction prices, which is not in line with this study's expectations. The next section further investigates this possible relationship by exclusively looking at the middle-income household submarket.

4.2 Hedonic pricing model subset

Before the first hypothesis can be rejected or accepted, identical regressions are performed but with the aforementioned subset. This subset includes only the observations between the 25% and

75% of transaction prices of the total dataset. Table 7 shows the most important result of the regression results with the logarithmic transformation winsorized price levels as the dependent variable. Model 3 excludes the control variables while model 4 includes them, for the same reasoning discussed in section 4.1. For an overview of the results of all the independent variables, see Table F2 in Appendix F.

Table 7: Subset regression results

VARIABLES	logprice_w (Model 3)	logprice_w (Model 4)
UWC_transaction	.016	.044***
	(.017)	(.013)
_cons	12.506***	11.97***
	(.005)	(.039)
Observations	18262	18261
R-squared	0	.222
Fixed Effects neighbourhood level	Yes	Yes
Control Variables	No	Yes

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

The overall results of models 3 and 4 are similar to those of models 1 and 2. The differences in results are: *Ntoilet, parking,* and *centre* are now insignificant; *Garden, Nbalcony,* and *good_condition_inside* are now significant at a 95% confidence interval; and *UWC_transaction* is positive in both models but only in model 4 is it significant at the 95% level.

Overall, the regression results do not differ much. Regarding model 4, if the dwelling is within 20 metres of an underground waste container at the transaction date, this is expected to increase the transaction price by 4,4% than the property not having an underground waste container at its transaction date, ceteris paribus. There is a decrease in magnitude compared to model 2, suggesting that a UWC has less impact on transaction prices when just the middle-income household submarket is accounted for instead of the whole housing market in Utrecht. Both results suggest however that a UWC has a positive effect on transaction prices, contradictory to the expectations. The first hypothesis states that the *transaction price of real estate is negatively affected by underground waste containers in proximity to their homes.* Concerning models 1 to 4, the results show insignificant results when control variables are excluded; and show evidence for the opposite effect when the control variables are included. Therefore, the results in this study suggest that the first hypothesis is rejected since the data favours the alternative. It was assumed that the UWC would be primarily experienced as a disamenity when the UWC is located near properties, while the data suggests that it is experienced as an amenity.

The results indicate that the disadvantages of a UWC near a resident's home have been overestimated in this study. The UWC increases the expected transaction price by 6,5% or 4,4%, which is modest in magnitude. According to this data, it can be deduced that the advantages of a UWC for an individual is more important than the disadvantages. Advantages of a UWC nearby are less walking distance to throw away the trash or that it creates a better street scene. The role of the social multipliers discussed in section 2.3 could play a role in this unexpected result. The theory of social multipliers states that an individual's behaviour influences the behaviour of others, and after a while, the whole neighbourhood is affected by this individual's behaviour. In the case of throwing away trash at a UWC at full capacity, the behaviour of the individual could go both ways. If an individual behaves 'badly' and places their trash bag beside the UWC, this eventually causes bad behaviour by all residents in the neighbourhood. However, if the individual does the 'right' behaviour and takes their trash back home, the negative externalities of the UWC are minimized while still retaining its advantages. Unfortunately, no variable in this study was used to measure the behaviour of residents or to measure the effects of social multipliers in a neighbourhood, and therefore it was not possible to control for this. Future studies may take this factor into account regarding amenities in which the behaviour of the individuals plays a role.

Naturally, there are some limitations to the statistical method applied. The method of hedonic pricing is only able to capture the willingness to pay of consumers of properties. Since UWCs are a relatively new (dis)amenity, it could be that residents in Utrecht are not yet aware of the linkages between the attributes of a UWC and its (dis)benefits. Therefore, it could be that the monetary (dis)value of the UWC is not yet reflected in the transaction prices. In addition, hedonic pricing methods assume that people have the opportunity to select the combination of features they prefer. This is highly dependent on their income level and the supply of properties available. Income is dependent on several external factors as well that are not included in this study but could be of importance, such as taxes or *interest* rates. In addition, another assumption with hedonic pricing models is that prices in the market will automatically adjust to any changes in the attributes. However, in reality, these adjustments are slow. In total, 51,3% of the transactions in the database only received UWCs in the years 2018 to 2020, and therefore the price change in the transaction may not yet have been adapted to the proximity of a UWC. Further research may account for this issue and only use observations where it is more certain that transaction prices have adapted to the installation of UWCs and do not lag.

4.3 Difference-in-differences model

In this section, the difference-in-differences model results are presented and discussed. Of all 6824 observations, 5328 observations were from Noord-West, while 1496 were from Overvecht, see Table 8 (excluding control variables) for an overview.

Table 8: Difference-in-differences

Number of observations in the DIFF-IN-DIFF: 6824

	Before	After	Total
Control	1716	3612	5328
Treated	545	951	1496
Total	2261	4563	6824

price_w	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
dummy_time	64580.192	2031.052	31.80	0	60598.697	68561.687	***
dummy_treat	-21398.548	2495.403	-8.58	0	-26290.317	-16506.779	***
DiD	-31197.49	3874.392	-8.05	0	-38792.507	-23602.473	***
Constant	184165.37	1364.731	134.95	0	181490.08	186840.67	***

Mean dependent var	218309.333	SD dependent var	85320.679
R-squared	0.151	Number of obs.	6824.000
F-test	497.793	Prob > F	0.000
Akaike crit. (AIC)	173218.183	Bayesian crit. (BIC)	173245.495
Control Variables	No		

**** p<.01, ** p<.05, * p<.1*

Note that in the difference-in-differences models the dependent variable is the winsorized price levels, and thus not the logarithmic transformation. This is done because the *DiD* coefficient is now readily interpretable and more convenient. The *dummy_time* variable has a positive coefficient and is significant, which explains that house prices were trending up over time, which is expected since the average transaction prices have increased in the years 2011-2019. This reflects the effect of the passage of time without UWCs installed in the neighbourhood. The *dummy_treat* variable is negative and significant which means that dwellings in Overvecht had lower house values before the installation of UWCs, which is also in line with the previous findings (see section 3.6). This represents the baseline difference between the neighbourhoods before the UWCs. The focus of interest, the coefficient for *DiD*, is the difference-in-differences estimator. The effect is significant at 99% with the treatment having a negative effect. This is the opposite effect of this study's expectations. The data and this difference-in-differences model suggests that the overall house values in a neighbourhood decrease when UWCs are installed in the neighbourhood. To be exact, the expected transaction prices in the treatment group -thus Overvecht- were 21398 euros lower at each observation in the baseline period (the period 2011-2014) than those of the control group, which is Noord-West. Following the installation of UWCs in Overvecht, the difference dropped by 31197 euros to 52596 euros at each observation. The difference in each time period — in this case, every year— remains the same in this model.

Table 9: Difference-in-differences

price_w	Coef.	St. Err.	t-value	P-value	(95% Conf.	Interval)	Sig
dummy_time	63442.33	1497.211	42.37	0	60507.327	66377.332	***
dummy_treat	-20546.202	6544.582	-3.14	.002	-33375.634	-7716.77	***
DiD	-19564.302	3081.755	-6.35	0	-25605.507	-13523.097	***
Constant	-56863.125	22693.955	-2.51	.012	-101350.39	-12375.859	**

Mean dependent var	218215.756	SD dependent var	85060.753
R-squared	0.664	Number of obs.	6822.000
F-test	419.328	Prob > F	0.000
Akaike crit. (AIC)	166858.596	Bayesian crit. (BIC)	167083.917
Control Variables	Yes		

**** p<.01, ** p<.05, * p<.1*

See Table 9 for the difference-in-differences model including control variables, and Table G2 in Appendix G for an overview of all the coefficients. The control variables are added for identification of the treatment effect and to reduce the error variance, thereby increasing statistical power. This is due to different trends in Noord-West and Overvecht unrelated to the treatment, such as income. These differences can now be controlled for, and the results would still be unbiased. The coefficients of *dummy_time, dummy_treat,* and *DiD* differ slightly, but still hold the same sign and are sufficiently significant. Therefore, these results suggest the same regarding the first model: that the treatment hurts the overall house prices at the neighbourhood level. Therefore, data of this study and its statistical approach suggest that the second hypothesis, that *the attractiveness of a neighbourhood is positively affected by the availability of underground waste containers*, is rejected.

Again, the results indicate the opposite of this study's expectations. The assumption was made when forming the hypotheses that only the households near UWCs experience the downsides. However, a neighbourhood with UWCs is expected to have an overall decrease in house prices compared to a neighbourhood without UWCs. Here, on the neighbourhood level, the negative externalities weigh more than the positive externalities. Considering the conclusion from the previous section, that the UWC for an individual property is seen as an amenity, it can be expected that on the neighbourhood level the UWC is regarded as a disamenity. This is because only a certain number of properties in the neighbourhood will have the amenity nearby; it could be that the benefits of a UWC weigh more for these properties, such as short walking distance. Therefore, on the neighbourhood level where most properties do not enjoy these advantages as much, the UWC is regarded as a negative externality. This conclusion only works under the assumption that certain externalities weigh more than others. In this case, the negative externality of having to walk more distance to a UWC must weigh more than, for example, the positive externality of a more beautiful street scene. A new question arises; what is the weight of certain advantages and disadvantages of a UWC. Unfortunately, no data is collected, or literature is known regarding this topic.

The method of differences-in-difference is not without disadvantages, and the results here are subject to some constraints and limitations. The most important assumption that was made is the parallel trend assumption, that the transaction prices in each neighbourhood developed equally. It could be that in the control or treatment group, the municipality of Utrecht introduced some small improvements such as improving a dangerous intersection. As mentioned before, there does not exist a direct test for this assumption, and in this study, a visualization was made to test for this, see Figure D2 in Appendix D. Here, the difference between the control and treatment group should always be constant over time. The difference-in-differences approach in this study uses a year as the time period; however, it is proposed that the smaller the time period tested, the more likely the parallel trend assumption hold (Colombia Public Health, 2021). Therefore, to reduce the biased estimation of the causal effect, future studies may reduce the time period to months. In addition, in this study, the number of suitable control- or treatment groups were very low. This is because the installation of UWCs was per sub-neighbourhood, and therefore the installation in the complete neighbourhood was a slow process, often spanning multiple years. As a result, the samples of the groups are relatively small, potentially resulting in unprecise estimates. Future studies may do multiple difference-in-differences models where the control- and treatment groups are at the sub-neighbourhood level instead of the whole neighbourhood level, and compare outcomes. Moreover, the time period of this study (2011-2019) was a time of relative economic instability, with the effects of the financial crisis still affecting house prices, and a huge increase in transaction prices increase from 2013. The results of this study may not necessarily apply to different time periods. Moreover, one assumption was that that the composition of individuals of the two groups remain unchanged over time. The dataset consists of cross-sectional data which may have resulted in compositional changes in treatment and control groups, and no validity tests for this assumption is performed. Finally, the group size of the control and treatment groups were respectively 5328 and 1496. Ideally, sample sizes should be equal in size, otherwise, this reduces statistical power. In conclusion, cautious implications of the results are advocated.

4.4 ANOVA and interaction

In this section, the tests for the third and final hypothesis is performed, *the magnitude of the effect of underground waste containers on transaction prices on the neighbourhood level decreases with an increase in rental properties.* As discussed in section 3.8, a two-way ANOVA is first carried out to check for evidence for a potential joint significance on the dependent variable. One of the assumptions which must be met is that the two independent variables are categorical. Since the variable for the percentage of rental properties is numerical, a new variable was created: *p_rent_cat*. This new independent variable consists of numbers one through five and represents the five quantiles of rental properties percentage levels respectively, see Table A1 in Appendix A for the creation of this variable. In addition, in Tables H1 and H2 in Appendix H the Levene's tests for homogeneity of variance are performed for both the independent variables. Unfortunately, Levene's tests show significant results for both independent variables. This is also true for the modified Levene's test, the Brown-Forsythe test, representing the W50 and W10 results in the aforementioned Tables. This means that the null hypothesis, that the variances are equal, is rejected. This is a violation of the assumption that variance is homogeneous. However, Stevens (1996) states that analysis of variance is still reasonably robust if the size of the groups is reasonably similar. This is the case for the categorized rental properties levels, but whether the property is close to a UWC does not fit this criterion. Therefore, the dataset fails to meet the assumption of homogeneity. The choice is made to still carry on with the two-way ANOVA test, but it is important to note that this test now may hold less statistical power.

Before proceeding to the two-way ANOVA results, numeric descriptive statistics reveal that the means of both independent variables differ much and are therefore likely to be statistically different. See Table H4 in Appendix H. Visualization is made of the mean of the winsorized logarithmic transformation price for each combination of groups of the two independent variables and presented in a line graph in Figure H3. An interaction effect can be seen as a set of non-parallel lines crossing. In this graph, the lines are not parallel but intersect twice, between categorized rental properties levels 1 & 2 and 3 & 4. Therefore, a statistically significant interaction is to be expected (Biostats, 2017). See Table 10 for the two-way ANOVA results.

Table 10: Two-way ANOVA

	Number of Obs.	= 35,973	R-squared	=	0.1156
	Root MSE	= .434202	Adj, R-squared	=	0.1153
Source	Partial SS	df	MS	F	Prob>F
Model	885.80565	9	98.42285	522.05	0.0000
UWC_transaction	.65876107	1	.65876107	3.49	0.0616
p_rent_cat	117.68421	4	29.421053	156.05	0.0000
UWC_transaction*p_rent_cat	10.036577	4	2.5091443	13.31	0.0000
Residual	6780.141	35,963	.18853102		
Total	7665.9467	35,972	.21310871		

There is a statistically significant main effect for categorized rental properties levels, but not for whether the property is close to a UWC at the 95% level. In addition, as expected there is a significant interaction effect, which means that there are simple main effects. Post hoc testing is needed to clarify the exact effects of this interaction. Therefore, the effect of one of the independent variables at a particular level of the other independent variable is reported. See Table H5 in Appendix H for the post hoc tests for the differences in whether the property is close to a UWC at each level of categorized rents levels. Using the per-family error rate, the differences in the former independent variable at levels 0%-20% till 60%-80% for the latter independent variable are statistically different, thus there is evidence supporting the hypothesis that the effect levels of a UWC have different effects on transaction prices dependent on the percentage of rental properties in the neighbourhood. Further tests must be performed to see the direction and magnitude of these effects. The final step of the analysis is adding the interaction effect to the hedonic pricing regression model.

See Table 11 for an overview of the regression models with added interaction effect, and Table I1 in Appendix I for the detailed results. Model 5 excludes the control variables, while model 6 includes them. Controls are included in model 6 to check for the robustness of the findings and reduce omitted-variable bias.

Table 11: Regression results with interaction effects

VARIABLES	logprice_w (Model 5)	logprice_w (Model 6)
UWC at time of transaction		
UWC	-0.106	-0.00875
	(0.120)	(0.0629)
Percentage of rental properties		
0%-20%	-	-
20%-40%	-0.0918	-0.0336
	(0.0725)	(0.0230)
40%-60%	-0.257***	-0.000522
	(0.0623)	(0.0286)
60%-80%	-0.339***	0.00609
	(0.0938)	(0.0292)
80%-100%	-0.414***	0.0245
	(0.0647)	(0.0356)
Interaction of two independent variables		
UWC * 0%-20%	-	-
UWC * 20%-40%	0.191	0.0792
	(0.131)	(0.0709)
UWC * 40%-60%	0.205	0.0754
	(0.151)	(0.0723)
UWC * 60%-80%	-0.0446	0.0915
	(0.149)	(0.0833)
UWC * 80%-100%	0.0499	0.138
	(0.133)	(0.0838)
_cons	12.73727	11.21263
Observations	35,973	35,971
R-squared	0.1156	0.6822
F-ratio	522.05	245.40
Fixed Effects Neighbourhood level	Yes	Yes
Control variables	No	Yes

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

In model 5, the only statistically significant result at 5% is the quantiles of the percentage of rent levels at levels 40%-60%, 60%-80%, and 80%-100%. The constant is equal to 12.73727 and represents the predicted value when all variables are at their base case, which is having no UWC nearby of the property and having between 0%-20% of rental properties in the respective neighbourhood. If this is the case for the property, then the predicted transaction price is 12.73727 in the logarithmic scale transformation (equal to €340194), ceteris paribus. However, it is insignificant. What the coefficients entail for the significant result, for example for 40%-60%, is that if the neighbourhood of the dwelling has rental properties between 40%-60% of total properties, the predicted transaction price is 12.73727-0.257=12.48027 in the logarithmic scale form (equal to €263095), ceteris paribus. In Table I3 all the predicted values for all groups are presented. In model 5, the interaction between the two independent variables is not significant at any combination.

In model 6, where the control variables are included, all the variables of interest are insignificant, including whether the property is close to a UWC. This means that in this model, there is no evidence that the average effect of having a UWC nearby differs by the percentage of rental properties in the neighbourhood. The lack of significant results in the models shows that there is weak and little evidence for the joint significance of the independent variables. The data used in this study suggests that it is not sufficient to make a credible conclusion, and therefore the third hypothesis is failed to be rejected or accepted. Possible explanations could be that the characteristics of the residents in Utrecht differ with those populations of past research, which was primarily the U.K. (see section 2.4), or there were outside factors that this study did not control for. While the two-way ANOVA indicated that interaction effects were to be expected, no significant results were found in the regressions. As mentioned before, Levene's tests showed that the variances were not equal and that the categorical independent groups were not of the same size. Therefore, an assumption of ANOVA was violated and could be the reason for spurious results.

Chapter 5. Conclusion

In this final section, a summary is given on what this study performed, and the key results are presented. Afterwards, some more limitations are discussed, and relevant recommendations are given for further research in this field.

5.1 Conclusion

The main aim of this study was to study the impact of a new type of amenity introduced by 'Het Nieuwe Inzamelen' on residential property prices. To be precise, this study concerned the research question '*what is the impact of underground waste containers on the neighbourhood attractiveness, reflected by the* transaction *prices of owner-occupied homes?'*. Three sub hypotheses were created to better understand the impact of underground waste containers. The key results of these sub-hypotheses are now discussed.

> ***Hypothesis 1:*** *The transaction price of real estate is negatively affected by underground waste containers in proximity to their homes.*

Regarding the first hypothesis, applying a hedonic pricing model the positive and negative externalities generated by underground waste containers located in the city of Utrecht from the year 2011 to 2020 were valued. The effect of the positive or negative externalities was proxied by having an underground waste container in the vicinity (<20 metres) to a dwelling. Model 2 of the results suggest that the presence of an underground waste container near a property has a statistically positive effect on the value of residential properties: house prices rise with a container nearby. This effect was found in both the housing market of Utrecht and the middle-income household submarket. However, this outcome was the opposite of this study's expectation since the assumption was made that a container would negatively affect properties nearby. Moreover, the results of the first four models are prone to constraints of the hedonic pricing method, and that underground waste containers are a relative new amenity that brings complications. Therefore, one must be careful in deriving inferences.

> ***Hypothesis** 2: The attractiveness of a neighbourhood is positively affected by the availability of underground waste containers.*

To further investigate the impact of underground waste containers, the scope was changed from studying the effects of transaction prices on individual properties to studying the effects of transaction prices on the neighbourhood. Applying a differences-in-difference statistical technique using data from 2011 to 2019, the results suggest that underground waste containers lower the average transaction price in a neighbourhood in the city of Utrecht. This indicates that the second hypothesis is also rejected. The hypotheses were formed with the assumption that an underground waste container would have contradicting influences on house prices, yet the directions of these influences were misjudged. However, the analysis, and therefore this conclusion, is subject to limitations of the dataset and statistical technique employed. Therefore, again a cautious approach is needed for the implications of the results.

> ***Hypothesis 3:*** *The magnitude of the effect of underground waste containers on transaction prices on the neighbourhood level decreases with an increase in rental properties*.

To study the possible combined effect of an underground waste container and the proportion of rental properties in the neighbourhood on the transaction prices of properties, a two-way ANOVA and hedonic regressions with added interaction effects were performed. While the results of the two-way ANOVA showed a possible joint significance, the results of model 6 show no significant interaction effects for this relationship. In addition, no interesting significant results were found, and the third hypothesis fails to be rejected. Hence, further research is needed to investigate the effect of rental properties in combination with underground waste containers on house prices.

5.2 Limitations and further research

Some limitations of this study have not yet been discussed. One of such limitations of this study has been the choice of the definition of 'close proximity'. Here, the exact definition of close proximity was if a property has its front door within 20 metres Euclidean distance to a UWC. Whether this buffer area would be a better fit for this study if it were e.g., 10, 20, or 50 metres is debatable. No research or data exists regarding the positive and negative externalities of a UWC, and to what extent the externalities diminish or increase when moving away from the UWC. Future studies may do regressions with multiple buffer distances. In addition, the coordinates received by the NVM were the front doors of the respective properties. This brings additional complications with it. For example, this study did not account for a possible garden or balcony being within a certain distance to a UWC. This could influence the transaction price since if a UWC were in proximity to the garden/balcony, residents could experience the positive/negative externalities of a UWC more easily. Besides, it could be that some properties did have no direct view on UWCs and experience the externalities differently. In this case, further research could focus on the question of 'what is the value of view?'.

The rejections of the first two hypotheses indicate that it is unclear whether a UWC is regarded as an amenity or disamenity, or both. To gain in-depth information about people's underlying reasoning and preferences regarding UWCs, qualitative survey research can be performed to better understand the issue from an individual perspective. In addition, measuring the behaviour of individuals regarding the use of UWCs can provide intuition in the relationship between (dis)amenities, behaviour, and property valuation. And finally, future studies may perform this research in other countries to correct for the lack of external validity, or in a different period.

Despite the limitations, the results yield different insights regarding the main research question. It suggests that while the containers have a positive influence on transaction prices in proximity to the property, the opposite is true for the overall effect of the containers in the neighbourhood. As is often the case in research, there is not a simple answer to the research question, and the effect of the containers is ambiguous. While the results are impacted by this study's design, this information does shed new light on the effects of twofold amenities on property price estimation and contributes to the body of knowledge on real estate valuation and urban economics. When more statistics become available concerning the containers and the valuation of property, future studies that succeed in investigating the impact of underground waste containers on the transaction price can use the results of this study as comparison material in aid for their research.

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Appendices

Appendix A: Variable transformation

Table A1: Attributes transformation

Original variable	Definition of Variable	Original measurement level/values	Created variables
Construction_period	Construction period of property	Ordinal: Unknown/before 1500/after transaction date (0), 1500-1905 (1), 1906-1930 (2), 1931-1944 (3), 1945-1959 (4), 1960-1970 (5), 1971-1980 (6), 1981-1990 (7), 1991-2000 (8), >2001 (9)	Monument: >1905 = no monument (0), unknown/before 1500/after transaction date + 1500-1905 = monument (1) Newly_constructed: <2001 = not newly constructed (0) >2001 = newly constructed (1)
PARKEER	Type of parking	Nominal: No parking (0), parking spot (2), carport and no garage (3), carport and garage (6), garage intended for more cars (8)	Parking: No parking (0), parking spot + carport and no garage + carport and garage + garage intended for more cars = parking (1)
TUINLIG	Lie of the garden	Nominal: No garden possible (0), north (1), north-east (2), east (3), south-east (4), south (5), south-west (6), west (7), north-west (8)	Garden: No garden possible = no garden (0), north + north-east + east + south-east + south + south-west + west + north-west = garden (1)
ONBI	Condition inside	Ordinal: poor (1), poor to moderate (2), moderate (3), moderate to sufficiently (4), sufficient (5), sufficiently to good (6), good (7), good to excellent (8), excellent (9)	Good_condition_inside: poor + poor to moderate + moderate +moderate to sufficiently + sufficient + sufficiently to good = not good (0) good + good to excellent + excellent = good (1)
ONBU	Condition outside	Ordinal: poor (1), poor to moderate (2), moderate (3), moderate to sufficiently (4), sufficient (5), sufficiently to good (6), good (7), good to excellent (8), excellent (9)	Good_condition_outside: poor + poor to moderate + moderate +moderate to sufficiently + sufficient + sufficiently to good = not good (0) good + good to excellent + excellent = good (1)
LIGCENTR	Location of the house in relation to the city centre	Nominal: Outside the built-up area (0), unknown (1), in residential area (2), in centre (3)	Centre: Outside the built-up area + unknown + in residential area = No city centre (0), in centre (1)
LIGDRUKW	Location of the house in relation to the road	Nominal: On a quite road (0), unknown (1), on a busy road (2)	Busy_road: On a quite road + unknown = quit road (0), busy road (1)
P_huurw	percentage of the total number of rental and social homes	Continuous from 0 to 100	P_rent_cat: 0% - 20% (1) 20% - 40% (2) 40% - 60% (3) 60% - 80% (4) 80% 100% (5)

Appendix B: Maps of Utrecht

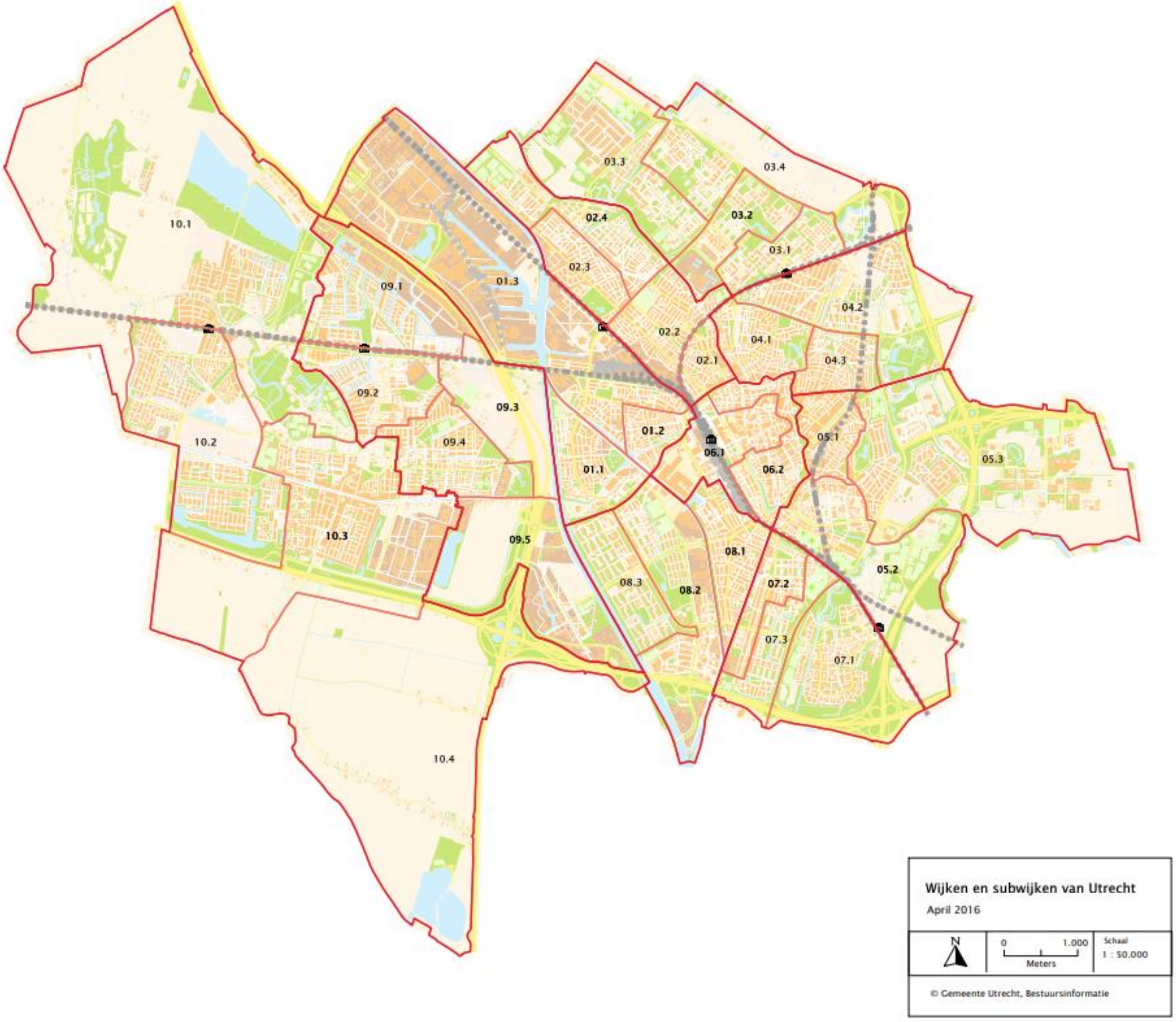

Figure B1: All districts in Utrecht. Source: https://www.utrecht.nl/fileadmin/uploads/documenten/bestuur-en-organisatie/publicaties/onderzoek-en-cijfers/indeling-wijken-buurten-straten/kaart-wijk-subwijk-indeling-utrecht.pdf

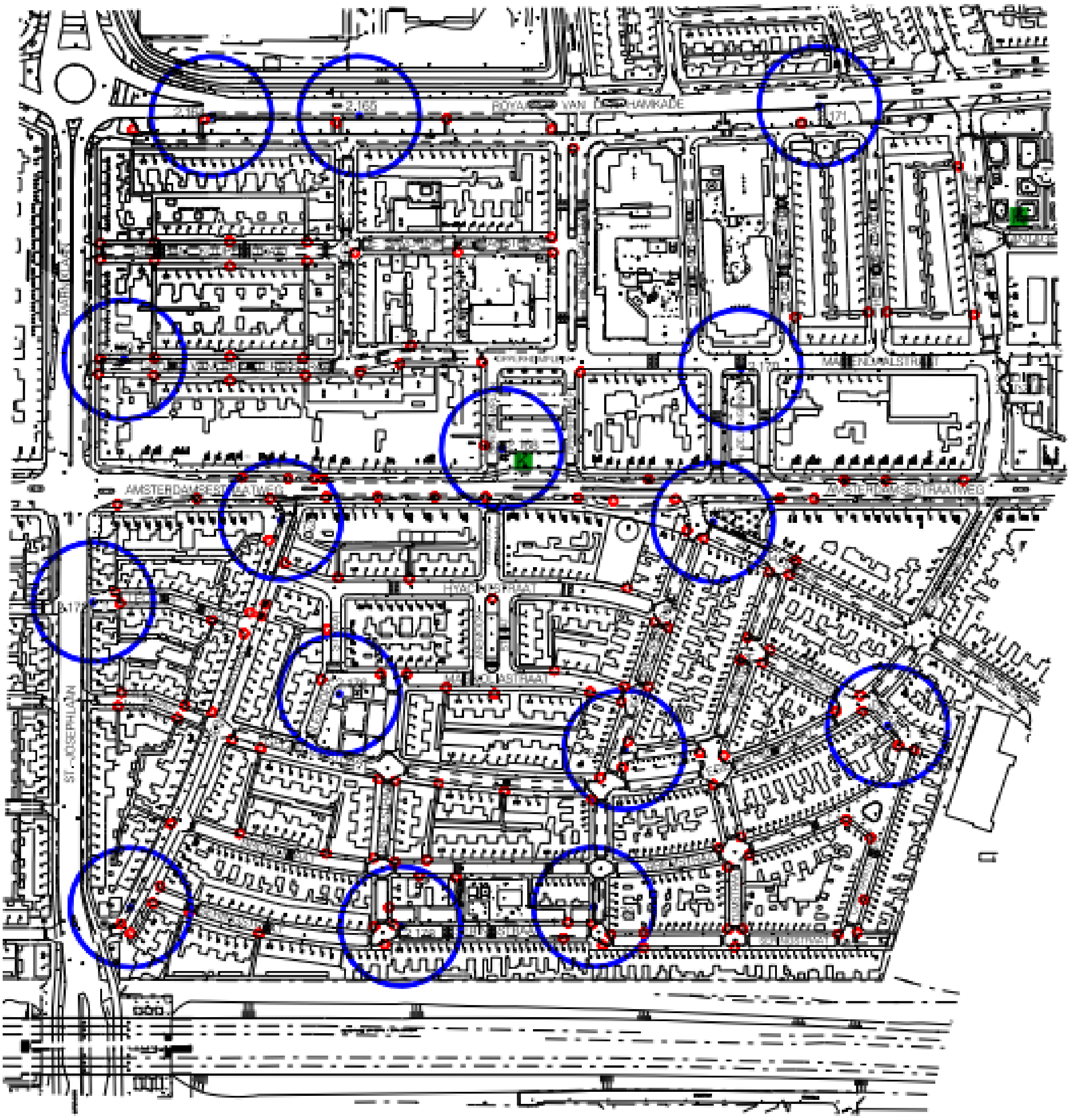

Figure B2: Map of neighbourhood with UWCs. Source: https://www.utrecht.nl/filead-min/uploads/documenten/wonen-en-leven/afval/het-nieuwe-inzamelen/noord-west/plattegrond-locaties-hni-bloemenbuurt.pdf

Appendix C: Histograms

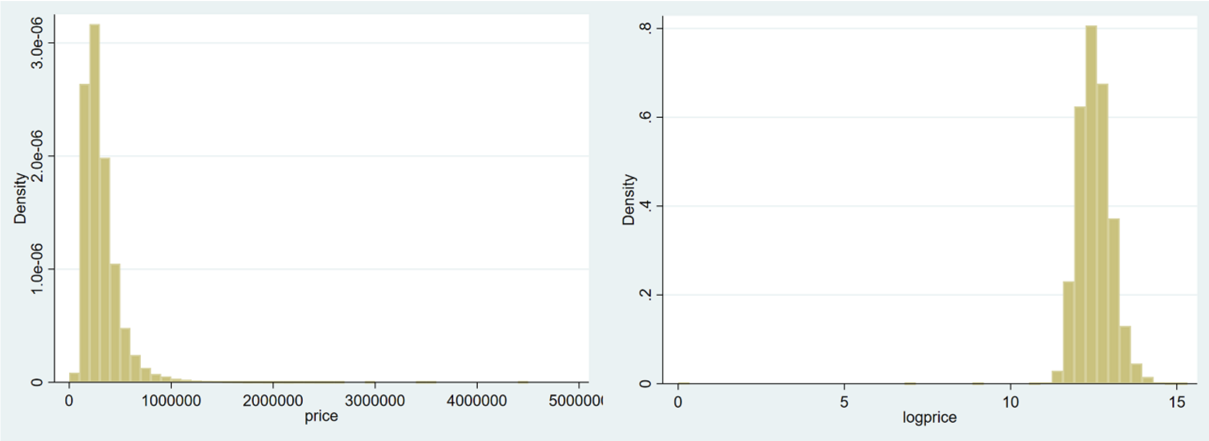

Figure C1: Histograms of variables price and logprice

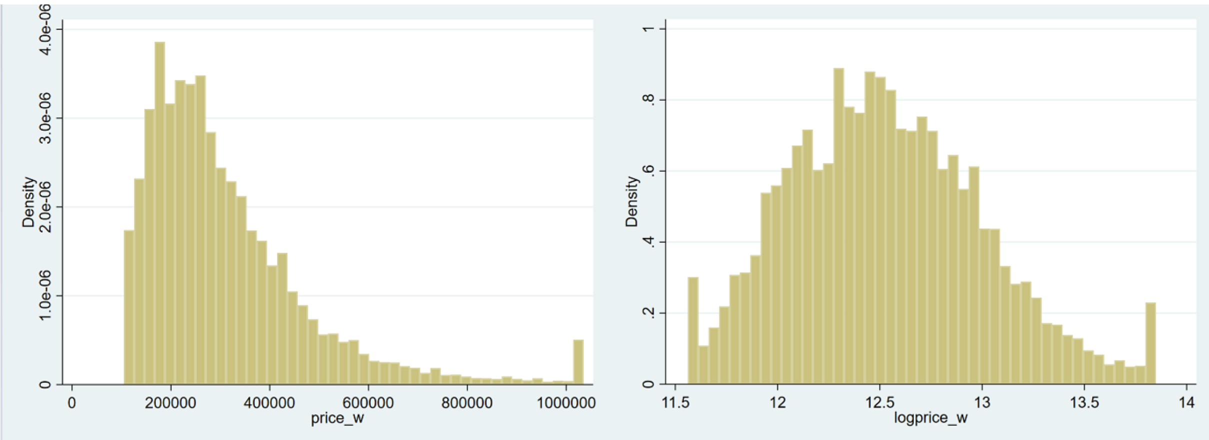

Figure C2: Histograms of variables price_w and logprice_w

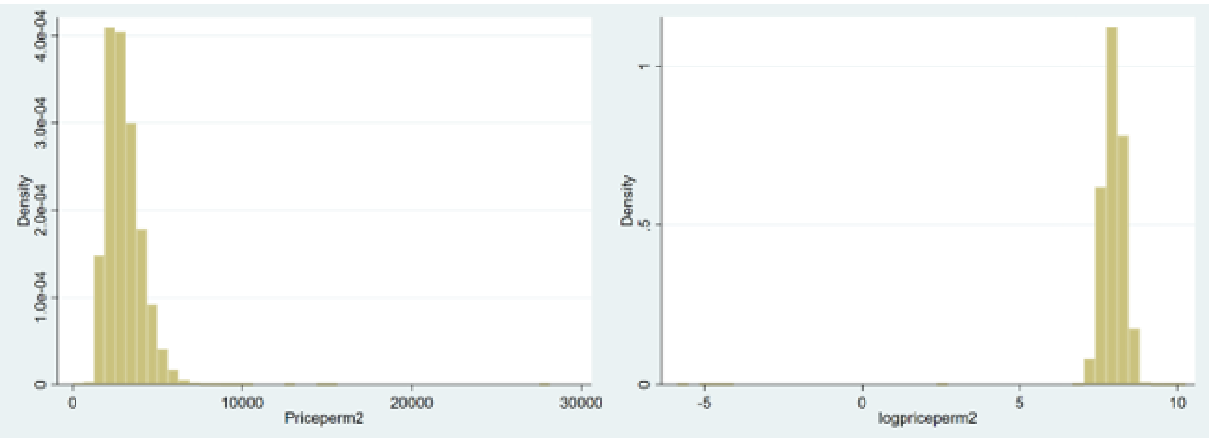

Figure C3: Histograms of variables Priceperm2 and logpriceperm2

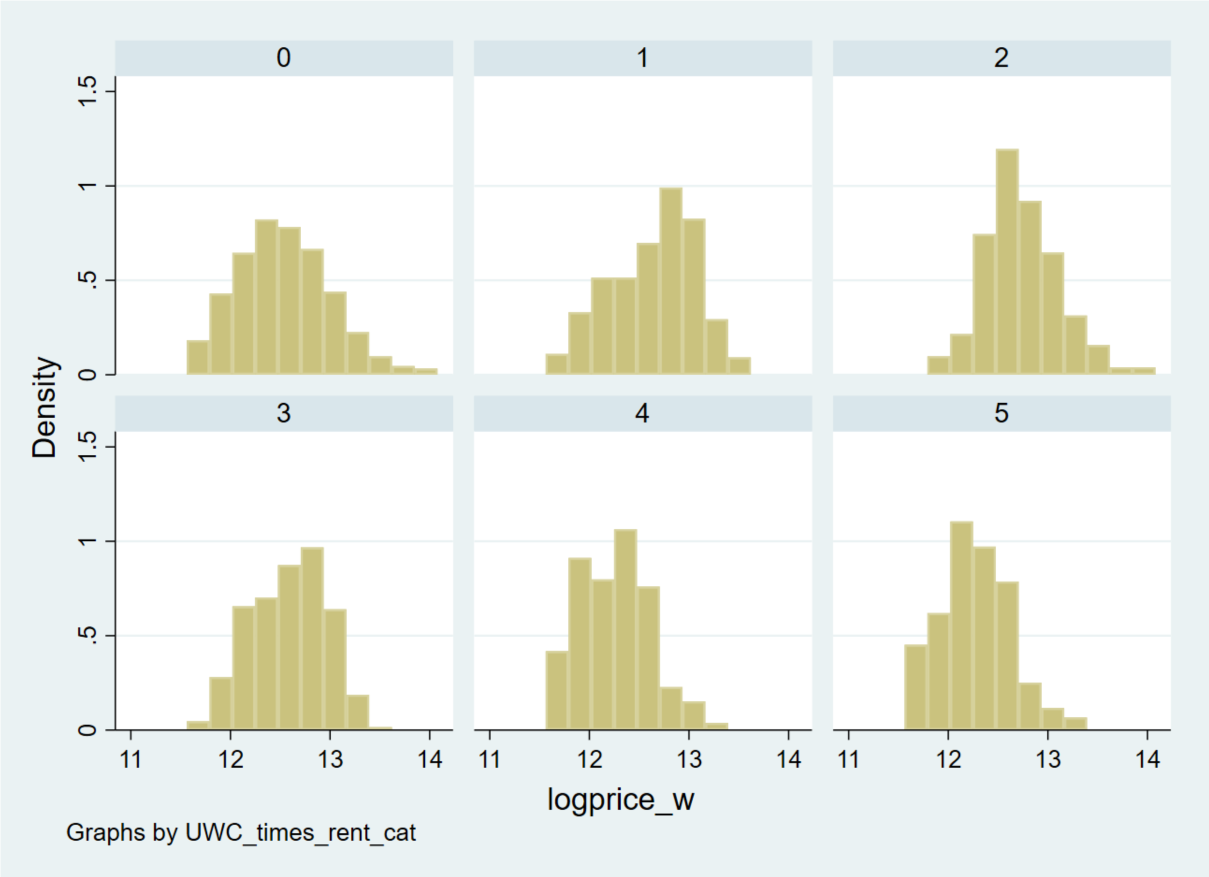

Figure C4: Histograms of each combination of UWC_transaction & p_rent_cat

Appendix D: Transaction prices Overvecht & Noord-West

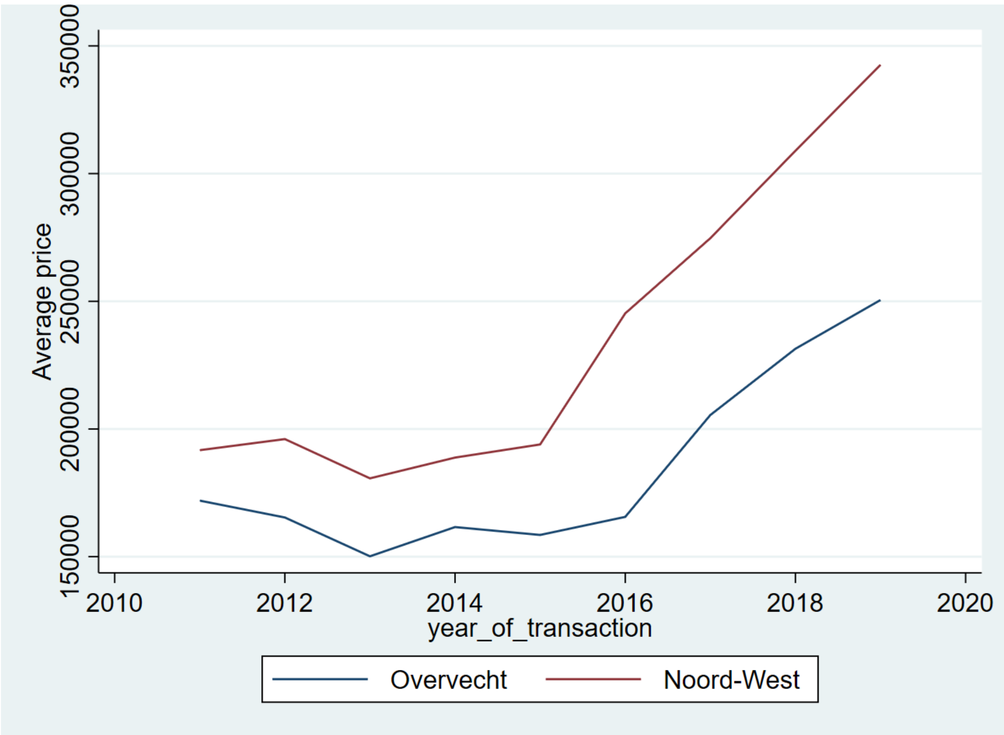

Figure D1: Line graph average transaction price per year (dependent variable is not winsorized)

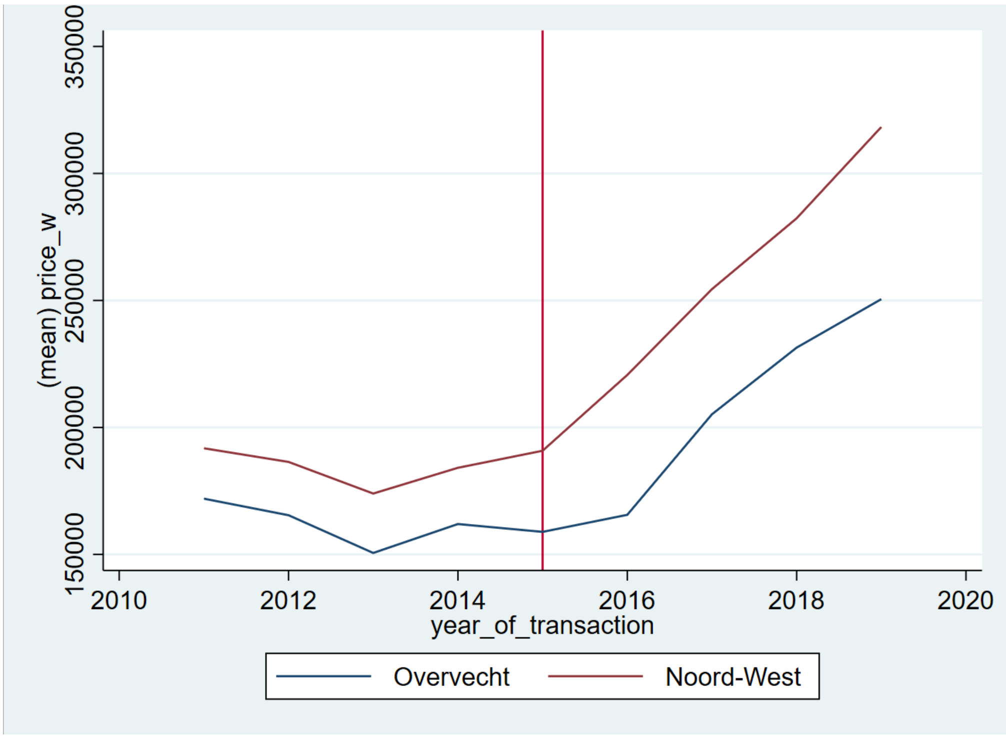

Figure D2: Average winsorized transaction price per year of Overvecht and Noord-West and year of treatment, represented by the vertical line.

Appendix E: Descriptive statistics subset

Table E1: Descriptive statistics subset

Variable	Obs	Mean	Std. Dev.	Min	Max
price	18262	274625.41	50386.601	195000	375000
price w	18262	274625.41	50386.601	195000	375000
logprice	18262	12.506	.183	12.181	12.835
logprice w	18262	12.506	.183	12.181	12.835
m2	18262	98.574	25.282	27	271
Monument	18262	.105	.307	0	1
Newly constructed	18262	.203	.402	0	1
House category	18262	.453	.498	0	1
Nrooms	18262	3.953	1.169	1	10
Ntoilet	18262	3.571	1.564	0	11
Nbalcony	18262	.297	.472	0	2
Nkitchen	18262	.871	.361	0	3
Attic	18262	.109	.311	0	1
Elevator	18262	.105	.306	0	1
Parking	18262	.165	.371	0	1
Garden	18262	.612	.487	0	1
Good condition inside	18262	.883	.322	0	1
Good condition outside	18262	.937	.243	0	1
Centre	18262	.041	.198	0	1
Busy road	18262	.022	.148	0	1
UWC transaction	18262	.032	.176	0	1
pop dens	18262	9764.219	4461.983	33	20225
non w	18262	935.244	826.153	15	5765
p rent	18262	47.769	16.261	2	89
Income	18261	33.719	6.667	16.6	56
unsafety	18262	28.91	9.626	16	50
Culture	18262	85.792	41.976	10	180
Catering	18262	57.147	34.594	5	340
d supermarket	18262	.571	.312	.2	2.7
d health	18262	.577	.265	.1	2.6
d daycare	18262	.386	.165	.2	1.8
water	18262	3.183	4.758	0	54
School	18262	23.509	8.75	3.7	39

Table E2: Variance inflation factor total

	VIF	1/VIF
d supermarket	4.974	.201
p rent	4.021	.249
d health	3.879	.258
Income	3.631	.275
Nrooms	3.224	.31
pop dens	3.214	.311
m2	3.158	.317
School	2.935	.341
House category	2.546	.393
non w	2.082	.48
d daycare	2.079	.481
unsafety	1.977	.506
water	1.898	.527
Culture	1.882	.531
Garden	1.788	.559
Catering	1.686	.593
Newly constructed	1.686	.593
Ntoilet	1.651	.606
Good condition ins~e	1.584	.631
Good condition out~e	1.548	.646
Nbalcony	1.433	.698
Parking	1.376	.727
Monument	1.359	.736
Centre	1.357	.737
Elevator	1.346	.743
Nkitchen	1.074	.931
Attic	1.07	.934
UWC transaction	1.022	.979
Busy road	1.016	.984
Mean VIF	2.155	.

Table E3: Pairwise Correlations

Variables	(1)	(2)	(3)	(4)
(1) m2	1.000			
(2) Nrooms	0.770	1.000		
(3) Ntoilet	0.525	0.525	1.000	
(4) Nkitchen	0.075	0.074	0.221	1.000

Table E4: Variance inflation factor

	VIF	1/VIF
Nrooms	2.59	.386
m2	2.588	.386
Ntoilet	1.522	.657
Nkitchen	1.055	.948
Mean VIF	1.939	.

Appendix F: Hedonic regression Tables

Table F1: Hedonic regression

VARIABLES	logprice_w (Model 1)	logprice_w (Model 2)
Independent variable of interest		
UWC_transaction	-.016	.065***
	(.05)	(.024)
Control Variables		
m2		.006***
		(0)
Monument		.029**
		(.013)
Newly_constructed		-.004
		(.018)
House_category		-.155***
		(.011)
Nrooms		.023***
		(.004)
Ntoilet		.011***
		(.002)
Nbalcony		.005
		(.007)
Nkitchen		.057***
		(.005)
Attic		-.038***
		(.007)
Elevator		.014
		(.013)
Parking		.063***
		(.013)
Garden		.008
		(.008)
Good_condition_inside		.113***
		(.01)
Good_condition_outside		.01
		(.011)
Centre		.085***
		(.016)
Busy_road		-.068***
		(.015)
pop_dens		.000***
		(0)
non_w		-.000***
		(0)
p_rent		.001
		(.001)
Income		.01***
		(.002)
unsafety		-.003***
		(.001)
Culture		.001***
		(0)
Catering		-.000
		(0)
d_supermarket		-.041
		(.05)
d_health		.041
		(.053)
d_daycare		-.076
		(.054)
water		.001
		(.002)
School		.006***
		(.001)
_cons	12.529***	11.166***
	(.03)	(.082)
Observations	35973	35973
R-squared	0	.681
Fixed Effects neighbourhood level	Yes	Yes

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Table F2: Hedonic regression, subset

VARIABLE	logprice_w (Model 3)	logprice_w (Model 4)
Independent variable of interest		
UWC_transaction	.016	.044***
	(.017)	(.013)
Control Variables		
m2		.003***
		(0)
Monument		.016***
		(.006)
Newly_constructed		.007
		(.008)
House_category		-.028***
		(.005)
Nrooms		.008***
		(.002)
Ntoilet		.002
		(.001)
Nbalcony		.008**
		(.004)
Nkitchen		.041***
		(.005)
Attic		-.017***
		(.004)
Elevator		.007
		(.007)
Parking		.002
		(.007)
Garden		.01**
		(.004)
Good_condition_inside		.027***
		(.006)
Good_condition_outside		.017**
		(.007)
Centre		.011
		(.008)
Busy_road		-.033***
		(.011)
pop_dens		.000***
		(0)
non_w		-.000***
		(0)
p_rent		.000
		(0)
Income		.003***
		(.001)
unsafety		-.001**
		(0)
Culture		.000**
		(0)
Catering		-.000
		(0)
d_supermarket		-.033*
		(.019)
d_health		.034*
		(.019)
d_daycare		-.054**
		(.023)
water		.001
		(.001)
School		.002***
		(0)
_cons	12.506***	11.97***
	(.005)	(.039)
Observations	18262	18261
R-squared	0	.222
Fixed Effects neighbourhood level	Yes	Yes

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Appendix G: Difference-in-differences Tables

Table G1: Difference-in-differences

Number of observations in the DIFF-IN-DIFF: 6824

	Before	After	Total
Control	1716	3612	5328
Treated	545	951	1496
Total	2261	4563	6824

Outcome var.	**price_w**	S. Err.	|t|	P>|t|
Before				
Control	1.8e+05			
Treated	1.6e+05			
Diff (T-C)	-2.1e+04	3866.548	-5.53	0.000***
After				
Control	2.5e+05			
Treated	2.0e+05			
Diff (T-C)	-5.3e+04	2866.099	18.35	0.000***
Diff-in-Diff	-3.1e+04	4812.974	6.48	0.000***

R-square: 0.15

* Means and Standard Errors are estimated by Linear Regression

** Inference: *** p<0.01; ** p<0.05; * p<0.1

Table G2: Difference-in-differences

price_w	Coef.	St. Err.	t-value	P-value	[95% Conf	Interval]	Sig
dummy_time	63442.33	1497.211	42.37	0	60507.327	66377.332	***
dummy_treat	-20546.202	6544.582	-3.14	.002	-33375.634	-7716.77	***
DiD	-19564.302	3081.755	-6.35	0	-25605.507	-13523.097	***
m2	1628.09	36.98	44.03	0	1555.597	1700.583	***
Monument	23381.997	3090.12	7.57	0	17324.393	29439.601	***
Newly_Constructed	6937.999	2442.153	2.84	.005	2150.613	11725.385	***
House_category	-29760.563	1900.38	-15.66	0	-33485.904	-26035.223	***
Nrooms	3289.093	846.024	3.89	0	1630.621	4947.565	***
Ntoilet	3500.158	494.766	7.07	0	2530.261	4470.054	***
Nbalcony	4639.933	1572.819	2.95	.003	1556.716	7723.151	***
Nkitchen	-10126.645	1880.279	-5.39	0	-13812.581	-6440.709	***
Attic	-5061.322	2071.81	-2.44	.015	-9122.718	-999.926	**
Elevator	10206.565	2292.14	4.45	0	5713.253	14699.878	***
Parking	12327.106	2407.474	5.12	0	7607.704	17046.509	***
Garden	7991.926	1660.941	4.81	0	4735.961	11247.892	***
Good_condition_inside	17235.919	1867.105	9.23	0	13575.808	20896.031	***
Good_condition_outside	8583.654	2686.845	3.19	.001	3316.596	13850.712	***
Centre	6851.838	5965.238	1.15	.251	-4841.898	18545.575	
Busy_road	-4779.648	2978.952	-1.60	.109	-10619.327	1060.032	
UWC_transaction	-5768.119	4337.795	-1.33	.184	-14271.558	2735.32	
pop_dens	2.803	.495	5.66	0	1.832	3.774	***
non_w	-9.62	2.231	-4.31	0	-13.993	-5.248	***
p_rent	-635.331	145.777	-4.36	0	-921.1	-349.562	***
Income	251.746	611.073	0.41	.68	-946.149	1449.64	
unsafety	1347.882	460.315	2.93	.003	445.521	2250.244	***
Culture	-96.94	56.819	-1.71	.088	-208.323	14.444	*
Catering	-87.972	53.579	-1.64	.101	-193.003	17.059	
d_supermarket	-26945.745	7901.31	-3.41	.001	-42434.79	-11456.701	***
d_health	-24511.254	6999.562	-3.50	0	-38232.59	-10789.918	***
d_daycare	-2997.471	11831.72	-0.25	.8	-26191.351	20196.408	
water	11853.06	1010.956	11.72	0	9871.269	13834.85	***
School	2258.343	186.406	12.12	0	1892.929	2623.758	***
Constant	-56863.125	22693.955	-2.51	.012	-101350.39	-12375.859	**

Mean dependent var	218215.756	SD dependent var	85060.753
R-squared	0.664	Number of obs	6822.000
F-test	419.328	Prob > F	0.000
Akaike crit. (AIC)	166858.596	Bayesian crit. (BIC)	167083.917
Control Variables	Yes		

*** *p<.01*, ** *p<.05*, * *p<.1*

Appendix H: ANOVA and interaction Tables

Table H1: Levene's test for *UWC_transaction*

UWC_transaction	Summary of logprice_w		
	Mean	Std. Dev.	Freq.
0	12.529	0.463	34,856
1	12.513	0.424	1,117
Total	12.529	0.462	35,973

W0 = 11.657575	df(1, 35971)	Pr > F = 0.00064012
W50 = 11.134746	df(1, 35971)	Pr > F = 0.00084811
W10 = 11.207201	df(1, 35971)	Pr > F = 0.00081564

Table H2: Levene's test for *p_rent_cat*

p_rent_cat	Summary of logprice_w		
	Mean	Std. Dev.	Freq.
1	12.734	0.435	8,428
2	12.648	0.412	7,001
3	12.483	0.426	8,020
4	12.395	0.482	5,399
5	12.321	0.427	7,125
Total	12.529	0.462	35,973

W0 = 34.992993	df(4, 35968)	Pr > F = 0.00000000
W50 = 31.764229	df(4, 35968)	Pr > F = 0.00000000
W10 = 32.181278	df(4, 35968)	Pr > F = 0.00000000

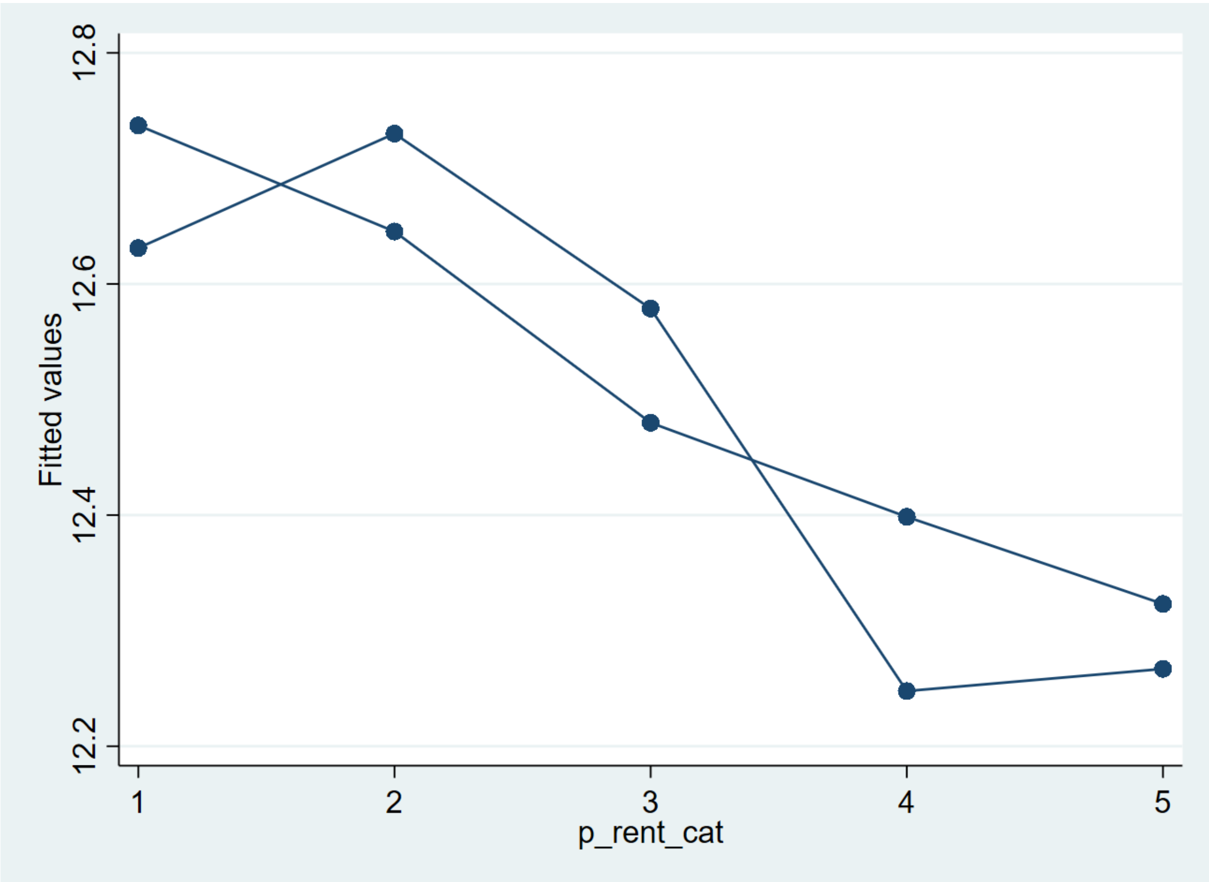

Figure H3: Visualization of means

Table H4: Tabulation of p_rent_cat & UWC_transaction

	p_rent_cat				
UWC_transaction	1	2	3	4	5
0. Obs.	8190	6778	7740	5284	6864
0. Mean	12.737	12.645	12.48	12.399	12.323
0. Std. Dev.	.435	.413	.427	.484	.429
1. Obs.	238	223	280	115	261
1. Mean	12.631	12.73	12.579	12.248	12.267
1. Std. Dev.	.426	.369	.381	.358	.357

Table H5: Simple Main Effects

Test of UWC_transaction at p_rent_cat(1): F(1/35963)	= 13.813361
Test of UWC_transaction at p_rent_cat(2): F(1/35963)	= 8.2148214
Test of UWC_transaction at p_rent_cat(3): F(1/35963)	= 13.980078
Test of UWC_transaction at p_rent_cat(4): F(1/35963)	= 13.568044
Test of UWC_transaction at p_rent_cat(5): F(1/35963)	= 4.218614
Critical value of F for alpha = .05 using ...	
Per-family error rate	= 6.6356009

Appendix I: Regression with interaction Tables

Table I1: Regression results

VARIABLES	logprice_w (Model 5)	logprice_w (Model 6)
UWC at time of transaction		
UWC	-0.106	-0.00875
	(0.120)	(0.0629)
Percentage of rental properties		
0%-20%		
20%-40%	-0.0918	-0.0336
	(0.0725)	(0.0230)
40%-60%	-0.257***	-0.000522
	(0.0623)	(0.0286)
60%-80%	-0.339***	0.00609
	(0.0938)	(0.0292)
80%-100%	-0.414***	0.0245
	(0.0647)	(0.0356)
Interaction of two independent variables		
UWC * 0%-20%		
UWC * 20%-40%	0.191	0.0792
	(0.131)	(0.0709)
UWC * 40%-60%	0.205	0.0754
	(0.151)	(0.0723)
UWC * 60%-80%	-0.0446	0.0915
	(0.149)	(0.0833)
UWC * 80%-100%	0.0499	0.138
	(0.133)	(0.0838)
Control Variables		
m2		0.00623***
		(0.000219)
Monument		0.0318***
		(0.0115)
Newly_constructed		-0.000574
		(0.0190)
House_category		-0.153***
		(0.0105)
Nrooms		0.0223***
		(0.00412)
Ntoilet		0.0108***
		(0.00192)
Nbalcony		0.00219
		(0.00668)
Nkitchen		0.0575***
		(0.00541)
Attic		-0.0387***
		(0.00672)
Elevator		0.0145
		(0.0134)
Parking		0.0637***
		(0.0123)
Garden		0.00788
		(0.00742)
Good_condition_inside		0.113***
		(0.00988)
Good_condition_outside		0.0109
		(0.0110)
Centre		0.0813***
		(0.0154)
Busy_road		-0.0674***
		(0.0153)
pop_dens		9.03e-06***
		(2.27e-06)
non_w		-4.52e-05***
		(1.32e-05)
Income		0.0103***
		(0.00131)
unsafety		-0.00331***
		(0.000802)

Culture		0.000615***
		(0.000214)
Catering		-0.000174
		(0.000220)
d_supermarket		-0.0410
		(0.0490)
d_health		0.0308
		(0.0543)
d_daycare		-0.0680
		(0.0534)
water		0.000685
		(0.00212)
School		0.00548***
		(0.00125)
Constant	12.74***	11.21***
	(0.0474)	(0.0610)
_cons	12.73727	11.21263
Observations	35,973	35,971
R-squared	0.1156	0.6822
Fixed Effects Neighbourhood level	Yes	Yes
Control variables	No	Yes

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

Table I3: Predictive margins

Model VCE:	Robust	Number of obs	=	35,973

	Margin	Delta-method Std.Err.	t	P>t	[95%Conf.	Interval]
UWC_transaction						
0	12.53	.02	537.89	0.000	12.48	12.58
1	12.51	.03	360.71	0.000	12.44	12.58
p_rent_cat						
1	12.73	.04	285.52	0.000	12.65	12.82
2	12.65	.05	235.1	0.000	12.54	12.75
3	12.48	.04	308.96	0.000	12.4	12.56
4	12.39	.08	156.63	0.000	12.24	12.55
5	12.32	.04	285.5	0.000	12.24	12.41
UWC_transaction#p_rent_cat						
0 1	12.74	.05	268.54	0.000	12.64	12.83
0 2	12.65	.05	23.4	0.000	12.54	12.75
0 3	12.48	.04	38.42	0.000	12.4	12.56
0 4	12.40	.08	153.12	0.000	12.24	12.56
0 5	12.32	.04	28.13	0.000	12.24	12.41
1 1	12.63	.09	143.77	0.000	12.46	12.81
1 2	12.73	.05	281.63	0.000	12.64	12.82
1 3	12.58	.01	128.7	0.000	12.38	12.77
1 4	12.25	.07	179.6	0.000	12.11	12.38
1 5	12.27	.05	224.93	0.000	12.16	12.38