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Master Thesis Report

The Effect of the High-rise Building Next Door on Your House Price

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The Effect of the High-rise Building Next Door on Your House Price

Abstract

This paper aims to find the effect of high-rise buildings on the price of residential properties. High-rise buildings are increasingly common in the Netherlands, and though much research has been conducted on the externalities of such buildings, not much research has been dedicated to understanding the effect specifically on residential property prices. Despite the concerns raised by citizens in the Netherlands on high-rise buildings construction, the Dutch government has remained keen on the sustainable construction of more high-rise buildings due to the potential benefits they are associated with. Land limitations and increasing land prices are key reasons to build upwards however, high-rise buildings present negative externalities, one of which is the effect on price of houses in the vicinity. The paper uses a detailed dataset which spans over 20 years for three major cities in the Netherlands provided by the Dutch Association of Realtors (NVM). Utilizing a difference in difference model the paper finds that a high-rise building within a 1km distance leads to a 2% decrease in house prices and the effect decays in distance as the negative externalities are limited to the local area of a high-rise. The shadows caused by such buildings are also a negative externality which the paper assesses. The paper utilizes a high-level method to estimate the effect on house prices but finds that it is potentially insignificant.

Keywords: High-rise, residential property prices, shadows

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1. Introduction

The Netherlands has seen an increase in the number of high-rise buildings over the last 20 years. An article in the NL Times published last year pointed out that the number of high-rise buildings will double by the year 2025 indicating the increasing demand for such buildings (NLTimes, 2019). The Netherlands is a densely populated country with 16 million inhabitants (Scheublin and Groep, 2008). The housing shortage, limited space and the increase in land prices, are amongst the key reasons why developers would be interested in building upwards (Ali and Kodmany, 2012). These buildings are also seen as a suitable solution to limit the shrinkage of green space due to urban development (Scheublin and Groep, 2008). Despite the concerns raised by citizens, the Dutch government has remained keen on the construction of more high-rise buildings. According to Scheublin and Groep (2008), Amsterdam's mayor, Eberhard van der Laan, noted in a televised interview, that more high-rises would help the Dutch capital and considering the current population of 800,000 residents with roughly 35,000 additional residents by 2020, building upwards is necessary (Scheublin and Groep, 2008). These estimates from 2008 have been realistic that Amsterdam's population is amounting to nearly 863,000 inhabitants this year[1]. The trend of urbanization is continuing around the world and it is expected that by 2050, 80% of the world's population will be living in urban centres (Ali and Aksamija, 2008).

High-rise buildings can modernize and beautify a cityscape (Shin and Woo, 2009). People appreciate high-rise buildings as they can be structurally and architecturally complex. The skyline in itself can be a tourist attraction adding to the city's tourism scene. Adding height to a building can generate additional rental income, status opportunities and dramatic views (Barr, 2010). The more industrialized and service-oriented countries become, the more high-rise buildings are required so that people and services are consolidated in order to conduct business in urban centers (Halsley and Stranger, 2008). High-rise buildings provide an excellent opportunity to exploit agglomeration economies. High-rise buildings (skyscrapers) are mostly commercial which provides an opportunity for a high density of workers to be clustered in space (Helsley and Strange, 2008). The proximity to nearby employment contributes to an increase in productivity by allowing businesses to draw on pools of skilled workers, share inputs and learn from their neighbors (Liu et al., 2018).

With mixed views from the public, architects, and planners on high-rise buildings, and with multiple projects planned and under construction in the country it is important to investigate their externalities. And therefore, the research question is: what are the effects of high-rise buildings on residential properties prices? And do the building shadows also affect the property prices?

The key addition of the paper to the current research is the investigation it carries into the effects of high-rise buildings on the price of residential properties in particular. Moreover, the paper explores the effect of shadows on nearby residential property prices. The shadows can potentially impact the residents' utility and the paper looks into whether this is reflected in the properties' prices. The paper provides an understanding of high-rise buildings implications so that they are taken into consideration when planning height restrictions, urban growth and when conducting housing transactions.

The paper uses utilizes a detailed set of housing transactions in three major cities in the Netherlands from the Dutch Association of Realtors (NVM) spanning over the last 20 years. Using a difference in difference method, incorporating the appropriate fixed effects and a careful selection of control and treatment groups to address possible endogeneity problems the paper finds that a high-rise building located within a 1km distance leads to a 2% decrease in house prices.

[1] Amsterdam population obtained from https://www.statista.com/statistics/753235/total-population-of-amsterdam/ accessed on 1 July 2020.

The remainder of this paper is structured as follows. Section 2 provides a detailed literature review. Section 3 presents the empirical methodology, followed by a description of the data in Section 4. Section 5 presents the results along with a discussion and Section 6 concludes.

2. Literature Review

What is considered a high-rise building?

The council of tall buildings and urban habitat (CTBUH) is an international institution specializing in high-rise buildings and develops the international standards for measuring and defining tall buildings. They indicate that there is no absolute definition of what constitutes a tall building. A 14-story building that is 50m high may not be considered a tall building in a high-rise city such as Chicago, but could still be considered a tall building in a provincial European city or a suburb (CTBUH, 2020).

In terms of the Netherlands, and according to Dutch building regulations, buildings are considered to be high-rise when they exceed 70 meters in height. Buildings that exceed this height require special regulations (Scheublin and Groep, 2008). When comparing this to other countries, high-rise buildings in the Netherlands, are not that high after all. For example, Dubai's tallest building named Burj Khalifa which currently holds the record of the tallest building in the world is more than 800m high. However, each country has its specific architectural and urban planning visions and therefore, the comparison between two completely different countries like the Netherlands and the United Arab Emirates would not be valid. Hence the building regulations in the Netherlands are different to those of the United Arab Emirates which emphasizes that cities are heterogenous in their urban form and architectural style.

History of high-rise buildings

High-rise buildings are not particularly a new idea as they have existed throughout history. The ancient empires in Egypt and Rome for example had massive buildings that were relatively high, given the construction abilities at the time such as the pyramids in Egypt, the tallest of which is 146.7 meters high when it was completed around 4,500 years ago (Guinness World Records, 2020). The pyramids were the tallest until the middle ages after which a series of high-rise buildings emerged. Most of which are religious, civic buildings and cathedrals (Helsley and Strange, 2008). Sagrada Familia in Barcelona which is 172.5m high upon completion (Sagrada Familia, 2020) and the St. Stephen's Cathedral in Vienna which is 107.2m high (Wien, 2020) are evident examples.

The building mechanism of industrial times followed a masonry structure where the base needed to be heavy in order to carry the upper narrower floors, however, with the introduction of structural steel in construction it became possible build higher (Helsley and Strange, 2008). The first high-rise building to be completely supported by a steel skeleton was the William Lebaron Jenney's Home Insurance building in 1885. The architect, Major William LeBaron Jenney, incorporated a steel frame that supported the great weight of the entire building and his technique was referred to as the Chicago Skeleton (Guinness World Records, 2020). This marked the point at which the limits to the size of an occupied building were not due to technological difficulties anymore but more so due to the restrictions imposed by the ambition of builders (Helsley and Strange, 2008).

In addition to steel incorporation, elevators also contributed to the history of high-rise buildings development. High-rise buildings became more common when elevators hit a mile stone upon the invention of over speed governor and safety brakes in 1854 (DEERNS, 2007). Moreover, according to Koster el al. (2014) Sullinvan (1991) indicated the role of vertical transportation affordability in high-rise buildings pointing out that the low cost and improvement of vertical transportation over the years has contributed more to the construction of such buildings (Koster et al., 2014).

Since then, high-rise buildings spread further around the world. The United States was one of the first countries in the world to see an increase in the construction of high-rise buildings. Ali and Kodmany

(2012) indicate that a huge progress was made in the development of tall buildings after WWII, first in the U.S., followed much later by Europe (Ali and Kodmany, 2012). The 100 meter high Masonic Temple located in Chicago built in 1892 was the first of such high buildings to be constructed in the U.S. but was demolished 47 years later (Chicago Reader, 1987). Several high-rise buildings followed on, and between the year 2000 and 2011 the number of tall buildings in the world doubled from 258 to 602 buildings (Ahmad et al., 2017).

What is the motivation to build high?

Other than the reasons of land limitation, and increasing land prices to explain the need to build upwards, there are also several additional reasons why cities may expand upwards, justifying the construction of high-rise buildings (Ali and Kodmany, 2012).

The migration into cities to make a living led to high densities where cities over time became more populated and building upwards to accommodate the overpopulation was the trivial solution (Ali and Kodmany, 2012). The trend of urbanization still continues and it is expected that by 2050, 80% of the world's population will be living in urban centres (Ali and Aksamija, 2008) , and the increased urban growth creates an increased interest in building high-rise buildings.

High-rise buildings can modernize and beautify a cityscape (Shin and Woo, 2009). People appreciate high-rise buildings and the skyline in itself can be a tourist attraction adding to the city's tourism scene. Adding height to a building can generate additional rental income, status opportunities and dramatic views (Barr, 2010). The tallest building in a city has some sort of prestige about it (Helsley and Stranger, 2008).

They also can help differentiate a city and provide a unique identity such as the Taipei 101 in Taiwan, and Burj Khalifa in Dubai. Those buildings were not exactly built out of need to accommodate large densities of people, but more to add to the city's image (the Tower Info, 2018). The Empire State Building for example was referred to as the Empty State Building for some time after it was constructed as there were more than forty vacant floors (Helsley and Stranger, 2008).

Another motivation to build high is the contest of skyscrapers, which are technically high-rise buildings but extreme in height. Barr (2010) defines them as buildings taller than 100m. One of the first skyscrapers ever built is The Empire State Building which was built in 1931 and upon completion was the tallest building in the world (CNN Library, 2019). Many skyscrapers followed afterwards, with the most recent title being held by the Burj Khalifa in Dubai which was built in 2009. Building skyscrapers is a strategic contest between rival builders which partially explains the overbuilding- there is some sort of inherent value on being the tallest (Halsley and Stranger, 2008). Hence why we see countries, and cities within a country, over taking each other over the title of the tallest building.

The more industrialized and service-oriented countries become, the more high-rise buildings are required so that people and services are consolidated in order to conduct business in urban centers (Halsley and Stranger, 2008).

The agglomeration economies of high-rise buildings explain further why buildings are built of that height. According to Drennan and Kelly (2011), Marshall (1890) identified three sources of agglomeration economies namely, input sharing, labor pooling and knowledge spillovers among firms. Economies of agglomeration are external economies which arise from the clustering of firms of the same sector, in space (Drennan and Kelly, 2011). High-rise buildings (skyscrapers) are mostly commercial which provides an opportunity for a high density of workers to be clustered in space (Helsley and Strange, 2008). The proximity to nearby employment contributes to an increase in productivity by allowing businesses to draw on pools of skilled workers, share inputs and learn from their neighbors (Liu et al., 2018). And hence high-rise buildings provide an excellent opportunity to exploit agglomeration economies.

Firms take these agglomeration economies into consideration when locating in such buildings to gain the benefit of high numbers of highly skilled workers being in close proximity to each other (Koster et al., 2014). The World Trade Center's twin towers in New York City together had about 50,000 workers (Liu et al., 2018) which is a clear example of an attempt to exploit agglomeration economies.

"Colin Buchanan et al.'s research shows that a doubling of employment density within a given area can lead to a 12.5% additional increase in output per worker in that area; for the service sector, the figure is far higher at 22%" (Ali and Kodmany, 2012, pp392).

Several cities in the world have understood this and adopted this kind of expansion in their urban structure. For example, in the USA, urban planners believed that larger buildings are necessary to keep up with the development of businesses and the increase in working middle class (DCE, 2007).

Within building effects

The effects of high-rise buildings actually start from units within the buildings themselves. According to Ki and Jayantha (2010), Tse and Love (2000) and Mok et al. (1995) find that structural attributes of a housing unit can raise its price such as the house size and floor level, and as such a unit at every floor higher comes with a price. This is due to higher floors having better views and therefore a higher property price (Ki and Jayantha, 2010). Liu et al. (2018) find the same effect and add that there may be prestige associated with high locations and these effects result in a high-floor premium in residential buildings (Liu et al., 2018). This is not limited to residential units. Commercial tenants also value the views of higher floors (Liu et al., 2018).

Independent of the building location Koster et al. (2014) found that Dutch firms are willing to pay more in order to locate their offices in a high-rise building (a building higher than the average) as workers are more productive in high-rise office buildings (Koster et al., 2014). High productive firms prefer to locate at the higher floors, whereas retail and lower productive firms tend to locate at lower floors (Liu et al., 2018).

The agglomeration economies in high-rise buildings allowing for higher productivity is reflected in the price of units within high-rise buildings (Koster et al., 2014). Office rents likely reflect land values, and if agglomeration economies are capitalized in land values then they are expected to be also reflected in office rents (Drennan and Kelly, 2011). Liu et al. (2018) mention that Ahlfeldt and McMillen (2015) find a positive relationship between building heights and land rents. The preference of more productive firms to locate at upper floors is also reflected in the rents where moving up from the second floor causes rent to increase by roughly 0.6% per floor with a steeper rent gradient high up off the ground at a typical high-rise building (one of about forty floors). However, given the trade off between vertical amenities and street access, when moving up from the ground floor to the second floor, rents drop by up to 50% as the product becomes less accessible and less attractive to the consumer (Liu et al., 2018).

A few incidents affected people's perception of high-rise buildings such as the September 11th attacks in the U.S.A. The attacks made people reluctant to be in dense city centers and high-rise buildings especially shortly after the attacks (Abadie and Dermisi, 2008). Abadie and Dermisi (2008) find that the economic activity in Central Business Districts are significantly affected by changes in the perceived level of terrorism. They conclude this based on the increased vacancy rates experienced in the three most distinctive landmark buildings in Chicago and their vicinities compared to other areas of Chicago (Abadie and Dermisi, 2008). Despite these incidents, agglomeration economies and high-rise buildings positive externalities continue to play an important role encouraging further construction of such buildings.

Where are high-rise buildings concentrated?

High-rise buildings are mostly in the centre of these cities where the value of land is high, which encourages developers to make most use of the land by building upwards (Ahmad et al., 2017). Such buildings tend to be in dense city centers, with high employment rates which is typically the case in Central Business Districts (CBD) of cities (Ali and Kodmany, 2012). Agglomeration economies are present in CBDs of the larger metropolitan office markets rather than the smaller or suburban office markets (Drennan and Kelly, 2010) which explains further why high-rise buildings tend to be in the city centers.

This also is partly due to height restrictions which municipalities place in certain parts of the city. Some cities restrict the heights of buildings and the density of urban development so that they protect public health and safety (Grether and Mieszkowski 1980). Authorities realize the externalities of high-rise buildings and therefore their location is regulated. For example, city officials in Dallas, Texas made land use regulations as a result of complaints from home owners towards office high-rise buildings in the vicinity (Thiboudeau, 1990). This is not specific to the U.S.A, as there are also similar restrictions in the Netherlands. For example, buildings in Breda are not allowed to be higher than the Grote Kerk's 97 meters high building (NL Times, 2019).

The effect of high-rise buildings is certainly not limited to the units within the buildings themselves but extends to the urban environment including the properties in the vicinity. High-rise buildings and the dense urban structure around them has both positive and negative externalities.

External effects of high-rise buildings

The effects of high-rise buildings is not limited to the occupants within them but also extends to the surrounding environment. Several positive and negative effects make high-rise buildings a debatable concept whether an advantageous addition or not to a neighborhood. Table 2.1 presents a summary of a selection of key external effects.

Table 2.1: High-rise Buildings Externalities

Negative		Positive	
Externality	**Literature**	**Externality**	**Literature**
Traffic and parking congestion	Broyer (2002) indicates they can cause traffic problems (Gifford, 2007). Shin and Woo (2009) also refer to the same effect.	**Increased social interaction**	Churchman (1999) indicates that high-rise buildings may provide better opportunities for social interaction (Gifford, 2007). Ding (2013) also finds the same effect
Damage to a neighbourhood character	Broyer (2002) indicates a clustering of high-rise buildings can damage to a neighbourhood's character (Gifford, 2007).	**Tourism**	Shin and Woo (2009) point out the uplift in technology innovation which constructing high-rise buildings encourages in order to have smart solutions for earth-quake resistance for example.
Crime and security issues	Gifford (2007) points out that high-rise buildings create room for strangers to share the semi- public areas within those buildings. The fear of strangers in such buildings is then associated with fear of crime.	**Agglomeration economies**	High-rise buildings provide an opportunity for a high density of workers to be clustered in space and therefore exploit agglomeration economies (Helsley and Strange, 2008)
Air circulation	clustering of high-rise buildings can create unpleasant restriction on air circulation. In Beijing there are locational variations of maximum building height, the purpose of which is to facilitate urban air circulation (Ding, 2013).	**Amenities**	Visitors and residents of high-rise buildings enjoy a great selection of amenities, and facilities resulting from the large number of people within a single building (Ali and Aksamija, 2008).
Visual intrusion	Thiboudeau (1990) argues that though high-rise buildings may cause visual intrusion which could negatively affect properties prices in the vicinity, these effects decrease rapidly with distance.	**Encouragement for innovation**	Shin and Woo (2009) points out the potential tourist spots which high-rise buildings can create.
Shadows	High-rise buildings have potential to affect the surrounding environment by casting shadows and blocking views and sunlight (Ali and Kodmany, 2012).	**Provision for green space**	Broyer (2002) indicates that the smaller footprint which high-rise buildings occupy leaves more space for parks and green and open space (Gifford, 2007).

As high-rise buildings impact their surrounding environment, the positive and negative externalities as a result may affect the price of residential properties in the vicinity.

Shadows effect

In addition to the externalities discussed above, the shadows resulting from high-rise buildings is an additional key effect which has potential to affect residential properties prices. High-rise buildings have potential to affect the surrounding environment by casting shadows and blocking views and sunlight (Ali and Kodmany, 2012). This effect on the urban environment around high-rise buildings such as parks has been investigated in the literature to some extent, but not on the price of residential properties. Shadows can be beneficial particularly when blocking the direct sun light to pedestrians during the hot summer months (Bongiorno et al., 2019) but the effect may not be as beneficial when it comes to the prices of residential properties in the vicinity.

The effect of development

Urban development tends to raise the price of properties in the vicinity (Hyun and Milcheva, 2019). Ki and Jayantha (2010) find that urban redevelopment creates positive externalities, which reflect on the environment in which the residential units are located. This plays a role and benefit residents in the vicinity and eventually reflects onto housing prices (Ki and Jayantha, 2010). As high-rise buildings can be considered a form of development, they essentially play a role in the effect on house prices.

This effect has been noted in several development projects, such as the effect of the Stratford region redevelopment as part of the London 2012 Olympics. The upgrades and infrastructure improvements in the area, contributed positively to the property prices. Research shows that properties up to 3 miles away from the Olympic Stadium sell for 5% higher (Kavetsos, 2012). Improvement of accessibility resulting from development are also reasons in the resulting increased house prices. Boarnet and Chalermpong (2010) point out that urban economic theory suggests that if highways improve accessibility, the accessibility premium will be reflected in higher land and house prices (Boarnet and Chalermpong, 2010). Hyun and Milcheva (2019) find that announcing an urban redevelopment in Seoul affected property prices in the vicinity, which indicates further evidence (Hyun and Milcheva, 2019). Their results show that after a project was announced to the public, apartment prices within 0.5 km from the project site had a 7.3% increase in their price. They also find that this effect faces a decay effect that the price premium decreases to 2.4% in 0.5–1 km radius from the project site and dissipates beyond 1 km (Hyun and Milcheva, 2019).

Furthermore, Thiboudeau (1990) looked into the effect of a high-rise office building in Dallas on the value of small residential properties in North Dallas in the U.S.A. Thiboudeau (1990) found that the high-rise (Lennox building) affected the value for nearby houses by discounting it by as much as 15%. And properties 1 kilometer away from Lennox sold for a 5% premium. The aggregate effect of Lennox ultimately increased aggregate residential property values of about 1% (Thiboudeau, 1990).

Regardless of the negative externalities that may affect the price of properties around high-rise buildings, they still present an influx of properties to the market. This addition is essentially an increase in the supply which has potential to cause a reduction in price. However, this may not apply to the analysis of this paper if 'city by year' fixed effects (discussed in section 5) are incorporated into the analysis in which case the effects are compared within a city. And therefore, the supply effect is likely to be negligible because the supply effect typically raises the supply curve within the city as the supply effect is potentially present at a higher level than a particular city. In other words, the research design (presented in section 3) essentially precludes from measuring the supply effect as it looks at properties within cities. Furthermore, there are constraints that would limit this supply effect reduction to house prices. The geographic limitations on the areas available to build houses, such as the water bodies which leads to less chances of investment on average relative to the size of the existing housing stock in the cities studied (Paciorek, 2013). And therefore, given the housing shortage in the cities being studied, particularly Amsterdam, and the constraints on supply present, an influx of properties through a high-rise can be considered an increase of supply which is of limited effect on house prices.

3. Empirical Methodology

This section describes the methodology, the model used in the analysis and the assumptions made in the process. Utilizing the dataset available (detailed in section 4) which covers house transactions in three major cities in the Netherlands, the paper's focus is determining the effect of a high-rise building on the price of residential properties located in the vicinity. A difference in difference (DiD) model is utilized to estimate this effect.

Let log p_{ijt} be the dependent variable which is the log of the price of property i, in neighborhood j, in year t. D_{ijt} is a dummy variable, which equals one if a property i, in neighborhood j, in year t, is at a distance (d) from a high-rise building. λ_t accounts for year fixed effects to control for the yearly increasing house price trend.

$$ln\, p_{ijt} = \beta_1 D_{ijt} + \lambda_t + \varepsilon_{ijt} \qquad (1)$$

Where β_1 captures the average treatment effect and ε_{ijt} is an identically and independently distributed error term. The error term absorbs some elements such as variables related to the environment in which the house is located, for example the presence of a canal, and its correlated to the treatment effect.

Equation 1 captures the essence of the treatment effect however does not fully address the omitted variable bias. The Beta (β_1), which represents the treatment effect may not be causal because it could be correlated to characteristics of a neighborhood that we don't observe presenting an endogeneity problem where the independent variable is correlated with the error term. Such as the fact that high-rise buildings are mostly located in centers of cities and not randomly distributed. High-rise buildings are built in expensive attractive areas for developers as they could generate higher profits due to higher rents in such areas, which perhaps can lead to a selection bias.

Since several possible unobserved factors characterize the treatment areas and can have an effect on house prices, detailed fixed effects are required in the model. Location (six digit Post Code- PC6) fixed effects are included to control for characteristics that do not change over time such as distance to a park for example. Therefore, location fixed effects (PC6) are meant to control for the unobserved time invariant attributes which may be correlated with the error term ε_{ijt}.

Considering this, the model would be a hedonic price model as follows:

$$ln\, p_{ijt} = \beta_1 D_{ijt} + C_{ijt} + \lambda_j + \lambda_t + \varepsilon_{ijt} \qquad (2)$$

where λ_j is six digit Post Code (PC6) fixed effects and C_{ijt} is a set of house control variables including but not limited to house type dummies (an apartment, semi detached or detached), construction year dummies ,house size, number of rooms, maintenance quality, and the inclusion of central heating.

Though equation 2 incorporates a set of detailed fixed effects there is still a possibility for an omitted variable bias and therefore a careful selection of control and treatment groups must be done to address this. Without an appropriate selection of treated and control groups we would not address the selection effects. Not only do we expect high-rise buildings to be located in places where stronger price growth is expected (as the developers' aim is higher profits) which is addressed by the PC6 fixed effects but also in places with higher price trends being higher in these areas compared to the suburbs for example. Using the appropriate control and treatment groups would address this variation. The appropriate selection of treatment and control groups enables us to observe house prices in areas which have the same price trends, looking at the variation in time and therefore three different alternatives were evaluated for the choice of treatment and control groups.

The first option considers the treatment group to be observations within a 1km buffer around the high-rise of interest, because the effect of high-rise buildings on nearby properties prices is expected to be local and control groups to be all other observations regardless whether close or far from a high-rise building. This option does not address the omitted variable bias problem because by including observations in all other areas, we do not specifically take into consideration areas in which high-rise buildings are likely to be constructed. Properties in central attractive areas are expected to have a higher price growth. This option selects control groups without considering their potential to be areas in which high-rise buildings would be constructed such as sub-urban areas and therefore is deemed un-suitable for the analysis.

The second option considers the treatment group to be observations within a 1km buffer around the high-rise of interest and the control group to be observations farther than 1km but less than 2km from the high-rise (treatment) of interest in order to exclude observations in the sub-urban areas. The control group in this option still does not form a comparable group to the treatment group as the observations would always be farther from the high-rise buildings than the treatment group observations which is problematic bearing in mind that the high-rise buildings overall effect is expected to be local, which again would introduce an omitted variable bias problem. Therefore, this option is also deemed un-suitable for the analysis.

The third option is the preferable option and is the source of identifying variation to measure the treatment effect. It considers the treatment group to be observations within a 1km buffer around the high-rise of interest and the control group to be observations also within a 1km buffer around a future high-rise buildings which has not been constructed yet (since high-rise buildings are constructed in different years), taking the reference year of analysis as the treatment construction date. Control group observations are a composite of years before and after the high-rise building (treatment) construction year. This leads to a much smaller sample, but addresses the problem of unobserved time trends and omitted variable bias as no unobserved characteristics of an area are present.

This option is preferred because it would enable us to identify a causal effect. It enables us to understand the trend in price change of properties before and after the treatment (variation in timing) because we are essentially comparing two areas of similar price trends. We look at the price trend before and after the construction of the treatment and compare those prices to the equivalent in the control area in which a high-rise still has not yet been constructed. This way we can capture the change in price trend due (and only due to) the high-rise building, addressing the problem of the omitted variable bias. The price change in this case would not be due to unobserved reasons as the only difference between control and treatment observations is the high-rise building presence and therefore this option adequately deals with differences in unobserved local trends. The differences in price changes within the city must be addressed. The aim is not to absorb all variation in price changes as this does not aid in identifying the effect of high-rise buildings, instead the aim is to keep the price changes related to high-rise buildings only.

There are two possibilities for the control group in this option where the first possibility is high-rise buildings within the data set (constructed between 2000 and 2019) but of a later construction date than the reference year (construction year of treatment). The second possibility is high-rise buildings planned in the future, further than the dataset years coverage (i.e. beyond year 2020). This consists of planned high-rise buildings or ones that have been planned but put on hold. Both control group possibilities will be considered to gain a larger number of control groups as a larger number of observations provides higher accuracy in the results. Therefore, this option (temporal variation) is chosen for the analysis as it provides the most suitable set of control and treatment groups. Provided this, transactions within 1km from the earliest constructed high-rise (as there could be multiple high-rise buildings present within 1km) taking place after the construction year are considered treated. And the transactions within the same distance taking place before the construction year of the high-rise building are considered control transactions.

The overall effect of high-rise buildings on nearby properties prices is expected to be local and therefore an area of a 1km buffer of those buildings is taken to be the area of interest. However, geographical extent analysis will be done using the same model but with larger distances where high-rise buildings beyond the 1km distance will also be tested to check if high-rise buildings located farther than a 1km distance can also affect house prices. The effect is expected to decay as the distance to the (earliest constructed) high-rise building increases.

4.1 Multiple high-rise buildings effect

One may argue that high-rise buildings tend to be clustered in space, and the presence of an additional high-rise buildings can also have an additional effect on property prices which would be useful to understand. Positive and negative externalities of high-rise buildings are more impactful when there are multiple towers in an area such as the shadows and agglomeration economies for example. Therefore, this paper looks into the effect of a second high-rise located within a 1km distance. To estimate this, we use:

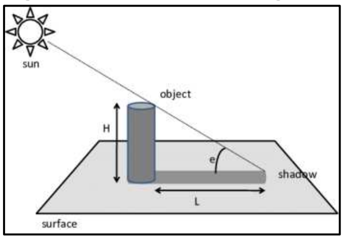
$$ln\, p_{ijt} = \beta_1 D_{ijt} + \beta_2 D2_{ijt} + C_{ijt} + \lambda_j + \lambda_t + \varepsilon_{ijt} \qquad (3)$$

where $D2_{ijt}$ is a dummy variable equal to one if there are two high-rise buildings present within 1km of a property.

4.2 Shadows

One of the negative externalities of high-rise buildings is the shadows they impose. The paper aims to understand if these shadows have an effect on house prices. The shadow length varies throughout the year as the sun altitude varies each day of the year. Short winter days result in longer shadows.[2] provided that the high-rise buildings in the data are 100m high and above, and provided that the highest building is 165m, the shadow length is estimated to be approximately 500m at most for the analysis. Therefore, the shadow assessment will consider housing transactions within a 500m buffer only as the shadows are a deemed a local effect of high-rise buildings. Figure 4.1 illustrates the method used to calculate the shadow length.

Figure 4.1: Shadow length calculation methodology



Source: https://www.researchgate.net/

[2] The sun altitude values for the Netherlands throughout the year are obtained from https://www.suncalc.org/ accessed on 19 May 2020.

The 500m buffer around high-rise buildings is split into a north and south sections. Houses located in the north section are assumed to receive shadows and houses located in the south section do not.

In order to understand the effect of shadows on house prices, a dummy variable is incorporated in the model which indicates whether a house is located to the north or south of a high-rise building. The model therefore is as follows:

$$ln\, p_{ijt} = \beta_1 D_{ijt} + \beta_3\, S_{ijt} + \beta_4\, S2_{ijt} + C_{ijt} + \lambda_j + \lambda_t + \varepsilon_{ijt} \qquad (4)$$

Where S_{ijt} takes a value of one if the property i, in location j, in a year t is located in the north of the high-rise and zero if the property is located in the south of the high-rise building.

Similarly to understand the effect of shadows by a second high-rise located within 500m, the variable $S2_{ijt}$ takes a value of one if the property i, in location j, in a year t is located in the north of both the first and second earliest constructed high-rise buildings within 500m and zero if the property is located in the south of those buildings.

4. Data Description

The analysis in this paper is based mainly on two datasets. The data was provided by the VU and complimented by further research. This predominantly consists of micro-data of housing transactions provided by the Dutch Association of Realtors (NVM) and information on buildings in North and South Holland covering 3 cities namely Amsterdam, Rotterdam and the Hague as these are the cities with the largest share of high-rise buildings in the Netherlands.

4.1 NVM data

The first dataset is the micro-data on housing property transactions provided by the NVM for the three cities of interest. This consists of 323,616 transactions spanning from the year 2000 to 2019. This is deemed a large enough sample to conduct the research intended. Every observation consists of information on each property with a total of 70 variables including the size in square meter, the number of rooms available, presence of a garden, a garage, and other housing characteristics. Moreover, each observation includes information on the transaction conducted such as the house price and the date of the transaction. The data also includes repeated sales; which are houses that were sold multiple times over the years which can be identified through the variable 'house ID'.

Observations taking place within the high-rise buildings were omitted as the interest is the effect of high-rise buildings on the surrounding residential properties rather than within. Properties with more than 10 rooms are excluded as the focus is on apartments in the urban city.

Furthermore, a few variables were created to serve the analysis. For example, a variable for the logarithm of price (log price) was created to obtain a normal distribution as the distribution of the price data is skewed due to some observations sold at an exceptionally high price affecting the distribution of the data. The (log price) normal distribution allows for more sensible interpretation of the regression coefficients[3]. Similarly, the logarithm of house size was created as the house size data distribution is also skewed.

The location of each transaction is available, and this is used to calculate the distance between each house and high-rise buildings in the vicinity through the use of Geographic Information System (GIS). The four closest high-rise buildings are then sorted in order as per their construction year to obtain the earliest constructed high-rise in the vicinity. These distances may vary for each property as the adjacent high-rise buildings are different for each property. The high-rise with the earliest construction year is deemed the building to cause an effect on the price of houses within the vicinity and therefore this distance is used in the analysis. The vicinity is then defined as a 1km distance for the baseline analysis and 1.5km and 2km for the geographic extent analysis. This is done through creating variables D, Da, and Db. Each takes a value of 1 if the earliest constructed high-rise is located within 1, 1.5 and 2km respectively.

As for shadows, the variable Sh1t is created to indicate properties located in the north section of the 1km buffer around the earliest constructed high-rise. Similarly, the variable Sh2t is created to indicate properties located in the north section of the 1km buffer around the second earliest constructed high-rise.

[3] The price data distribution plots are included in Appendix A.

4.2 Netherlands Buildings Information

The second dataset is buildings information for North and South Holland which covers the 3 cities of interest; The Hague, Amsterdam and Rotterdam and includes information on exact location, height, construction date, number of floors and the buildings use. The dataset spans from 1960 to present. For the analysis, buildings that are 100 meters and higher were extracted as the high-rise buildings of interest. Unoccupied buildings as well as buildings constructed prior to year 2000 were excluded[4] from the dataset.

Table 4.1 provides a list of the highest 10 existing high-rise buildings in which we note that they are mainly mixed use or commercial/offices/residential. The Maastoren Tower, located in Rotterdam and constructed in 2006 is currently the highest building with a height of 165 meters.

Table 4.1: Top 10 highest existing buildings in the Netherlands.

Building	Height (m)	Constructed
Maastoren	165m	2010
New Orleans	158m	2010
City Tower (Babylon)	158m	2011
Montevideo	152m	2005
De Rotterdam	151m	2013
Millennium Tower	149m	2000
World Port Centre	134m	2001
Het Strijkijzer	132m	2007
De Kroon	131m	2011
Prinsenhof	128m	2006

Source: Buildings Dataset

The data was complimented with information (construction year and height) on the missing existing buildings using the TU Delft database[5]. The equivalent information for planned high-rise buildings was researched and added to the dataset[6]. Figures 4.1 to 4.3 show the location of the existing and planned high-rise buildings in the three cities and we note that the high-rise buildings are predominantly located in the city center.

4 As the housing transactions dataset available goes back to the year 2000 only, 100m and higher buildings constructed prior to the year 2000 are excluded from the analysis.

5 3D Basisregistratie Adressen en Gebouwen (BAG) Delft tool is used to obtain existing buildings height and year of construction accessed via: http://3dbag.bk.tudelft.nl/ on 20 May 2020

6 List of existing and proposed buildings (100m and higher) along with the sources is provided in Appendix B.

Figure 4.1: Spatial distribution of high-rise buildings (100m and higher) in Rotterdam.

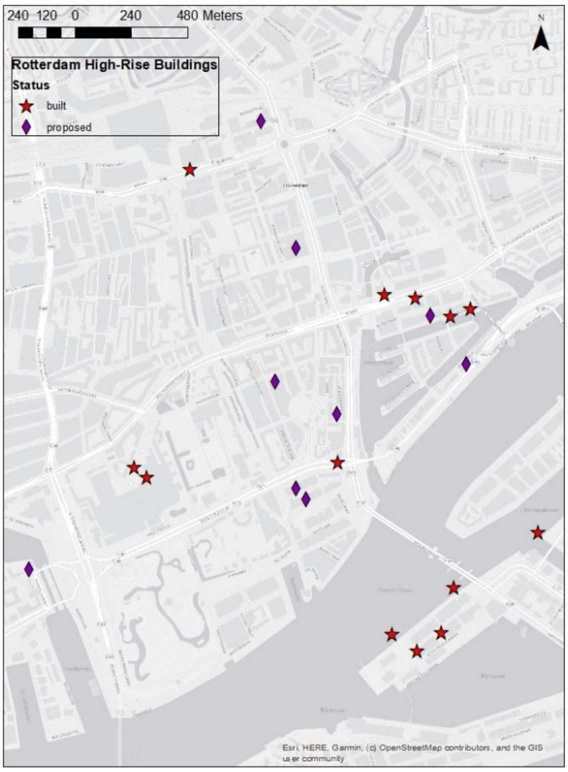


Figure 4.2: Spatial distribution of high-rise buildings (100m and higher) in Amsterdam.

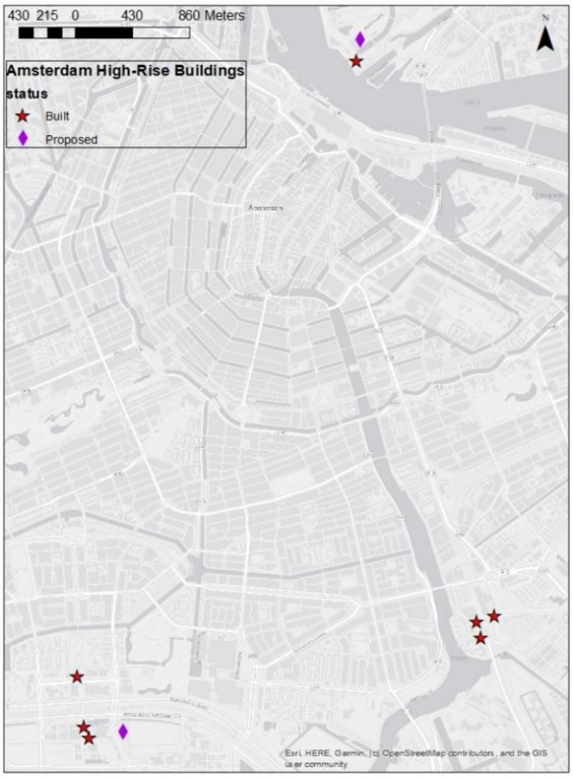
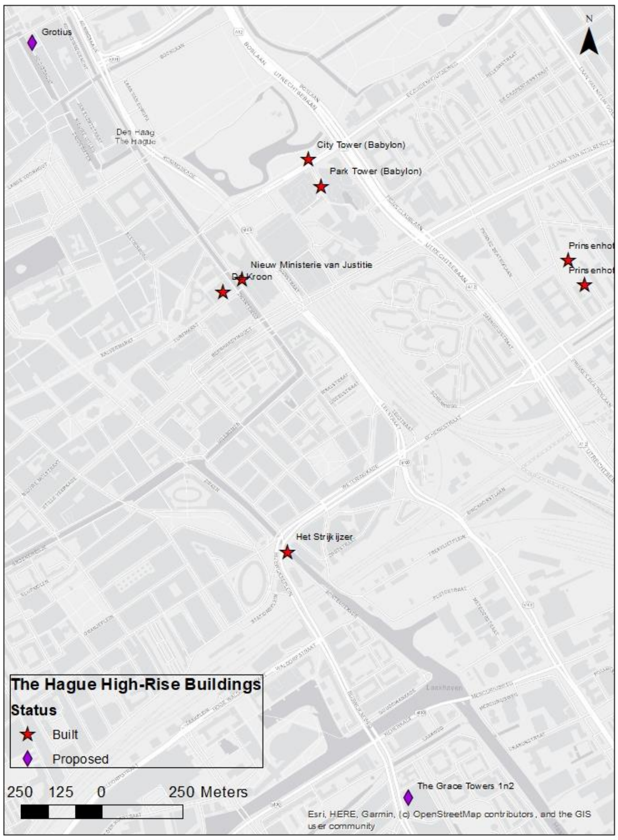


Figure 4.3: Spatial distribution of high-rise buildings (100m and higher) in The Hague.



4.3 Descriptive Statistics

The high-rise buildings dataset consists of a total of 40 high-rise buildings which are 100m or higher, and constructed post the year 2000. 9 buildings are in Amsterdam,2 of which are proposed, 22 in Rotterdam, 9 of which are proposed and 9 in The Hague, 2 of which is proposed. The average height is 134m, the maximum is 165m and the minimum is 100m.

Looking at the housing transactions for the 3 cities combined, about 78% of the properties are apartments, 14% are terraced houses, 6% are semi-detached and 1% are detached houses. The highest transaction price is 10M Euros, and the lowest is 10 thousand Euros and the average is 270 thousand Euros. The average transaction price per square meter is about 2,700 Euros. The oldest property was constructed in the year 1905 and the most recent post the year 2000. On average the number of rooms is 3 in each property. About 4% are newly built. 84% of the properties are in good maintenance state and 87% have central heating. The drop in the number of transactions from the original is due to the exclusion of properties within the high-rise buildings, and properties with more than 10 rooms.

Looking into each city of interest, about 87% of the properties in Amsterdam are apartments and 9% are terraced houses. The highest transaction price is 10M Euros, and the lowest is 12 thousand Euros. The average price is 319 thousand Euros. The average house size is 89m^2. The oldest property was constructed in the year 1905 and the most recent post the year 2000.

About 68% of the properties in Rotterdam are apartments and 21% are terraced houses. The highest transaction price is 3.8M Euros, and the lowest is 10 thousand Euros. The average price is 211

thousand Euros. The average house size is 105m^2. The oldest property was constructed in the year 1905 and the most recent is post the year 2000.
About 75% of the properties in The Hague are apartments and 17% are terraced houses. The highest transaction price is 8M Euros, and the lowest is 10 thousand Euros. The average price is 242 thousand Euros. The average house size is 111m^2. The oldest property was constructed in the year 1905 and the most recent post the year 2000.

Table 4.2 provides a summary description of the overall transactions in the 3 cities. Descriptive statistics for each of the three cities individually is included in Appendix C.

Table 4.2: Summary descriptive statistics of transactions in the 3 cities.

Variable	Observations	Mean	Std. Dev.	Min	Max
D (high-rise within 1km)	321,391	0.827	0.378	0	1
Da (high-rise within 1.5km)	321,391	0.797	0.402	0	1
Db (high-rise within 2km)	321,391	0.793	0.405	0	1
Dc (high-rise within 500m)	321,391	0.843	0.364	0	1
D2 (2 high-rises within 1km)	321,391	0.726	0.446	0	1
Sha_1t (shadow by 1 high-rise)	321,391	0.335	0.472	0	1
Sha_2t (shadow by 2 high-rises)	321,391	0.211	0.408	0	1
Price	321,391	266863	205657	10000	1.00E+07
Price (log)	321,391	12.3	0.589	9.21	16.1
price for a sqm	321,391	2720	1439	108	70000
Size (log)	321,391	4.51	0.407	3.26	6.28
No. of Rooms	321,391	3.73	1.48	1	10
Terraced	321,391	0.143	0.35	0	1
Semi Detached	321,391	0.0574	0.233	0	1
Detached	321,391	0.0111	0.105	0	1
Apartment	321,391	0.788	0.408	0	1
Maintenance quality is good	321,391	0.84	0.367	0	1
New built	321,391	0.0357	0.185	0	1
Garage	321,391	0.0912	0.288	0	1
Garden	321,391	0.986	0.118	0	1
Central heating present	321,391	0.874	0.332	0	1
Listed	321,391	0.0184	0.134	0	1
Construction year missing	321,391	0.00937	0.0964	0	1
Construction year 1906-1930	321,391	0.235	0.424	0	1
Construction year 1931-1944	321,391	0.145	0.352	0	1
Construction year 1945-1959	321,391	0.0852	0.279	0	1
Construction year 1960-1970	321,391	0.0898	0.286	0	1
Construction year 1971-1980	321,391	0.0494	0.217	0	1
Construction year 1981-1990	321,391	0.0835	0.277	0	1
Construction year 1991-2000	321,391	0.105	0.307	0	1
Construction year post 2000	321,391	0.0903	0.287	0	1

5. Results and Discussion

This section presents the findings of the study and discusses the causal effects found in the analysis. Using the data and methodology presented earlier in the paper, several regressions were conducted in order to test and quantify the effect of a single and multiple high-rise buildings on the price of residential properties in the vicinity as well as the effect of shadows they impose.

First the baseline effect is presented in which the effect of the earliest constructed high-rise building within a 1km distance is investigated utilizing the difference in difference model (Equation 2). Several high-rise buildings in the data are present in the vicinity of housing transactions, and therefore the effect of the earliest constructed building is taken into consideration as it is deemed the building causing the potential effect on price. To understand the effect further, the model is then relaxed in two dimensions in order to analyze the development of the effect. The first dimension investigates the effect of a high-rise building if located farther than 1km to understand the relationship of the effect to distance (Equation2). The second dimension investigates the effect if more than one high-rise building is present within 1km from a housing transaction (Equation 3). The shadow effect is included in the model (Equation 4) to investigate the effect of a high-rise, and 2 high-rise buildings shadows on the price of residential properties.

5.1 Single High-rise Building

Baseline

The overall effect of a single high-rise building that is within a 1km distance is analyzed using the difference in difference model (Equation 2) which includes housing controls to make sure that the effect is not over or underestimated. Some of these control variables do not change over time and hence we note in the results that their coefficients drop out of consequence regressions. The time invariant effects are absorbed by the fixed effects in the model. Since several possible unobserved factors characterize the treatment areas and can have an effect on house prices, as they are attractive locations, such detailed fixed effects are included in the model. The year fixed effects in the model control for the yearly increasing price trend. Location (Pc6) fixed effects in the model control for characteristics that do not change over time such as distance to a park for example. They are essentially added to control for all unobserved time-invariant characteristics of a neighborhood which may be correlated with the error term. Since the 3 cities; Rotterdam, The Hague and Amsterdam have different price trends, the model is also regressed using 'city by year' fixed effects in order to cater for this variation in price trends between the cities. Furthermore, the model is regressed using house ID fixed effects absorbing the time invariant effects to understand the effect at the house level using repeated sales which are houses in the data sold multiple times over the years.

Four combinations of these fixed effects are used and presented in Table 5.1. The effects found are likely to be causal provided the selection of treatment and control groups (discussed in section 3: methodology). The regression command 'reghdfe' was used to run the model with all its fixed effects.

Column (1) presents the results for the model with year and PC6 fixed effects combined. Column (2) then presents the results using the year and house ID fixed effects combined. Column (3) presents the results for the model with 'city by year' and PC6 fixed effects combined. And finally, Column (4) presents the results but with 'city by year' and house ID fixed effects combined.

In both Column (1) and Column (2) year fixed effects are used only, which addresses the yearly increase of house prices. However, with the data covering 3 major cities in the Netherlands which have different price trends, 'city by year' fixed effects were necessary in order to take this into consideration. Therefore Column (3) and Column (4) are produced in which we note that the coefficients are smaller compared to Column (1) and Column (2) which is potentially caused by the data containing a larger amount of high-rise buildings in Rotterdam, in which the price trend is slower than the other two cities in the data; The Hague and Amsterdam. We note that the results in Column (4) where 'city by year' and house ID fixed effects were used, have relatively larger standard error compared to Column (3). The number of observations is also smaller for Column (4) compromising the accuracy as it is a conservative specification considering house ID as a fixed effect. This consists a selective sample of only properties or houses which have been sold more than once in different years in the sample period which may not be a random group and is deemed quite conservative. Therefore Column (3) specification is deemed the most reliable and considered as the preferred specification.

The building effect is represented by the variable D which is defined as the treatment effect for a high-rise building within a 1km distance. The coefficient -0.021 for this variable suggests that the presence of a high-rise building within 1km leads to a 2% decrease in house prices and it is statistically significant at the 1% significance level. This is due to the negative externalities a high-rise building can potentially cause such as the relatively higher traffic generation, and visual intrusion. The R^2 for this specification is 0.934 which is sufficient as it is a high enough value (close to 1). The coefficients of control variables in the table show results that reflect the effect of improved housing attributes or essentially enhanced housing quality on the price of a particular house. For example, we note that for an additional 1% square meter in the house size we get a 0.72% increase in the price and it is statistically significant at the 1% significance level. For each additional room in the house, the house price increases by 1.8% and it is statistically significant at the 1% significance level. Having a good maintenance quality in the house increases the price by 13.5% since a better quality house would sell for a higher price, and it is statistically significant at the 1% significance level. Central heating present in the house increases the price by 6% which also is expected as a central heating system in the house improves the quality, and it is statistically significant at the 1% significance level. Houses constructed post the year 2000 sell for a higher price indicating that people value modern newly built properties which is also statistically significant at the 1% significance level.

Table 5.1: Baseline- overall effect of a single high-rise building within 1km.

Dependent variable: Log Price

	(1) Year and PC6	(2) Year and House ID	(3) City by Year and PC6	(4) City by Year and House ID
Treatment -High-Rise within 1km	-0.046***	-0.045***	-0.021***	-0.028***
	(0.004)	(0.007)	(0.004)	(0.006)
Size (Ln)	0.720***	0.255***	0.730***	0.290***
	(0.005)	(0.034)	(0.005)	(0.032)
Number of Rooms	0.018***	0.002	0.015***	0.001
	(0.001)	(0.004)	(0.001)	(0.004)
Terraced	0.146***		0.149***	
	(0.007)		(0.006)	
Semidetached	0.146***		0.151***	
	(0.011)		(0.011)	
Detached	0.421***		0.403***	
	(0.030)		(0.029)	
Maintenance quality is good	0.127***	0.137***	0.127***	0.136***
	(0.003)	(0.006)	(0.003)	(0.006)
newbuilt	0.044***	0.053**	0.041***	0.041
	(0.010)	(0.027)	(0.009)	(0.025)
Garage	0.057***	0.015	0.060***	0.014*
	(0.004)	(0.009)	(0.004)	(0.009)
Garden	-0.045***	0.001	-0.049***	-0.017
	(0.011)	(0.030)	(0.010)	(0.028)
Central heating	0.059***	0.070***	0.058***	0.068***
	(0.003)	(0.007)	(0.003)	(0.007)
Listed (as cultural heritage)	0.034***	0.012	0.017**	-0.004
	(0.008)	(0.018)	(0.008)	(0.017)
Construction year missing	0.199***		0.191***	
	(0.017)		(0.016)	
Construction year 1906-1930)	-0.048***		-0.039***	
	(0.007)		(0.007)	
Construction year 1931-1944)	-0.059***		-0.069***	
	(0.008)		(0.008)	
Construction year 1945-1959	-0.089***		-0.093***	
	(0.010)		(0.010)	
Construction year 1960-1970	-0.069***		-0.073***	
	(0.015)		(0.014)	
Construction year 1971-1980	-0.098***		-0.100***	
	(0.013)		(0.013)	
Construction year 1981-1990	-0.080***		-0.083***	
	(0.010)		(0.010)	
Construction year 1991-2000	0.060***		0.055***	
	(0.009)		(0.009)	
Construction year post 2000	0.090***		0.094***	
	(0.010)		(0.010)	
Observations	30,836	8,807	30,836	8,807
R-squared	0.929	0.969	0.934	0.973

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Geographical Extent

In order to understand whether the effect changes with distance, high-rise buildings located farther away are considered. The effect is then tested if the building (with the earliest construction date) is within 1.5km and 2km. The same model is used for this analysis (equation 2) but using a distance of 1.5km and 2km respectively. Similar to the baseline analysis, the regression is done using four specifications of fixed effects. This is presented in Table 5.2.

Looking at the preferred specification Column (3), we note that the coefficients for the variables Da and Db representing the effect of the high-rise building within 1.5km and 2km, suggest that the presence of a high-rise building within 1.5km leads to a 1.9% decrease in the house price and a 1.6% decrease in the house price respectively. Both coefficients are statistically significant at the 1% significance level. Comparing these coefficients to the equivalent in the baseline scenario, we note that the effect is less, indicating that the effect decays with distance. That is potentially due to the effect of a high-rise building being a local effect. Negative externalities of high-rise buildings such as shadows and potential traffic congestion are only present in the close vicinity of such buildings and as we move farther away, the traffic generated by such buildings dissipates, the visual intrusion decreases, and the negative externalities in general are less present, which is reflected in the decaying effect on house prices.

The geographical extent analysis is limited to 2km because analyzing the price of houses farther than 2km would start picking other effects unrelated to the presence of a high-rise building which would distort the results. As noted earlier, high-rise buildings are present in the centre of cities which are expensive areas where developers can charge higher prices and so considering houses far from the city centre (i.e. farther than 2km) will not enable us to understand the effect of high-rise buildings on the price trend of houses in such expensive areas, as the data would then include houses which aren't in such attractive central areas.

In addition to this, a robustness check is done for a high-rise building located within 500m only. This is shown in Table 5.3. We note that the coefficient for the variable Dc representing the effect of a high-rise within 500m on house prices in the preferred specification Column (3) to be -0.14 but statistically insignificant. The standard error is relatively larger, and the number of observations is considerably less than the 1km analysis and therefore the baseline is chosen to be the 1km distance.

Table 5.2: Geographical extent - effect of a single high-rise building within 1.5km and 2km.

Dependent variable: Log Price

	(1)	(2)	(3)	(4)
Treatment (D) High-Rise within 1km	-0.046***	-0.045***	-0.021***	-0.028***
	(0.004)	(0.007)	(0.004)	(0.006)
Treatment (Da) High-Rise within 1.5km	-0.047***	-0.046***	-0.019***	-0.028***
	(0.003)	(0.004)	(0.003)	(0.004)
Treatment (Db) High-Rise within 2km	-0.048***	-0.049***	-0.016***	-0.025***
	(0.002)	(0.004)	(0.002)	(0.004)
House Controls	Yes	Yes	Yes	Yes
House ID Fixed Effects	Yes	Yes	Yes	Yes
PC6 Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
City by Year Fixed Effects	No	No	Yes	Yes
Observations	61,781	17,302	61,781	17,302
R-squared	0.934	0.972	0.939	0.976

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 5.3: Effect of a high-rise building within 500m.

Dependent variable: Log Price

	(1)	(2)	(3)	(4)
Treatment (Dc) High-Rise within 500m	-0.041***	-0.027**	-0.014	-0.010
	(0.008)	(0.013)	(0.008)	(0.014)
House Controls	Yes	Yes	Yes	Yes
House ID Fixed Effects	Yes	Yes	Yes	Yes
PC6 Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
City by Year Fixed Effects	No	No	Yes	Yes
Observations	8,099	2,126	8,099	2,126
R-squared	0.932	0.968	0.937	0.972

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

5.2 Multiple High-rise Buildings

The overall effect of multiple high-rise buildings located within a 1km distance is analyzed using the same difference in difference model (equation 3) using four combinations of fixed effects. This is presented in Table 5.4. The overall effect by the second high-rise is represented by the coefficient for the variable D2. Once, again the preferred specification is Column (3) as it takes into consideration the different price trends of the 3 cities in the sample and has a larger amount of observations compared to Column (4), and hence a better accuracy. The coefficient for the second high-rise within a 1km distance in the preferred specification is -0.016 and is statistically significant at the 5% significance level. This suggests that the presence of a second high-rise building within 1km leads to a 1.6% decrease in house prices. This is comparable to the effect of the first high-rise building effect indicating that the presence of second building leads to an additional reduction in house prices. This is potentially due to the further negative externalities which a second high-rise building would introduce such as further traffic congestion, further view blockage and hindrance to air circulation in the area.

Table 5.4: Effect of second high-rise buildings within 1km.

Dependent variable: Log Price

	(1)	(2)	(3)	(4)
Treatment (D) a High-Rise within 1km	-0.045***	-0.044***	-0.021***	-0.028***
	(0.004)	(0.007)	(0.004)	(0.006)
Treatment (D2) 2 High-Rise buildings within 1km	-0.072***	-0.081***	-0.016**	-0.044***
	(0.006)	(0.010)	(0.007)	(0.012)
House Controls	Yes	Yes	Yes	Yes
House ID Fixed Effects	Yes	Yes	Yes	Yes
PC6 Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
City by Year Fixed Effects	No	No	Yes	Yes
Observations	19,078	4,707	19,078	4,707
R-squared	0.921	0.967	0.927	0.972

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

5.3 Shadow Effect

The shadow effect is investigated by considering observations where both the earliest and second earliest high-rise buildings are within 500m, and particularly observations located in the north of these buildings. This distance is chosen since building shadows for the most part are local and would hardly exceed a 500 meters distance as discussed previously in the methodology section. The shadow effect of the first high-rise and second high-rise are represented by the variables Sh1t and Sh2t in Table 5.5. We note in the preferred specification, Column (3) that the shadow coefficient for the first high-rise is 0.008 and is statistically insignificant. Similarly the coefficient for the second high-rise is 0.011 and is also statistically insignificant. This indicates that the shadows effect is negligible. However, provided that the method utilized to estimate the effect is somewhat high-level, it is prone to measurement error, which is reflected in the relatively larger standard error, and therefore the result being biased towards zero.

Table 5.5: High-rise buildings shadows effect

Dependent variable: Log Price

	(1)	(2)	(3)	(4)
Treatment (Dc) a High-Rise within 500m	-0.045***	-0.038**	-0.019*	-0.021
	(0.010)	(0.016)	(0.010)	(0.016)
Shadows by first high-rise (Sh1t)	0.007	0.019	0.008	0.020
	(0.009)	(0.016)	(0.008)	(0.015)
Shadows by second high-rise (Sh2t)	-0.001	-0.019	0.011	-0.012
	(0.008)	(0.015)	(0.009)	(0.015)
House Controls	Yes	Yes	Yes	Yes
House ID Fixed Effects	Yes	Yes	Yes	Yes
PC6 Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
City by Year Fixed Effects	No	No	Yes	Yes
Observations	8,099	2,126	8,099	2,126
R-squared	0.932	0.968	0.937	0.972

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

6. Conclusion

This paper studied the effect of high-rise buildings on residential properties prices. Using a dataset spanning over 20 years from the NVM for three major cities in the Netherlands, the paper utilized a difference in difference model to find the effect. The paper presents the positive and negative externalities associated with high-rise buildings and finds that the effects are not present only in units within the buildings but also on properties surrounding the high-rise buildings. In order to determine the effect, a careful selection of treatment and control groups was done so that a causal effect is identified. Treatment and control groups are properties located in the centre of cities which make an attractive location for high-rise buildings in which developers tend to charge higher prices.

The effect was first determined for a single high-rise if present within a 1km distance, and then investigated further if the high-rise is located at a farther distance of 1.5km and 2km. The paper finds that a high-rise building within 1km leads to a 2% reduction in house prices. Furthermore, a high-rise within a 1.5km and 2km distance leads to a reduction of 1.9% and 1.6% in house prices respectively and all coefficients are statistically significant at the 1% significance level, indicating that the effect decays with distance. Furthermore, the paper investigates the effect of an additional high-rise building present within a 1km distance and finds that this leads to a further reduction of 1.6% in house prices, statistically significant at the 5% significance level. This explains the complaints residents voiced out when more high-rise buildings were announced in the country and particularly Rotterdam. Moreover, the paper investigates the effect of shadows on house prices, and finds that shadows do not particularly have an effect on house prices. However, the method utilized to determine shadows is high-levelled and therefore prone to measurement error and the effect found is statistically insignificant. Such an effect on house prices shall be taken into account by developers, real estate agents, as well as municipalities so that residents are potentially compensated for their loss.

There are several opportunities for further research to understand these effects further. The effect on commercial properties and offices could be investigated to understand if also high-rise buildings lead to a reduction in price on these properties as they do on residential properties. Moreover, further research could look into the shadows effect further using a detailed methodology which assigns different shadow values for different properties where the shadows is considered a continuous variable that varies in time, to find an accurate effect of the shadows on property prices.

High-rise buildings have both negative and positive externalities. There are benefits to building high up, and in a world where urbanism is on the rise, it is perhaps much needed in several cities in the world, however, we must be aware of the pros and cons so that the expansion of such buildings is well managed and done in a sustainable manner.

7. References

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8. Appendices

Appendix A: Price Data Distribution

Figure A1: Histogram of log price data

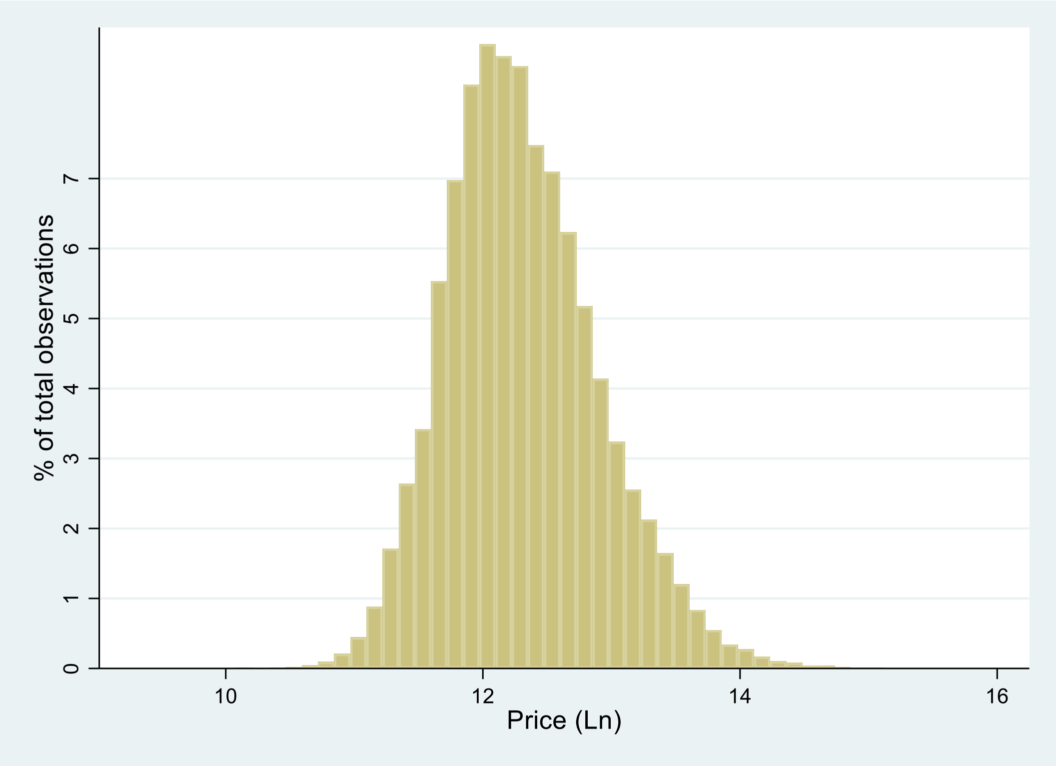
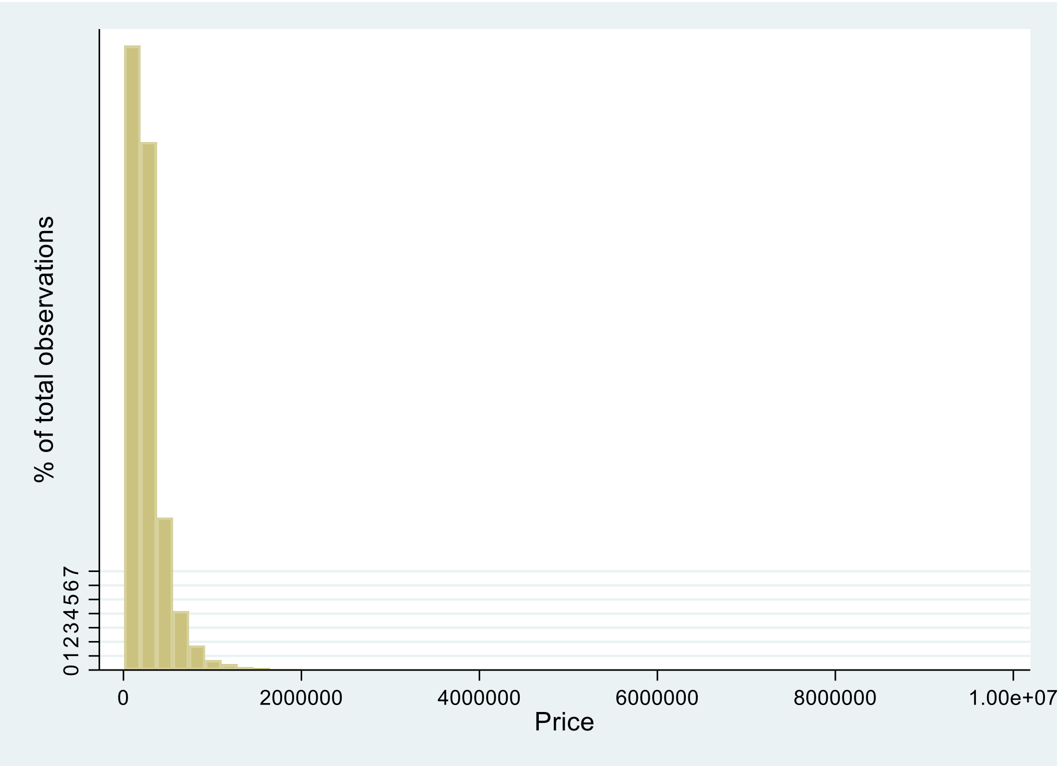


Figure A2: Histogram of price data



Appendix B: List of existing and proposed buildings, 100m and higher.

No.	City	Building Name	Height	Construction Year	Information Source
1	Rotterdam	Hoge Heren II	102	2000	Netherlands Buildings Data shapefile
2	Rotterdam	World Port Center	134	2000	Netherlands Buildings Data shapefile
3	Rotterdam	Millenium Tower	149	2000	Netherlands Buildings Data shapefile
4	The Hague	Prinsenhof	118	2001	Netherlands Buildings Data shapefile
5	Amsterdam	Rembrandt Tower	123	2001	https://www.amsterdamtips.com/tallest-buildings-in-amsterdam
6	Amsterdam	Mondriaan Toren (The Office Operators)	123	2002	https://www.skyscrapercenter.com/building/mondriaan-toren/5377
7	Amsterdam	World Trade Centre	106	2004	https://www.amsterdamtips.com/tallest-buildings-in-amsterdam
8	Rotterdam	Waterstadtoren	109	2004	Netherlands Buildings Data shapefile
9	Amsterdam	ITO Toren	100	2005	https://www.amsterdamtips.com/tallest-buildings-in-amsterdam
10	Rotterdam	Montevideo	152	2005	Netherlands Buildings Data shapefile
11	Rotterdam	De Coopvaert	105	2006	Netherlands Buildings Data shapefile
12	The Hague	Prinsenhof	128	2006	Netherlands Buildings Data shapefile
13	The Hague	Het Strijkijzer	132	2007	Netherlands Buildings Data shapefile
14	Amsterdam	Amsterdam Symphony towers	105	2009	https://www.amsterdamtips.com/tallest-buildings-in-amsterdam
15	Rotterdam	The Red Apple	127	2009	Netherlands Buildings Data shapefile
16	Rotterdam	Erasmus Medisch Centrum Locatie Hoboken	114	2010	Netherlands Buildings Data shapefile
17	Rotterdam	New Orleans	158	2010	Netherlands Buildings Data shapefile
18	The Hague	De Kroon	131	2011	Netherlands Buildings Data shapefile
19	The Hague	City Tower (Babylon)	158	2011	Netherlands Buildings Data shapefile
20	Rotterdam	Maastoren	165	2011	Netherlands Buildings Data shapefile
21	Rotterdam	Nieuwbouw Erasmus Medisch Centrum	125	2012	Netherlands Buildings Data shapefile
22	The Hague	Nieuw Ministerie van Justitie	146	2012	Netherlands Buildings Data shapefile
23	Rotterdam	100HOOG	106	2013	Netherlands Buildings Data shapefile
24	The Hague	Park Tower (Babylon)	113	2013	Netherlands Buildings Data shapefile
25	Rotterdam	De Rotterdam	149	2013	Netherlands Buildings Data shapefile
26	Amsterdam	Amstel tower	103	2018	https://www.amsterdamtips.com/tallest-buildings-in-amsterdam
27	Amsterdam	Valley Noordtoren	103	2020	http://www.pss-archi.eu/immeubles/NL-363-64549.html
28	Rotterdam	Boompjes 55-57 (The Terraced Tower)	110	2020	https://nieuws.top010.nl/boompjes-55-57-rotterdam.htm
29	Amsterdam	Maritim Congress Hotel	114	2020	https://www.skyscrapercenter.com/building/maritim-congress-hotel/30216
30	Rotterdam	CasaNova	110	2021	https://www.skyscrapercenter.com/building/casanova/32907
31	Rotterdam	Witte de With (Cooltoren)	150	2021	https://thecooltower.nl/
32	Rotterdam	De Zalmhaven	212	2021	https://www.skyscrapercenter.com/building/de-zalmhaven/6837
33	The Hague	Grotius	120	2022	https://www.mvrdv.nl/projects/392/grotius-towers
34	Rotterdam	Baan Tower	150	2022	https://nieuws.top010.nl/baan-toren-rotterdam.htm
35	Rotterdam	Postkantoor	150	2022	https://www.funda.nl/nieuwbouw/rotterdam/project-40266988-post-rotterdam-postkantoor-coolsingel/
36	Rotterdam	Havana & Philadelphia	165	2022	https://www.skyscrapercenter.com/building/havana-philadelphia/30531
37	Amsterdam	(Y towers) Residential Tower Overhoeks	110	2023	https://www.amsterdamtips.com/tallest-buildings-in-amsterdam
38	Rotterdam	Treehouse	140	2024	https://www.skyscrapercenter.com/building/tree-house/36664
39	The Hague	The Grace Tower 1 &2	180	2025	https://www.e-architect.co.uk/holland/the-grace-towers-in-the-hague
40	Rotterdam	Schiekadeblok	230	2026	https://www.rotterdam.nl/wonen-leven/schiekadeblok/Ambitiedocument-Schiekadeblok.pdf

Appendix C: Individual city descriptive statistics

Table C1: Amsterdam

	Observations	Mean	Std. Dev.	Min	Max
D (high-rise within 1km)	145,619	0.923	0.267	0	1
Da (high-rise within 1.5km)	145,619	0.895	0.306	0	1
Db (high-rise within 2km)	145,619	0.882	0.322	0	1
Dc (high-rise within 500m)	145,619	0.952	0.215	0	1
D2 (2 high-rises within 1km)	145,619	0.892	0.311	0	1
Sha_1t (shadow by 1 high-rise)	145,619	0.369	0.483	0	1
Sha_2t (shadow by 2 high-rises)	145,619	0.208	0.406	0	1
Price	145,619	315768	233231	11900	1.00E+07
Price (log)	145,619	12.5	0.539	9.38	16.1
price for a sqm	145,619	3578	1563	140	70000
Size (log)	145,619	4.39	0.412	3.26	6.24
No.of Rooms	145,619	3.28	1.3	1	10
Terraced	145,619	0.0923	0.289	0	1
Semi Detached	145,619	0.031	0.173	0	1
Detached	145,619	0.00953	0.0972	0	1
Apartment	145,619	0.867	0.339	0	1
Maintenance quality is good	145,619	0.884	0.32	0	1
New built	145,619	0.0357	0.186	0	1
Garage	145,619	0.084	0.277	0	1
Garden	145,619	0.986	0.119	0	1
Central heating present	145,619	0.884	0.32	0	1
Listed	145,619	0.0317	0.175	0	1
Construction year missing	145,619	0.00653	0.0805	0	1
Construction year 1906-1930	145,619	0.276	0.447	0	1
Construction year 1931-1944	145,619	0.0872	0.282	0	1
Construction year 1945-1959	145,619	0.0445	0.206	0	1
Construction year 1960-1970	145,619	0.0898	0.286	0	1
Construction year 1971-1980	145,619	0.0355	0.185	0	1
Construction year 1981-1990	145,619	0.0919	0.289	0	1
Construction year 1991-2000	145,619	0.113	0.317	0	1
Construction year post 2000	145,619	0.0889	0.285	0	1

Table C2: Rotterdam

	Observations	Mean	Std. Dev.	Min	Max
D (high-rise within 1km)	77,631	0.824	0.381	0	1
Da (high-rise within 1.5km)	77,631	0.823	0.382	0	1
Db (high-rise within 2km)	77,631	0.841	0.365	0	1
Dc (high-rise within 500m)	77,631	0.865	0.342	0	1
D2 (2 high-rises within 1km)	77,631	0.638	0.48	0	1
Sha_1t (shadow by 1 high-rise)	13,651	0.365	0.482	0	1
Sha_2t (shadow by 2 high-rises)	13,651	0.145	0.352	0	1
Price	77,631	210363	153319	10000	3800000
Price (log)	77,631	12.1	0.549	9.21	15.2
price for a sqm	77,631	1950	783	108	26981
Size (log)	77,631	4.58	0.369	3.26	6.28
No.of Rooms	77,631	3.87	1.38	1	10
Terraced	77,631	0.208	0.406	0	1
Semi Detached	77,631	0.0974	0.296	0	1
Detached	77,631	0.0165	0.127	0	1
Apartment	77,631	0.678	0.467	0	1
Maintenance quality is good	77,631	0.826	0.379	0	1
New built	77,631	0.0367	0.188	0	1
Garage	77,631	0.0935	0.291	0	1
Garden	77,631	0.983	0.129	0	1
Central heating present	77,631	0.867	0.339	0	1
Listed	77,631	0.00866	0.0926	0	1
Construction year missing	77,631	0.0167	0.128	0	1
Construction year 1906-1930	77,631	0.124	0.329	0	1
Construction year 1931-1944	77,631	0.186	0.389	0	1
Construction year 1945-1959	77,631	0.13	0.337	0	1
Construction year 1960-1970	77,631	0.103	0.304	0	1
Construction year 1971-1980	77,631	0.0697	0.255	0	1
Construction year 1981-1990	77,631	0.122	0.328	0	1
Construction year 1991-2000	77,631	0.111	0.314	0	1
Construction year post 2000	77,631	0.097	0.296	0	1

Table C3: The Hague

	Observations	Mean	Std. Dev.	Min	Max
D (high-rise within 1km)	98,141	0.732	0.443	0	1
Da (high-rise within 1.5km)	98,141	0.62	0.485	0	1
Db (high-rise within 2km)	98,141	0.583	0.493	0	1
Dc (high-rise within 500m)	98,141	0.725	0.447	0	1
D2 (2 high-rises within 1km)	98,141	0.683	0.465	0	1
Sha_1t (shadow by 1 high-rise)	98,141	0.253	0.435	0	1
Sha_2t (shadow by 2 high-rises)	98,141	0.319	0.466	0	1
Price	98,141	238991	179862	10000	8000000
Price (log)	98,141	12.2	0.602	9.21	15.9
price for a sqm	98,141	2056	820	143	27632
Size (log)	98,141	4.63	0.38	3.26	6.27
No.of Rooms	98,141	4.29	1.58	1	10
Terraced	98,141	0.167	0.373	0	1
Semi Detached	98,141	0.0647	0.246	0	1
Detached	98,141	0.00931	0.0961	0	1
Apartment	98,141	0.759	0.428	0	1
Maintenance quality is good	98,141	0.786	0.41	0	1
New built	98,141	0.0348	0.183	0	1
Garage	98,141	0.1	0.3	0	1
Garden	98,141	0.988	0.108	0	1
Central heating present	98,141	0.865	0.342	0	1
Listed	98,141	0.00632	0.0792	0	1
Construction year missing	98,141	0.00777	0.0878	0	1
Construction year 1906-1930	98,141	0.262	0.44	0	1
Construction year 1931-1944	98,141	0.198	0.398	0	1
Construction year 1945-1959	98,141	0.11	0.313	0	1
Construction year 1960-1970	98,141	0.0791	0.27	0	1
Construction year 1971-1980	98,141	0.0539	0.226	0	1
Construction year 1981-1990	98,141	0.0403	0.197	0	1
Construction year 1991-2000	98,141	0.0898	0.286	0	1
Construction year post 2000	98,141	0.087	0.282	0	1