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What is the impact of stations Noord and Noorderpark of the Noord/Zuidlijn on local house prices in Amsterdam?

Master Thesis

Bob Hevink

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Colophon

Author	Bob Hevink
Student number	S3550869
E-mail	b.b.a.hevink@student.rug.nl
Supervisor	Dr. X. Liu

Abstract

In 2018, sixteen years after its announcement, the Noord/Zuidlijn was completed. The metro line connects the northern part of Amsterdam to the southern part, via the inner city. Despite negative portrayals of the project in the media, the number of users has increased annually and the overall satisfaction level with the line is high. The municipality of Amsterdam plans to extend the metro line, making it important to understand the potential consequences for the value of properties located in close proximity to the new stations. Increasing knowledge on this topic can be beneficial for the assessment of current and future policies and measures. To estimate the effect of the completion of the Noord/Zuidlijn on local house prices, a difference-in-differences approach was used. The metro stations Noord and Noorderpark, located in the northern district of the city, were analyzed since this part of the city did not have access to a metro line before. The results of the analysis show that house prices within 250 meters of the metro stations decreased, while prices beyond this distance increased gradually. The highest effect was observed in the area between 500-750 meters from the stations, the effect of the completion moved in a concave way. The study shows that the completion of the Noord/Zuidlijn had a positive external effect on surrounding house prices.

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1. Introduction

Amsterdam has experienced significant growth in population over the years due to the influx of new residents. The population is continuing to grow with an average annual increase of 11,000 residents since 2009 (CBS, 2021a). At the same time, house prices have risen tremendously, making Amsterdam the most expensive city in the Netherlands to live in. According to CBS (2021b), the average transaction price in Amsterdam has increased by 113% in the first quarter of 2021, compared to 2013. This has resulted in many residents relocating due to unaffordable housing costs (Het Parool, 2017; NOS, 2019; Parool, 2018).

Partly due to the increasing population and expensive housing, residents have moved further away from the city center, which has expanded the city borders (Municipality of Amsterdam, 2020). To connect the northern part of the city, which is separated by water, to the rest of Amsterdam, the municipality initiated a new metro infrastructure project in 2002, called the Noord/Zuidlijn. The project connects the northern part of the city, through the inner city, to the financial district of Amsterdam, the Zuidas. The northern district did not have access to metro lines before, making it a significant project. Originally planned for completion in eight years, until 2011, the project was finally completed in 2018.

Despite its importance to the city, the Noord/Zuidlijn was often portrayed negatively in the media (NRC, 2018). The construction process caused parts of the city to sink, houses were damaged and numerous leakages occurred, especially near Central Station and the northern district of Amsterdam. The completion date was also delayed multiple times, causing frustration for residents living near the metro stations. Even after its completion, the infrastructure was thought to have caused deterioration and social stratification in the districts Noord and Nieuw-West (Parool, 2019). However, the metro line transports 1.4 million passengers in Amsterdam weekly, with 100,000 passengers using it every business day in 2019 (GVB, 2019). Since the completion of the new line, the satisfaction level among residents regarding the metro in Amsterdam has increased to a level of 7.9 out of 10 (CROW, 2020). The municipality of Amsterdam (2021) has also highlighted the positive impact of infrastructure projects, as they provide new employment opportunities and attract firms to the city.

The municipality is planning to extend the metro line to neighbouring cities. The extension of public infrastructure is a significant policy decision that can have far-reaching consequences on a community. In light of this, policymakers must thoroughly comprehend the implications of such decisions to develop and implement effective policies. This research aims to contribute to policymakers' understanding by examining the effect of the new metro line on house prices in the northern district of Amsterdam. Homeowners, who hold almost 60% of their wealth in the form of their homes, are another key stakeholder who can benefit from this research, as changes in their environment can have significant impacts on their property values and wealth (CBS, 2019). Additionally, the results of this study may be of interest to private parties in the real estate sector, such as investors and tenants. These parties need to be aware of the effects of new transportation infrastructure in order to make informed decisions about buying or selling residential real estate or choosing between renting and buying a dwelling. Overall, this research has significant societal relevance due to its potential to inform policymakers, homeowners and private parties in the real estate sector.

This study aims to investigate the impact of Noord/Zuidlijn on house prices in the northern part of Amsterdam, after completion. Specifically, this paper will focus on the effects of the Noord and Noorderpark stations, by examining the potential presence of externalities across spatial and temporal dimensions. The case study will be researched with a scope of four years before and three years after the stations began operating, using the difference-in-differences (DID) method. The following research question will be attempted to answer: *What is the impact of stations Noord and Noorderpark of the Noord/Zuidlijn on local house prices in Amsterdam?*

This paper builds upon work of Von Thünen (1863), Alonso (1964), and Mills (1972) that established the importance of the relationship between commuting costs and housing costs in determining residential location choices. Subsequent literature has argued that an increase in transport opportunities can have two main external effects on house prices (Lyon, 1972). The first external effect is improved accessibility, which often has a positive impact on house prices. Improved accessibility causes a reduction in commuting costs, such as costs for public transport and car possession (Ewing & Cervero, 2001; Brown & Cropper, 2001; Chapple & Loukaitou-Sideris, 2019). This enhances customers to purchase a dwelling at a higher cost. Furthermore, improved accessibility induces a socioeconomic benefit: Households are willing and able to pay a premium for a dwelling, due to the enhancement of resources and opportunities, such as the prospect of employment and social interaction (Hansen, 1959; Engwicht, 1993; Chatman & Noland, 2014; Ewing et al., 2016; Franklin & Waddell, 2003). The second external effect is a more intangible visual or noise effect, such as noise pollution, congestions and changes in the urban landscape, which may reduce the desirability of living close to the facility (Mas & Maudos, 2004; Chen et al., 1998; Lyon, 1972).

The paper contributes to economic literature on transport infrastructure and house prices, which has produced mixed evidence on the impact of the first on the latter (e.g., Mas & Maudos, 2004; Giuliano et al., 2010; Hess & Almeida, 2007; Atkinson-Palombo, 2010; Ahlfeldt, 2013; Gibbons & Machin, 2005, Dubé et al., 2014; Mohammad et al., 2015). Some studies have found a positive effect of new transport infrastructure on house prices (Tian et al., 2017; McMillen & McDonald, 2004; Perk et al., 2010). Other research reports insignificant or negligible effects (Nelson, 1982; Andersson et al., 2010; Li & Saphores, 2012). One of the challenges in studying the impact is the dense network of public transport in Western countries, which may make it difficult to measure a substantial increase in external effects (Banister & Berechman, 2000). The impact on house prices is higher in areas where the availability of transportation is sparse, according to these authors. In the Netherlands, limited research has been conducted on the effect of large-scale transportation projects on residential areas where transport access is sparse. The northern part of Amsterdam provides an interesting case study for this research as it had limited access to public transport and did not have access to metro lines before the Noord/Zuidlijn. This paper provides the first estimates of the effect of the completed Noord/Zuidlijn on residential values using the DID method.

The paper is structured in five chapters. In the second chapter, a review of the existing literature on the relationship between transport and house prices is conducted. Chapter 3 outlines the research methodology and data collection. The fourth chapter presents the results of the analysis, including robustness checks and a sensitivity analysis. The conclusion and discussion are covered in the final chapter.

2. Literature Review

This section provides a theoretical background and discusses studies that have investigated the link between the external effects of public transport and the impact on house prices.

2.1 Empirical overview

McMillen and McDonald (2004) conducted a study to identify the impact of a newly built transit line on local house prices in Chicago. The authors examined the effect of the 11-mile line on houses within a radius of 1.5 miles before and after its opening in 1993. A repeat-sales and hedonic approach, as well as data from 17,034 single-family house transactions between 1983 and 1999 were used. The results revealed that the announcement and completion of the transit line had a positive impact on property values. The effect was temporary, however. The prices of homes close to the new stations increased from 4.2% before 1987 to 19.4% during 1991 and 1996, after which the increase stabilized. Interestingly, between 1997 and 1999, the prices of properties further away from the stations rose at a faster rate than those in the vicinity.

Dubé et al. (2014) used the hedonic method with the DID approach to measure the effect of a new commuter rail transit on house prices in Montreal. The authors developed a spatial DID (SDID), which allows for an autoregressive process over the dependent variable and omits spatial autocorrelation. The research included 27,294 property repeated sales between 1992 and 2009, with a comparison of the DID and SDID estimators. The authors determined that the SDID estimator is especially useful when many alternative transportation modes exist in an area or when there is a mismatch between transport supply and demand. The results show that the new transportation line had an impact on property values. The location rent, however, was not formed linearly, but in a U-shape. The marginal effect to the proximity commands a higher growth rate of house prices ranging from approximately 5% up to 500 meters, a little over 2% between 500 meters and 1 km and approximately 3.5% between 1 km and 1.5 km. The presence of other amenities was considered crucial, some dwellings experienced lower growth in house prices than dwellings with no changes in environmental amenities.

Diao et al. (2017) applied the SDID method to investigate the impact of the Circle Line (CCL) in Singapore on non-landed private housing values. Non-landed property is built on land owned by the government and then leased to the building owner. The study focused on the CCL extension that was constructed between 2009 and 2012. The non-landed housing types constituted 74% of the housing stock. The authors employed a network distance measure and a local-polynomial-regression approach to analyze the data from 21,954 transactions. The results revealed that houses located within 600 meters of the closest CCL-station experienced a significant price increase of 10.6% after the opening of the network line. The study also found a significant anticipation effect as early as 12 months prior to the opening of the CCL.

Research by Ahlfeldt (2013) examined the impact of a new metro line in London on local property prices from 1995 to 2008. Both pre- and post-opening data were included. The authors used a partial equilibrium approach to determine the effect. The study considers the position of the station in a network hierarchy and effective accessibility, in addition to other literature. Alternative transportation modes were included also. By utilizing a gravity equation model, each location in the Greater London area was weighted by its share of employment and travel time. The results indicate that for each percentage point increase in access, property prices increased by about 2.5%. Additionally, the study found a negative relationship between property prices and the distance to the CBD, with an average price decline of 2.4% per kilometer.

Mohammad et al. (2017) have used 39,308 data points of property sales to measure the impact of a new metro line in Dubai. The paper includes both a hedonic pricing method and a DID method, the differences in results between these two methods were investigated. Data covered pre- and post-observations of 2007 to 2011. Both residential and commercial real estate were investigated within three catchment areas: 0.5 kilometer, 1 kilometer and 1.5 kilometers. The results show a concave effect, in which property price decreased in proximity to the metro (-9%) and increased further away (7.8%). The effect was found to be larger for commercial properties than for residential properties. The DID model estimated a 7.8% increase in sales prices for residential properties within 1 kilometer of a station. Prices of commercial properties increased by 41%. The hedonic price model found the effects to be smaller. The peak impact on real estate values occurred within 701 to 900 meters of a station.

Research by Agostini and Palmucci (2008) in Santiago, Spain, measured the effect of the extension of an existing subway on house prices. The study used property data from pre-announcement to during construction, including 6,804 observations from 2000 till 2004. Both the hedonic price estimation and a natural experiment approach have been employed. After the initial announcement of the extension, house prices rose between 4.2% and 7.9%. The authors claim that various actors start speculating on possible future effects of the new infrastructure, which then affects house prices. When locations of the stations were revealed, the surrounding property prices rose by another 3.1 to 5.5%. Additionally, prices of houses in the direct vicinity of the stations increased more than the prices of dwellings located between 800 and 1,000 from the station. These results suggest that the closer a property is located to a subway station, the more prices increase.

Gibbons and Machin (2005) studied the economic benefits of access to public transportation on house prices. The study focused on the construction of new railway stations in London in the late 1990s and included both pre- and post-opening property values. Micro-level data covered the entire London metropolitan area, instead of using sample areas, making the research unique in the United Kingdom. A total of 7,474 property sales were included in the research. The authors used a DID approach and found that property prices increased by 5.8% per kilometer reduction in distance to a new station.

Bowes and Ihlanfeldt (2001) conducted a study on the impact of rail station proximity on house prices. To account for externalities emitted by stations, the authors used a hedonic price model and neighbourhoods crime and retail employment equations. The focus of the research was to investigate the premium homeowners are willing to pay to live close to a railway station, by implementing the factors access advantage, commercial services, negative externality effects and crime rate. The study used a dataset of 31 stations of the rapid transit of Atlanta, including 22,388 observations from 1991 to 1994. The model explained nearly 50% of the variation in sales prices. The findings show that properties within a quarter mile of the stations sell for 19% less compared to properties located beyond three miles of a station. However, homeowners are willing to pay a premium to live close to a station, but not too close, especially in low-income neighbourhoods. These households rely most on public transit. Moreover, the research revealed that homeowners are willing to pay more for a house in the proximity of a station when it is located close to the CBD.

The effect of road and railway noise on property prices has been investigated by Andersson et al. (2009). Both the roads and the railroads already existed. The researchers used a regression technique on a Swedish dataset, covering all single-family houses in a municipality from 1996 to 2006. Properties were divided into two groups: up to 1 kilometer or 1-2 km from the nearest station. The distance by road to the nearest entrance of the motorway was used to determine accessibility by car. The results show that a 1 dB increase in road and railway noise is associated with a 1.2% and a 0.4% decrease in property prices, respectively. Road noise was found to have a more substantial impact on property prices than railway noise.

Overall, the findings of these studies suggest that a new metro line has an impact on house prices. While much of the literature on this topic has identified a significant positive effect on property values following the construction of a public infrastructure project, the distance to the metro station has been found to play a crucial role in determining the magnitude of the effect. The impact of the line decreases with distance from the station and may not be significant in the long term.

Properties in the immediate vicinity of the metro stations are also found to become less valuable, because of the negative externalities. The values then increase gradually further away in a concave line. This effect usually peaks within 250-750 meters of a station and gradually decreases again beyond 1,000-2,000 meters, depending on the area and the availability of other public transport options. In areas with a dense network of public transport stations, the effect of a new metro line may be less. Additionally, the effect of a new line may vary depending on the location of the stations, possibly reflecting differences in neighbourhood characteristics. This research provides insight into the effects of public transport on places with limited transport opportunities, as Amsterdam-Noord lacked access to metro lines prior to the Noord/Zuidlijn.

2.2 Hypotheses

Based on the direction of this research and existing literature, the following two-sided research hypothesis has been drawn up:

H0: The presence of the completed metro stations Noord and Noorderpark of the Noord/Zuidlijn does not result in significant changes in local house prices.
H1: The presence of the completed metro stations Noord and Noorderpark of the Noord/Zuidlijn does result in significant changes in local house prices.

3. Methodology and Data

In this section, the empirical framework and a description of the data is presented. Additionally, the treatment and control area are carefully defined.

3.1 Difference-in-differences approach

Literature on the relationship between transport and house prices has commonly employed hedonic pricing (HP) and difference-in-differences (DID) methods. HP models are useful for controlling the heterogeneity of dwellings, but cannot identify a causal relationship between new public infrastructure and local house prices. This is because these models do not account for neighbourhood variables and possible anticipation effects (Gibbons & Machin, 2005; Van Duijn et al., 2016). The alternative is the DID approach, which is based on the hedonic theory and focuses on spatial and temporal dimensions of the relationship.

The DID approach compares changes in outcomes over time between a treatment group and a control group. Houses in the treatment group are located within a certain distance of a project. It receives treatment in the sense that the prices of these houses have possibly been influenced by the external effects from the new public infrastructure. The transaction or appraisal year is thus later than the year of completion. This treatment group is compared to the area that is not affected by the project, the control group. A key assumption of the DID approach is that the characteristics of both the treatment and control group are comparable. A second assumption is that the change in outcomes from pre- to post-intervention in the control group is a good proxy for the counterfactual change in the untreated potential outcome in the treatment group (McMillen, 2010; Dubé et al., 2013; Gibbons & Machin, 2008). Controlling for neighbourhood amenities avoids inconsistent and biased estimates between the treatment and control group.

The reasons mentioned above define why a DID approach has been chosen in favor of a standard hedonic model. The method fits the aim of the research best since it can capture changes in house prices after the completion of the Noord/Zuidlijn within the treatment group.

Literature suggests that the treatment group should generally be set at 1 or 2 kilometers from the project, depending on the size of the area and existing transport options (Ahlfeldt, 2013; Gibbons & Machin, 2005; Agostini & Palmucci, 2008). The remaining residential real estate within a radius of 2 or 3 kilometers is typically designated as the control group. In this study, the treatment group is set at properties within 0 to 1,000 meters of a metro station, while the control group is set at 1,000 to 2,000 meters. To ensure that no houses in the control group receive treatment, different areas are targeted in the sensitivity analysis. Baseline specifications and robustness checks are also used to investigate the decay of possible external effects over space.

3.2 Statistical model

In this paper, the relationship between house prices and the new metro stations is analyzed by including various variables such as housing characteristics, year of house price, the distance of a house to a metro station and neighbourhood characteristics. To address the potential external effects of the Noord/Zuidlijn, the model in this paper is based on the model by Schwartz et al. (2006). This model, called the base model, is as follows:

$$\text{Log}\left(P_{ijt}\right) = \alpha + \beta_1 R_i + \beta_2 AR_{it} + \beta_3 A_{it} + \sum_{K=1}^{K} \gamma_k X_{kit} + \theta_j N_j + \varepsilon_{it}$$

Where P_{idt} is the WOZ value of residential property i in year t, located in neighbourhood j. R_i is a dummy taking value 1 if the property is located inside the treatment group. Dummy variable AR_{it} takes value 1 if the property i is located in the treatment group R and the WOZ year of the property is after the completion of the project. This is the main variable of interest, as it shows whether there are external effects after the project is completed within the treatment group. Fourth, A_{it} is a dummy variable taking value 1 if the WOZ value of the property after completion is known, 0 otherwise. X_{kit} are property-related characteristics k of property i sold in year t, including the construction year and floor area of the properties. Dummy variable N_j takes 1 for neighbourhood j and 0 otherwise. It controls for unobserved, time-invariant neighbourhood characteristics, postal code areas in this paper. ε_t is an idiosyncratic error term. Parameters β_1, β_2, β_3, γ_k and θ_j are to be estimated.

Since literature suggests that the effect of new transport lines on house prices is often concave, the distance to the metro stations is added in the second model:

$$\text{Log}\left(P_{ijt}\right) = \alpha + \beta_1 D_i + \beta_2 AD_{it} + \beta_3 A_{it} + \sum_{K=1}^{K} \gamma_k X_{kit} + \theta_j N_j + \varepsilon_{it}$$

This model uses the distance between the metro station and each property, dividing the treatment group into four distance ring dummies D_i. This results in coefficients of each 250 meters, up to 1,000 meters, which could show that the stations have a different effect in each distance ring. The control group remains the same. The nonlinearity of the effect is measured across distance, this controls for the robustness of the model.

3.3 Data residential prices

The WOZ dataset has been used in this paper. This governmental dataset combines data from the municipalities in the Netherlands and Key register Addresses and Buildings (in Dutch: Basisregistratie Adressen en Gebouwen, BAG). The dataset contains the dependent variable of this research, which is the value of residential real estate, or the WOZ value. Each municipality determines this value by appraisal. The building characteristics and the location of the property are compared to other properties, by using transaction prices (Rijksoverheid, 2023). The outcome represents the market value of the property as of January 1st of the previous year. The dataset covers the years 2014 till 2021, set by municipalities between 2015 and 2022. The WOZ value is a well-accepted estimate for property prices in the Netherlands. Moreover, owner-occupied and rental homes are calculated in the same way, unlike transaction prices that often differ between these two. In addition to the WOZ value, the dataset contains the construction year and floor area of the properties. Neighbourhood characteristics are grouped by using the postal code of the dwellings.

The dataset is a valuable resource for this study because it provides a value for every dwelling in the control group, which makes the results better to interpret. Additionally, the dataset accounts for some of the anticipation effects, even though construction began before 2014. Households have had time to anticipate to the upcoming changes in their vicinity. For this research, data from the northern part of Amsterdam has been used, as the two metro stations under investigation are located there. Before conducting the analysis, the Euclidean distance between the Noord and Noorderpark metro stations and the location of all dwellings in the treatment and control groups was calculated. First, all addresses were transformed into latitude and longitude coordinates using a geocoding tool, which allowed for the visualization of the location of all dwellings. The properties were then imported into the Geographic Information System software QGIS. All dwellings beyond 2,000 meters from both metro stations were dropped, resulting in a control group that includes 33,563 unique objects, with 268,496 values being researched. The control group is displayed in figure 3.1.

The data was cleaned by removing WOZ values less than € 50,000 and over € 1,500,000. Moreover, dwellings with a floor area less than 25 square meters were removed, so were floor areas over 250 square meters. As a result, 145,982 observations are left. From these observations, 83,512 are located in the control group and 62,470 in the treatment area. To control for the assumption that the treatment and control group are identical, the control group was limited to a radius of 2,000 meters from the metro stations. Amsterdam is more compact than other major cities mentioned in the literature and this way the city center, which contains a wider range of public infrastructure and a larger proportion of pre-1900s buildings, is excluded. Table 3.1 shows the characteristics of the treatment and control groups. The average WOZ value in the treatment area is € 254,847, slightly lower than the average value in the control group € 265,756. The difference can be explained by locational differences. To address this issue, local spatial fixed effects were included in the research. The floor area is identical between the treatment and the control group. The construction years show some differences, however. While many houses in both groups were built between 1960 and 1980, the control group contains a higher proportion (19.6%) of houses built after 2010. This group includes many high-end apartments near the IJ, which may partly explain the higher average value of the control group.

Figure 3.1 Addresses in treatment and control group

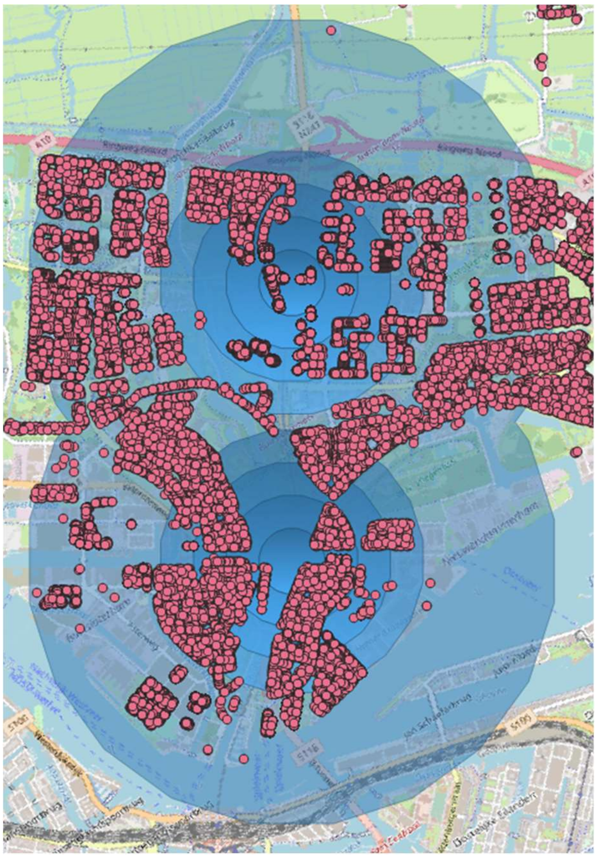

Table 3.1 Descriptive statistics total area, treatment group and control group

	Total group		Treatment group (0-1,000 meters)		Control group (1,000-2,000 meters)	
	mean	sd	mean	sd	mean	sd
wozvalue	259,925	132,544	254,847	121,165	265,756	144,291
floorarea	76.058	26.432	74.702	26.586	77.616	26.167
Before 1901	0.001	0.035	0.001	0.027	0.002	0.043
1901-1929	0.191	0.393	0.255	0.436	0.117	0.322
1930-1949	0.073	0.261	0.099	0.299	0.044	0.205
1950-1959	0.015	0.124	0.007	0.085	0.025	0.156
1960-1969	0.216	0.411	0.151	0.358	0.290	0.454
1970-1979	0.173	0.378	0.135	0.342	0.216	0.412
1980-1989	0.113	0.317	0.161	0.367	0.059	0.236
1990-1999	0.058	0.233	0.085	0.279	0.026	0.159
2000-2009	0.029	0.168	0.032	0.176	0.026	0.158
2010-Present	0.130	0.336	0.073	0.260	0.196	0.397
N	219,981		117,590		102,391	

4. Results

In this section, the results of the DID model are described. The aim is to measure a possible effect of the project on house prices after the completion of the Noord/Zuidlijn. The results of the base model and the model with distance ring dummies are described consecutively. Lastly, a sensitivity analysis is performed to test the robustness of the results.

4.1 Difference-in-differences models

Table 4.1 presents the coefficients and standard errors of the variables in the base model, comparing the treatment group (0-1,000 meters) to the control group (1,000-2,000 meters). The table displays three columns. The first column presents the effect of only year-fixed effects, being WOZ year dummies. The R-squared is limited to 18.9%. In the second column, the floor area and the construction period dummies were added to the model, resulting in an R-squared of 58.8%. To account for spatial-fixed effects, the postal code dummies were added in the third column. The R-squared increases to 59.1%. This suggests that the model is a good fit with respect to the hedonic price literature. All available control variables were added in the third column, which makes it the preferred model. The coefficients of all control variables are shown in Appendix C. As can be expected, dwellings built before 1960 were valued relatively high. Houses constructed between 1960 and 1980 were valued lower, likely because of the construction style of that period.

The third column presents that houses in the treatment group were valued with 8.5% less than comparable houses before the completion of the project. The coefficient is significant at the 1%-level. This indicates that houses located within a 1,000 meters of the metro stations were selling for a lower price, as municipalities base WOZ values on transactions. However, a positive trend appears after completion of the two metro stations. House prices within the treatment group increased by 2.0%. This suggests that the completion of the Noord/Zuidlijn did lead to a positive change in house prices in the treatment group, in line with earlier research on this topic (Tian et al., 2017; McMillen & McDonald, 2004; Perk et al., 2010). These studies suggest that the house price difference between a treatment and control group changes in favor of the treatment group.

Table 4.1 Estimation results base model

	(1)	(2)	(3)
Sample	<2,000 meters	<2,000 meters	<2,000 meters
Treatment group	0-1,000 meters	0-1,000 meters	0-1,000 meters
Control group	1,000-2,000 meters	1,000-2,000 meters	1,000-2,000 meters
Treatment group	-0.0288***	-0.0862***	-0.0854***
	(0.00228)	(0.00176)	(0.00312)
Treatment group after	0.00430	0.0206***	0.0197***
completion	(0.00369)	(0.00260)	(0.00255)
After completion	0.410***	0.416***	0.416***
	(0.00275)	(0.00193)	(0.00190)
Year fixed effects	Yes	Yes	Yes
Structural characteristics	No	Yes	Yes
Postal code	No	No	Yes
Observations	219,981	219,981	219,981
R-squared	0.189	0.588	0.591

Dependent variable is WOZ value. Completion date is July 21st 2018. Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The coefficients obtained when using distance ring dummies are presented in table 4.2. The control variables were added in the same way as in the base model. The third column shows the highest R-squared of 60.1%, making it the preferred column. The R-squared is slightly higher than in the base model, indicating a better proportion of variance for the dependent variable that is explained by the independent variables. The coefficients of all the control variables can be found in appendix C.

All coefficients in the table are significant at the 1%-level. Before the completion of the Noord/Zuidlijn, house prices were lower in all four distance rings compared to the control group. The house prices were particularly lower within 250 meters of the two metro stations. Noise and visual complaints are the most commonly reported issues in literature (Mas & Maudos, 2004; Chen et al., 1998). The sinkages, damages and leakages that occurred during construction, as well as the delay of the Noord/Zuidlijn, may have influenced the prices also. The difference in house prices even worsened after completion of the project. Complaints that arise during the construction phase can even have an impact after the project is completed, as argued by Van Dijk (2011). This is linked to changes in consumer attitudes and perceptions that anticipate expected house price changes. Therefore, the negative portrayal of the project in the media, as described in the first chapter, could be one of the reasons for the decrease in house prices in this area. However, as displayed in appendix C, the number of observations in this area is limited compared to the other distance ring dummies. This partly explains the magnitude of the coefficients.

In contrast to the distance ring 0-250 meters, house prices in the other three rings improved after 2018. This indicates that houses were valued for a premium in this area. Multiple studies have found that the benefits of improved accessibility eventually outweigh the negative sentiment after the construction period (Diao et al., 2017; McMillen & McDonald, 2004). The coefficients of the ring 500-750 meters shows the highest premium value at 5.7%, after which the positive effect reduces in the ring 750-1,000 meters. The positive external effect after completion moves in a non-linear way over space, with a concave effect. This finding is in line with research by Mohammad et al. (2017), which also found that house prices decreased in the proximity of the metro line after completion and increased further away in a concave line. Residents of these three distance rings enjoyed the benefits of increased accessibility, but did not experience a visual or noise effect, such as noise pollution, congestions and changes in the urban landscape (Hansen, 1959; Engwicht, 1993; Chatman & Noland, 2014; Ewing et al., 2016; Franklin & Waddell, 2003).

Appendix C displays the coefficients of both metro stations when using the distance ring dummies, as the effect of a new line on house prices can differ between the various stations of that line (Devaux et al., 2017). After the completion of the Noord/Zuidlijn, houses within 250 meters of the Noorderpark station experienced a price increase of 9.3% compared to houses in the control group, indicating that the negative external effects near the station disappeared after completion. This can be interpreted as part of anticipation effects. All coefficients for Noorderpark station show positive results, while house prices in the same distance ring from

Noord station decreased. The difference could be explained by the location of Noorderpark station near a park and other amenities, whereas Noord station is more secluded. As argued by Banister and Berechman (2000), the impact on house prices is higher in areas where the availability of transportation is sparse.

Table 4.2 Estimation results model with distance ring dummies

	(1)	(2)	(3)
Sample	<2,000 meters	<2,000 meters	<2,000 meters
Treatment group	0-1,000 meters	0-1,000 meters	0-1,000 meters
Control group	1,000-2,000 meters	1,000-2,000 meters	1,000-2,000 meters
Buffer 0-250	-0.125***	-0.121***	-0.165***
	(0.00658)	(0.00441)	(0.00535)
Buffer 250-500	-0.0666***	-0.110***	-0.132***
	(0.00328)	(0.00266)	(0.00381)
Buffer 500-750	-0.0273***	-0.0751***	-0.0897***
	(0.00309)	(0.00237)	(0.00358)
Buffer 750-1000	0.0128***	-0.0558***	-0.0562***
	(0.00302)	(0.00233)	(0.00315)
After 0-250	-0.283***	-0.245***	-0.243***
	(0.0127)	(0.0100)	(0.00989)
After 250-500	-0.00677	0.0254***	0.0223***
	(0.00561)	(0.00373)	(0.00370)
After 500-750	0.0486***	0.0579***	0.0570***
	(0.00472)	(0.00313)	(0.00311)
After 750-1000	0.0387***	0.0397***	0.0392***
	(0.00465)	(0.00335)	(0.00332)
After completion	0.411***	0.415***	0.416***
	(0.00272)	(0.00191)	(0.00188)
Year fixed effects	Yes	Yes	Yes
Structural characteristics	No	Yes	Yes
Postal code	No	No	Yes
Observations	219,981	219,981	219,981
R-squared	0.206	0.597	0.601

Dependent variable is WOZ value. Completion date is July 21st 2018. Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2 Sensitivity analysis

Sensitivity analyses help to identify the model process constants that are most promising for calibration. In this regard, an analysis is performed on the final model with distance rings, as it demonstrates the highest R-squared. The robustness of the estimations is assessed by testing the stability of the model in different conditions.

The robustness of the model has been tested by changing coverage of the control group, the treatment area remained 1,000 meters. The main results are displayed in table 4.3, all coefficients are shown in appendix C. The first column of table 4.3 is equal to the third column of table 4.2 and includes the distance rings with a control group of 1,000-2,000 meters. The second and the third models show coefficients with control groups of 1,000-1,500 meters and 1,000-2,500 meters, respectively. The R-squared is at least 58% in all three columns. The estimated coefficients are also predominantly consistent between the three, confirming the robustness of the estimations. All coefficients show a significant negative value before completion, which turn positive in the distance rings 250-500 meters, 500-750 meters and 750-1,000 meters compared to the three control groups.

Table 4.3 Estimation results sensitivity analysis

	(1)	(2)	(3)
Sample	<2,000 meters	<1,500 meters	<2,500 meters
Treatment area	0-1,000 meters	0-1,000 meters	0-1,000 meters
Control area	1,000-2,000 meters	1,000-1,500 meters	1,000-2,500 meters
Buffer 0-250	-0.165***	-0.162***	-0.169***
	(0.00535)	(0.00540)	(0.00535)
Buffer 250-500	-0.132***	-0.128***	-0.134***
	(0.00381)	(0.00387)	(0.00380)
Buffer 500-750	-0.0897***	-0.0880***	-0.0929***
	(0.00358)	(0.00364)	(0.00358)
Buffer 750-1000	-0.0562***	-0.0523***	-0.0590***
	(0.00315)	(0.00322)	(0.00314)
After 0-250	-0.243***	-0.239***	-0.239***
	(0.00989)	(0.0100)	(0.00986)
After 250-500	0.0223***	0.0251***	0.0251***
	(0.00370)	(0.00404)	(0.00364)
After 500-750	0.0570***	0.0598***	0.0599***
	(0.00311)	(0.00348)	(0.00303)
After 750-1000	0.0392***	0.0419***	0.0421***
	(0.00332)	(0.00368)	(0.00325)
After completion	0.416***	0.413***	0.416***
	(0.00188)	(0.00248)	(0.00188)
Year fixed effects	Yes	Yes	Yes
Structural characteristics	Yes	Yes	Yes
Postal code	Yes	Yes	Yes
Observations	219,981	188,843	233,553
R-squared	0.601	0.588	0.610

Dependent variable is WOZ value. Completion date is July 21st 2018. Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5. Conclusion and Discussion

This research studied the impact of the completion of the Noord/Zuidlijn on house prices in the vicinity of two metro stations. The metro stations are located close to each other, both in the district Amsterdam Noord that did not have a metro line before the Noord/Zuidlijn. The study is relevant since the municipality of Amsterdam has plans to extend the metro line, which could be beneficial for various stakeholders. Literature suggests that new transportation lines can have positive and negative effects. The study employed the DID approach, which was the most appropriate for this research.

The results indicate that house prices within 1,000 meters from the metro stations were lower than comparable houses. However, house prices within the treatment group increased by 2.0% after completion of the project. WOZ values within 250 meters of the stations decreased, likely due to visual or noise effects, such as noise pollution, congestions and changes in the urban landscape. The most positive impact was observed between 500-750 meters from the stations. The positive external effect after completion moved in a non-linear way over space, the effect is concave. However, the results varied between the two stations. The area around Noorderpark station experienced a higher value increase than Noord station, possibly due to its location near a park and other amenities.

Despite the interesting findings, the study has limitations. Since it is a case study, results may not apply to other public infrastructure projects. Second, the used dataset offered limited availability of structural housing characteristics, such as number of rooms and the availability of outside space. Nevertheless, the variables resulted in an R-squared is 59.1%. The third limitation is that the study relies on values set by the municipality rather than actual transaction prices, which may have biased the outcome slightly. Moreover, the effect of the project's construction periods or important announcements was not considered.

Further research could include more control variables or by examining the long-term effects of the project. Another interesting aspect to investigate could be the growth of livability and amenities around the metro stations, such as new shops, offices and crime rates.

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Appendix A - Stata do-file

```
cd "C:\Users\bobhe\Documents\Stata"
import delimited "Data_noordzuid_def", clear

// data cleaning

drop if missing(wozvalue)
drop if wozvalue < 50000
drop if wozvalue > 1500000

drop if floorarea < 25
hist floorarea
drop if floorarea > 250

drop if constryear==0
drop if constryear > 2021

gen constr_bef_1901 = (constryear < 1901)
gen constr_1901_1929 = (constryear > 1900 & constryear < 1930)
gen constr_1930_1949 = (constryear > 1929 & constryear < 1950)
gen constr_1950_1959 = (constryear > 1949 & constryear < 1960)
gen constr_1960_1969 = (constryear > 1959 & constryear < 1970)
gen constr_1970_1979 = (constryear > 1969 & constryear < 1980)
gen constr_1980_1989 = (constryear > 1979 & constryear < 1990)
gen constr_1990_1999 = (constryear > 1989 & constryear < 2000)
gen constr_2000_2009 = (constryear > 1999 & constryear < 2010)
gen constr_2010_present = (constryear > 2009)

gen postcod4 = substr(postal_cod,1,4)
destring postcod4, replace

destring wozyear, replace
tabulate wozyear
gen wozdateDMYeq = date(wozyeardmy,"DMY")
format wozdateDMYeq %td

gen year2014 = wozyear < 2015
gen year2015 = wozyear > 2014 & wozyear < 2016
gen year2016 = wozyear > 2015 & wozyear < 2017
gen year2017 = wozyear > 2016 & wozyear < 2018
gen year2018 = wozyear > 2017 & wozyear < 2019
gen year2019 = wozyear > 2018 & wozyear < 2020
gen year2020 = wozyear > 2019 & wozyear < 2021
gen year2021 = wozyear > 2020


// creating natural logarithm of value

hist wozvalue
gen lnwozvalue = ln(wozvalue)
drop if missing(lnwozvalue)
hist lnwozvalue

// creating project & target area

gen controlarea = distancenoord < 2500 | distancenoorderpark < 2500
drop if controlarea ==0

gen treatmentgroup = (distancenoord > 0 & distancenoord < 1000) | (distancenoorderpark > 0 & distancenoorderpark <
 1000)
```

```
tabulate treatmentgroup

gen controlgroup = 1
replace controlgroup = 0 if treatmentgroup==1
tabulate controlgroup

drop if treatmentgroup==0 & controlgroup==0

// creating dummies for distance buffers

gen buffer0250n = distancenoord < 250
tabulate buffer0250n
gen buffer250500n = (distancenoord > 250 & distancenoord < 500)
tabulate buffer250500n
gen buffer500750n = (distancenoord > 500 & distancenoord < 750)
tabulate buffer500750n
gen buffer7501000n = (distancenoord > 750 & distancenoord < 1000)
tabulate buffer7501000n

gen buffer0250np = distancenoorderpark < 250
tabulate buffer0250np
gen buffer250500np = (distancenoorderpark > 250 & distancenoorderpark < 500)
tabulate buffer250500np
gen buffer500750np = (distancenoorderpark > 500 & distancenoorderpark < 750)
tabulate buffer500750np
gen buffer7501000np = (distancenoorderpark > 750 & distancenoorderpark < 1000)
tabulate buffer7501000np

gen buffer0250 = buffer0250n + buffer0250np
tabulate buffer0250
gen buffer250500 = buffer250500n + buffer250500np
tabulate buffer250500
gen buffer500750 = buffer500750n + buffer500750np
tabulate buffer500750
gen buffer7501000 = (buffer7501000n==1) | (buffer7501000np==1)
tabulate buffer7501000

// creating dummies completion

gen beforecompletion = wozdateDMYeq>=td(01jan2014) & wozdateDMYeq <= td(21jul2018)
gen aftercompletion = wozdateDMYeq>td(21jul2018) & wozdateDMYeq <= td(1jan2021)
tabulate beforecompletion


// interaction variables treatmentgroup & before/after completion

gen Treatment_before = treatmentgroup * beforecompletion
tabulate Treatment_before
gen Treatment_after = treatmentgroup * aftercompletion
tabulate Treatment_after
gen Control_before = controlgroup * beforecompletion
tabulate Control_before
gen Control_after = controlgroup * aftercompletion
tabulate Control_after

// Ineteraction variables targetarea, Before & after announcement buffers
gen Beforebuffer0250 = buffer0250 * beforecompletion
```

```
gen Beforebuffer250500 = buffer250500 * beforecompletion
gen Beforebuffer500750 = buffer500750 * beforecompletion
gen Beforebuffer7501000 = buffer7501000 * beforecompletion

gen Afterbuffer0250 = buffer0250 * aftercompletion
gen Afterbuffer250500 = buffer250500 * aftercompletion
gen Afterbuffer500750 = buffer500750 * aftercompletion
gen Afterbuffer7501000 = buffer7501000 * aftercompletion


gen Beforebuffer0250n = buffer0250n * beforecompletion
gen Beforebuffer250500n = buffer250500n * beforecompletion
gen Beforebuffer500750n = buffer500750n * beforecompletion
gen Beforebuffer7501000n = buffer7501000n * beforecompletion

gen Afterbuffer0250n = buffer0250n * aftercompletion
gen Afterbuffer250500n = buffer250500n * aftercompletion
gen Afterbuffer500750n = buffer500750n * aftercompletion
gen Afterbuffer7501000n =  buffer7501000n * aftercompletion


gen Beforebuffer0250np = buffer0250np * beforecompletion
gen Beforebuffer250500np = buffer250500np * beforecompletion
gen Beforebuffer500750np = buffer500750np * beforecompletion
gen Beforebuffer7501000np = buffer7501000np * beforecompletion

gen Afterbuffer0250np = buffer0250np * aftercompletion
gen Afterbuffer250500np = buffer250500np * aftercompletion
gen Afterbuffer500750np = buffer500750np * aftercompletion
gen Afterbuffer7501000np = buffer7501000np * aftercompletion


// creating publication tables total, treatment and project group
estpost sum wozvalue floorarea constr_bef_1901 constr_1901_1929 constr_1930_1949 constr_1950_1959 constr_1960_1969
 constr_1970_1979 constr_1980_1989 constr_1990_1999 constr_2000_2009 constr_2010_present

esttab, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f)))) nonumber nomtitle
esttab using datanoordzuid.rtf, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f)))) nonumber nomtitle

estpost sum wozvalue floorarea constr_bef_1901 constr_1901_1929 constr_1930_1949 constr_1950_1959 constr_1960_1969
 constr_1970_1979 constr_1980_1989 constr_1990_1999 constr_2000_2009 constr_2010_present if treatmentgroup==1

esttab, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f)))) nonumber nomtitle
esttab using datanoordzuidtreatment.rtf, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f))))

estpost sum wozvalue floorarea constr_bef_1901 constr_1901_1929 constr_1930_1949 constr_1950_1959 constr_1960_1969
 constr_1970_1979 constr_1980_1989 constr_1990_1999 constr_2000_2009 constr_2010_present if treatmentgroup==0

esttab, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f)))) nonumber nomtitle
esttab using datanoordzuidcontrol.rtf, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f))))

// creating publication tables buffer areas

estpost sum wozvalue floorarea constr_bef_1901 constr_1901_1929 constr_1930_1949 constr_1950_1959 constr_1960_1969
 constr_1970_1979 constr_1980_1989 constr_1990_1999 constr_2000_2009 constr_2010_present if buffer0250

esttab, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f)))) nonumber nomtitle
```

```
esttab, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f)))) nonumber nomtitle
esttab using buffer0250n2.rtf, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f))))

estpost sum wozvalue floorarea constr_bef_1901 constr_1901_1929 constr_1930_1949 constr_1950_1959 constr_1960_1969
 constr_1970_1979 constr_1980_1989 constr_1990_1999 constr_2000_2009 constr_2010_present if buffer250500

esttab, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f)))) nonumber nomtitle
esttab using buffer250500n2.rtf, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f))))

estpost sum wozvalue floorarea constr_bef_1901 constr_1901_1929 constr_1930_1949 constr_1950_1959 constr_1960_1969
 constr_1970_1979 constr_1980_1989 constr_1990_1999 constr_2000_2009 constr_2010_present if buffer500750

esttab, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f)))) nonumber nomtitle
esttab using buffer500750n2.rtf, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f))))

estpost sum wozvalue floorarea constr_bef_1901 constr_1901_1929 constr_1930_1949 constr_1950_1959 constr_1960_1969
 constr_1970_1979 constr_1980_1989 constr_1990_1999 constr_2000_2009 constr_2010_present if buffer7501000

esttab, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f)))) nonumber nomtitle
esttab using buffer7501000n2.rtf, cell((mean(fmt(%9.3f)) sd(fmt(%9.3f))))


// Regression analysis DID
ssc install outreg2

// Base model with wozyear
reg lnwozvalue treatmentgroup Treatment_after aftercompletion, r
estat vif
outreg2 using baselinemodel1.doc, label

// Base model with wozyear & structural characteristics
reg lnwozvalue treatmentgroup Treatment_after aftercompletion floorarea constr_bef_1901 constr_1901_1929
constr_1930_1949 constr_1950_1959 constr_1960_1969 constr_1970_1979 constr_1980_1989 constr_1990_1999
constr_2000_2009 i.constr_2010_present, r
estat vif
outreg2 using basemodelstructural1.doc, label

scatter wozyear

// Base model with wozyear & structural characteristics & postal code dummies

reg lnwozvalue treatmentgroup Treatment_after aftercompletion floorarea i.constr_bef_1901 constr_1901_1929
constr_1930_1949 constr_1950_1959 constr_1960_1969 constr_1970_1979 constr_1980_1989 constr_1990_1999
constr_2000_2009 constr_2010_present i.postcod4, r
estat vif
outreg2 using basemodelstructpostal1.doc, label
predict r, resid
sktest r

reg lnwozvalue treatmentgroup Treatment_after aftercompletion floorarea constr_bef_1901 constr_1901_1929
constr_1930_1949 constr_1950_1959 constr_1960_1969 constr_1970_1979 constr_1980_1989 constr_1990_1999
constr_2000_2009 i.constr_2010_present i.postcod4 i.wozyear
estat hettest

//correlations
corr treatmentgroup Treatment_after aftercompletion floorarea constr_bef_1901 constr_1901_1929 constr_1930_1949
constr_1950_1959 constr_1960_1969 constr_1970_1979 constr_1980_1989 constr_1990_1999 constr_2000_2009
constr_2010_present wozyear
```

```
// Model with distance buffers, wozyear
reg lnwozvalue buffer0250 buffer250500 buffer500750 buffer7501000 Afterbuffer0250 Afterbuffer250500
Afterbuffer500750 Afterbuffer7501000 aftercompletion, r
estat vif
outreg2 using Model2buffers1.doc, label

// Model with distance buffers, wozyear & structural characteristics

reg lnwozvalue buffer0250 buffer250500 buffer500750 buffer7501000 Afterbuffer0250 Afterbuffer250500
Afterbuffer500750 Afterbuffer7501000 aftercompletion floorarea constr_bef_1901 constr_1901_1929 constr_1930_1949
constr_1950_1959 constr_1960_1969 constr_1970_1979 constr_1980_1989 constr_1990_1999 constr_2000_2009 i.
constr_2010_present, r
estat vif
outreg2 using Model2buffersstructural1.doc, label

// Model with distance buffers, wozyear & structural characteristics & postal code dummies

reg lnwozvalue buffer0250 buffer250500 buffer500750 buffer7501000 Afterbuffer0250 Afterbuffer250500
Afterbuffer500750 Afterbuffer7501000 aftercompletion floorarea constr_bef_1901 constr_1901_1929 constr_1930_1949
constr_1950_1959 constr_1960_1969 constr_1970_1979 constr_1980_1989 constr_1990_1999 constr_2000_2009
constr_2010_present i.postcod4, r
estat vif
outreg2 using Model2buffersall2500.doc, label


reg lnwozvalue buffer0250n buffer250500n buffer500750n buffer7501000n Afterbuffer0250n Afterbuffer250500n
Afterbuffer500750n Afterbuffer7501000n aftercompletion floorarea constr_bef_1901 constr_1901_1929 constr_1930_1949
 constr_1950_1959 constr_1960_1969 constr_1970_1979 constr_1980_1989 constr_1990_1999 constr_2000_2009
constr_2010_present i.postcod4, r
estat vif
outreg2 using Model2buffersnall.doc, label

reg lnwozvalue buffer0250np buffer250500np buffer500750np buffer7501000np Afterbuffer0250np Afterbuffer250500np
Afterbuffer500750np Afterbuffer7501000np aftercompletion floorarea constr_bef_1901 constr_1901_1929
constr_1930_1949 constr_1950_1959 constr_1960_1969 constr_1970_1979 constr_1980_1989 constr_1990_1999
constr_2000_2009 constr_2010_present i.postcod4, r
estat vif
outreg2 using Model2buffersnpall.doc, label
```

Appendix B - OLS Assumptions

Zero conditional mean assumption

The error term must not show a systematic pattern and have a mean of 0. A constant error has been added to the base model to test this assumption.

No multicollinearity

This assumption has been tested to check for strong correlations between two or more independent variables. A correlation matrix is drafted and studied. Coefficients with magnitudes of .80 or higher are regarded multicollinear, the matrix shows no such coefficients. A Variance Inflation Factor (VIF) model has been drafted also, which shows multicollinearity above 10. No multicollinearity has been found in the independent variables.

	treatm~p	Treatm~r	afterc~n	floora~a	con~1901	con~1929	con~1949	con~1959	con~1969	con~1979	con~1989	con~1999	con~2009	constr~t	wozyear
treatmentg~p	1.0000														
Treatment_~r	0.4828	1.0000													
aftercompl~n	0.0015	0.6412	1.0000												
floorarea	-0.0550	-0.0405	-0.0135	1.0000											
constr_~1901	-0.0153	-0.0080	-0.0023	0.0447	1.0000										
constr_~1929	0.1745	0.0706	-0.0180	-0.2666	-0.0172	1.0000									
constr_~1949	0.1057	0.0413	-0.0122	-0.0885	-0.0100	-0.1367	1.0000								
constr_~1959	-0.0717	-0.0365	-0.0060	0.0029	-0.0044	-0.0609	-0.0353	1.0000							
constr_~1969	-0.1678	-0.0904	-0.0210	-0.0537	-0.0186	-0.2549	-0.1476	-0.0658	1.0000						
constr_~1979	-0.1062	-0.0619	-0.0189	0.0818	-0.0162	-0.2222	-0.1286	-0.0574	-0.2399	1.0000					
constr_~1989	0.1603	0.0629	-0.0150	-0.1160	-0.0127	-0.1738	-0.1006	-0.0449	-0.1876	-0.1636	1.0000				
constr_~1999	0.1269	0.0507	-0.0110	0.2106	-0.0088	-0.1202	-0.0696	-0.0310	-0.1298	-0.1131	-0.0885	1.0000			
constr_~2009	0.0192	0.0008	-0.0104	0.1799	-0.0061	-0.0842	-0.0488	-0.0217	-0.0909	-0.0792	-0.0620	-0.0429	1.0000		
constr_201~t	-0.1820	-0.0150	0.1069	0.2216	-0.0137	-0.1877	-0.1087	-0.0485	-0.2027	-0.1767	-0.1382	-0.0956	-0.0670	1.0000	
wozyear	-0.0008	0.5436	0.8459	-0.0076	-0.0021	-0.0184	-0.0114	-0.0065	-0.0223	-0.0206	-0.0161	-0.0118	-0.0115	0.1124	1.0000

Variable	VIF	1/VIF
treatmentg~p	4.26	0.234872
Treatment_~r	2.81	0.355720
aftercompl~n	2.16	0.462186
floorarea	1.27	0.789499
1.const~1901	1.02	0.981661
constr_~1929	3.15	0.317011
constr_~1949	1.97	0.508526
constr_~1959	1.33	0.753906
constr_~1969	3.19	0.313312
constr_~1979	2.75	0.364004
constr_~1989	2.36	0.424425
constr_~1999	1.73	0.578357
constr_~2009	1.27	0.784526
postcod4		
1022	1.54	0.649979
1023	2.70	0.370117
1024	4.09	0.244240
1025	3.75	0.266367
1027	1.01	0.990957
1031	2.09	0.479591
1032	2.02	0.493899
1034	5.12	0.195267
Mean VIF	2.46	

Errors normally distributed

This assumption was tested by drafting a skewness and kurtosis test. The graph below shows both P-values are 0.00. This indicates that the data does not have a normal distribution. Due to the central limit theorem, large samples can be seen as given. The data includes 219,981 values, which is large enough to assume that this will not bias the results.

Skewness and kurtosis tests for normality

				Joint test	
Variable	Obs	Pr(skewness)	Pr(kurtosis)	Adj chi2(2)	Prob>chi2
r	219,981	0.0000	0.0000	.	.

No autocorrelation

Autocorrelation occurs if there is correlation between the error values. Data collected over time is likely to depend on each other. To deal with this issue, spatial and time-fixed effects are added as control variables.

Homoscedasticity

A Breusch-Pagan/Cook-Weisberg test has been performed to test this assumption. The P-value of the graph below is 0.00, this indicates that there is heterogeneity in the model. To deal with this issue, robust standard errors were added to the model.

```
Breusch-Pagan/Cook-Weisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of lnwozvalue

H0: Constant variance

    chi2(1) = 15309.64
Prob > chi2 =   0.0000
```

Appendix C - Descriptive Statistics

Table C1 Estimation results base model

	(1)	(2)	(3)
Sample	<2,000 meters	<2,000 meters	<2,000 meters
Treatment group	0-1,000 meters	0-1,000 meters	0-1,000 meters
Control group	1,000-2,000 meters	1,000-2,000 meters	1,000-2,000 meters
Treatment group	-0.0288***	-0.0862***	-0.0854***
	(0.00228)	(0.00176)	(0.00312)
Treatment group after	0.00430	0.0206***	0.0197***
completion	(0.00369)	(0.00260)	(0.00255)
After completion	0.410***	0.416***	0.416***
	(0.00275)	(0.00193)	(0.00190)
Floor area		0.0111***	0.0111***
		(3.93e-05)	(3.95e-05)
Before 1901		0.409***	0.388***
		(0.0281)	(0.0289)
1901-1929		0.220***	0.190***
		(0.00372)	(0.00402)
1930-1949		0.260***	0.238***
		(0.00416)	(0.00437)
1950-1959		0.194***	0.125***
		(0.00555)	(0.00626)
1960-1969		-0.0587***	-0.0589***
		(0.00341)	(0.00334)
1970-1979		-0.0716***	-0.0623***
		(0.00342)	(0.00332)
1980-1989		0.205***	0.180***
		(0.00386)	(0.00387)
1990-1999		0.118***	0.121***
		(0.00384)	(0.00381)
2000-2009		0.120***	0.110***
		(0.00427)	(0.00406)
Postal code 1022			-0.0346***
			(0.00486)
Postal code 1023			0.0528***
			(0.00408)
Postal code 1024			-0.0389***
			(0.00427)
Postal code 1025			-0.0367***
			(0.00289)
Postal code 1027			0.0977
			(0.101)
Postal code 1031			-0.0382***
			(0.00331)
Postal code 1032			-0.0472***
			(0.00298)
Postal code 1034			-0.0656***
			(0.00396)
Constant	12.21***	11.32***	11.36***
	(0.00173)	(0.00471)	(0.00575)
Observations	219,981	219,981	219,981
R-squared	0.189	0.588	0.591

Table C2 Estimation results model with distance ring dummies

	(1)	(2)	(3)
Sample	<2,000 meters	<2,000 meters	<2,000 meters
Treatment group	0-1,000 meters	0-1,000 meters	0-1,000 meters
Control group	1,000-2,000 meters	1,000-2,000 meters	1,000-2,000 meters
Before 0-250	-0.125***	-0.121***	-0.165***
	(0.00658)	(0.00441)	(0.00535)
Before 250-500	-0.0666***	-0.110***	-0.132***
	(0.00328)	(0.00266)	(0.00381)
Before 500-750	-0.0273***	-0.0751***	-0.0897***
	(0.00309)	(0.00237)	(0.00358)
Before 750-1000	0.0128***	-0.0558***	-0.0562***
	(0.00302)	(0.00233)	(0.00315)
After 0-250	-0.283***	-0.245***	-0.243***
	(0.0127)	(0.0100)	(0.00989)
After 250-500	-0.00677	0.0254***	0.0223***
	(0.00561)	(0.00373)	(0.00370)
After 500-750	0.0486***	0.0579***	0.0570***
	(0.00472)	(0.00313)	(0.00311)
After 750-1000	0.0387***	0.0397***	0.0392***
	(0.00465)	(0.00335)	(0.00332)
After completion	0.411***	0.415***	0.416***
	(0.00272)	(0.00191)	(0.00188)
Floor area		0.0109***	0.0109***
		(3.89e-05)	(3.91e-05)
Before 1901		0.387 ***	0.358***
		(0.02852)	(0.0294)
1901-1929		0.204***	0.175***
		(0.00358)	(0.00388)
1930-1949		0.229***	0.212***
		(0.00405)	(0.00424)
1950-1959		0.175***	0.106***
		(0.00548)	(0.00617)
1960-1969		-0.0840***	-0.0840***
		(0.00331)	(0.00319)
1970-1979		-0.0832***	-0.0656***
		(0.00330)	(0.00318)
1980-1989		0.165***	0.128***
		(0.00378)	(0.00384)
1990-1999		0.0940***	0.106***
		(0.00380)	(0.00376)
2000-2009		0.105***	0.0899***
		(0.00425)	(0.00402)
Postal code 1022			-0.0205***
			(0.00454)
Postal code 1023			0.0198***
			(0.00418)
Postal code 1024			-0.0689***
			(0.00432)
Postal code 1025			-0.0638***
			(0.00297)
Postal code 1027			0.0720
			(0.100)
Postal code 1031			-0.0761***
			(0.00335)
Postal code 1032			-0.0881***

			(0.00321)
Postal code 1034			-0.107***
			(0.00409)
Constant	12.21***	11.35***	11.43***
	(0.00172)	(0.00472)	(0.00579)
Observations	219,981	219,981	219,981
R-squared	0.206	0.597	0.601

Table C3 Descriptive statistics distance ring dummies, Noord & Noorderpark

	(Noord) 0-250 meters		(Noord) 250-500 meters	
	mean	sd	mean	sd
wozvalue	173,187	95,788	234,731	113,020
floorarea	68.979	19.038	79.121	24.125
Before 1901	0.000	0.000	0.000	0.000
1901-1929	0.000	0.000	0.000	0.000
1930-1949	0.000	0.000	0.000	0.000
1950-1959	0.000	0.000	0.000	0.000
1960-1969	0.000	0.000	0.198	0.399
1970-1979	0.465	0.499	0.484	0.500
1980-1989	0.000	0.000	0.068	0.252
1990-1999	0.000	0.000	0.066	0.249
2000-2009	0.000	0.000	0.027	0.164
2010-Present	0.535	0.499	0.155	0.362
N	3,994		12,950	
	(Noord) 500-750 meters		(Noord) 750-1,000 meters	
	mean	sd	mean	sd
wozvalue	271,313	135,407	274,681	136,300
floorarea	89.417	27.589	83.955	26.416
Before 1901	0.000	0.000	0.000	0.000
1901-1929	0.000	0.000	0.006	0.079
1930-1949	0.000	0.000	0.109	0.311
1950-1959	0.000	0.000	0.002	0.049
1960-1969	0.426	0.495	0.312	0.463
1970-1979	0.203	0.402	0.175	0.380
1980-1989	0.035	0.183	0.116	0.321
1990-1999	0.183	0.386	0.192	0.394
2000-2009	0.055	0.228	0.061	0.240
2010-Present	0.099	0.298	0.026	0.158
N	17,858		23,057	

	(Noorderpark) 0-250 meters		(Noorderpark) 250-500 meters	
	mean	sd	mean	sd
wozvalue	259,746	97,168	249,148	103,408
floorarea	72.504	22.655	69.005	23.188
Before 1901	0.000	0.000	0.000	0.000
1901-1929	0.589	0.492	0.833	0.373
1930-1949	0.122	0.327	0.057	0.231
1950-1959	0.021	0.145	0.002	0.047
1960-1969	0.000	0.000	0.001	0.033
1970-1979	0.000	0.000	0.001	0.023
1980-1989	0.000	0.000	0.011	0.103
1990-1999	0.191	0.393	0.026	0.158
2000-2009	0.077	0.266	0.050	0.219
2010-Present	0.000	0.000	0.020	0.141
N	3,724		14,698	
	(Noorderpark) 500-750 meters		(Noorderpark) 750-1,000 meters	
	mean	sd	mean	sd
wozvalue	247,198	107,669	265,972	131,430
floorarea	62.071	23.067	68.428	26.697
Before 1901	0.001	0.038	0.003	0.051
1901-1929	0.398	0.490	0.298	0.457
1930-1949	0.258	0.438	0.198	0.398
1950-1959	0.012	0.109	0.019	0.137
1960-1969	0.003	0.054	0.008	0.088
1970-1979	0.000	0.000	0.019	0.135
1980-1989	0.282	0.450	0.406	0.491
1990-1999	0.012	0.108	0.004	0.062
2000-2009	0.000	0.000	0.000	0.000
2010-Present	0.034	0.180	0.046	0.209
N	22,505		21,298	

Table C4 Estimation results model with distance ring dummies, Noord & Noorderpark

	(Noord)	(Noorderpark)
Sample	<2,000 meters	<2,000 meters
Treatment group	0-1,000 meters	0-1,000 meters
Control group	1,000-2,000 meters	1,000-2,000 meters
Before 0-250	-0.218***	-0.0179**
	(0.00698)	(0.00706)
Before 250-500	-0.147***	-0.0269***
	(0.00473)	(0.00497)
Before 500-750	-0.128***	0.0255***
	(0.00436)	(0.00435)
Before 750-1000	-0.0592***	0.0303***
	(0.00341)	(0.00429)
After 0-250	-0.464***	0.0934***
	(0.0138)	(0.00713)
After 250-500	-0.0377***	0.0644***
	(0.00532)	(0.00415)
After 500-750	0.00935**	0.0873***
	(0.00408)	(0.00361)
After 750-1000	0.00457	0.0589***
	(0.00399)	(0.00434)
After completion	0.438***	0.405***
	(0.00141)	(0.00151)
Floor area	0.0108***	0.0111***
	(3.74e-05)	(3.97e-05)
Before 1901	0.306***	0.390***
	(0.0289)	(0.0311)
1901-1929	0.0876***	0.142***
	(0.00416)	(0.00431)
1930-1949	0.119***	0.167***
	(0.00449)	(0.00503)
1950-1959	0.0261***	0.0670***
	(0.00639)	(0.00649)
1960-1969	-0.107***	-0.0797***
	(0.00321)	(0.00330)
1970-1979	-0.0819***	-0.0855***
	(0.00315)	(0.00328)
1980-1989	0.103***	0.129***
	(0.00384)	(0.00398)
1990-1999	0.0735***	0.0784***
	(0.00366)	(0.00368)
2000-2009	0.0544***	0.0892***
	(0.00397)	(0.00402)
Postal code 1022	0.0744***	-0.0366***
	(0.00441)	(0.00507)
Postal code 1023	0.147***	0.171***
	(0.00279)	(0.00527)
Postal code 1024	-0.00379	0.0441***
	(0.00322)	(0.00408)
Postal code 1025	0.0427***	-0.0219***
	(0.00340)	(0.00391)
Postal code 1027	0.158	0.189*
	(0.0999)	(0.102)

Postal code 1031	-0.0387***	-0.0201***
	(0.00340)	(0.00341)
Postal code 1032	-0.00358	-0.00103
	(0.00269)	(0.00377)
Postal code 1034	-0.0415***	0.0121***
	(0.00302)	(0.00397)
Constant	11.38***	11.30***
	(0.00516)	(0.00578)
Observations	219,981	219,981
R-squared	0.608	0.591

Table C5 Estimation results sensitivity analysis

	(1)	(2)	(3)
Sample	<2,000 meters	<2,000 meters	<2,500 meters
Treatment group	0-1,000 meters	0-1,000 meters	0-1,000 meters
Control group	1,000-2,000 meters	1,000-1,500 meters	1,000-2,500 meters
Before 0-250	-0.165***	-0.162***	-0.169***
	(0.00535)	(0.00540)	(0.00535)
Before 250-500	-0.132***	-0.128***	-0.134***
	(0.00381)	(0.00387)	(0.00380)
Before 500-750	-0.0897***	-0.0880***	-0.0929***
	(0.00358)	(0.00364)	(0.00358)
Before 750-1000	-0.0562***	-0.0523***	-0.0590***
	(0.00315)	(0.00322)	(0.00314)
After 0-250	-0.243***	-0.239***	-0.239***
	(0.00989)	(0.0100)	(0.00986)
After 250-500	0.0223***	0.0251***	0.0251***
	(0.00370)	(0.00404)	(0.00364)
After 500-750	0.0570***	0.0598***	0.0599***
	(0.00311)	(0.00348)	(0.00303)
After 750-1000	0.0392***	0.0419***	0.0421***
	(0.00332)	(0.00368)	(0.00325)
After completion	0.416***	0.413***	0.413***
	(0.00188)	(0.00248)	(0.00174)
Floor area	0.0109***	0.0109***	0.0109***
	(3.91e-05)	(3.60e-05)	(3.77e-05)
Before 1901	0.358***	0.371***	0.348***
	(0.0294)	(0.0299)	(0.0287)
1901-1929	0.175***	0.169***	0.175***
	(0.00388)	(0.00419)	(0.00384)
1930-1949	0.212***	0.226***	0.216***
	(0.00424)	(0.00473)	(0.00420)
1950-1959	0.106***	0.103***	0.120***
	(0.00617)	(0.00671)	(0.00619)
1960-1969	-0.0840***	-0.0707***	-0.0822***
	(0.00319)	(0.00411)	(0.00319)
1970-1979	-0.0656***	-0.0558***	-0.0617***
	(0.00318)	(0.00386)	(0.00318)
1980-1989	0.128***	0.127***	0.129***
	(0.00384)	(0.00427)	(0.00378)
1990-1999	0.106***	0.0984***	0.114***
	(0.00376)	(0.00435)	(0.00370)
2000-2009	0.0899***	0.0988***	0.0911***
	(0.00402)	(0.00460)	(0.00405)
Postal code 1022	-0.0205***	-0.0217***	-0.0193***
	(0.00454)	(0.00460)	(0.00453)
Postal code 1023	0.0198***	-0.00763	0.0236***
	(0.00418)	(0.00515)	(0.00420)
Postal code 1024	-0.0689***	-0.107***	-0.0763***
	(0.00432)	(0.00481)	(0.00431)
Postal code 1025	-0.0638***	-0.0747***	-0.0661***
	(0.00297)	(0.00312)	(0.00293)
Postal code 1027	0.0720	-	0.406***
	(0.100)		(0.0122)
Postal code 1031	-0.0761***	-0.0741***	-0.0768***
	(0.00335)	(0.00334)	(0.00335)
Postal code 1032	-0.0881***	-0.0870***	-0.0895***

	(0.00321)	(0.00320)	(0.00320)
Postal code 1034	-0.107***	-0.124***	-0.111***
	(0.00409)	(0.00418)	(0.00407)
Constant	11.43***	11.43***	11.43***
	(0.00579)	(0.00608)	(0.00567)
Observations	219,981	188,843	233,553
R-squared	0.601	0.588	0.610