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Investigation into the effect of air quality on property values mediated by land use

Master thesis

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Abstract: This study examines the effect of land use on the relationship between property values and air quality. A multilevel model is used to test this mediating effect. Data for the analysis is retrieved from the NVM, RIVM and CBS. Furthermore, a number of environmental en locational variables are created using GIS software. Results reveal that green land use indeed affects the relationship between property values and air quality. However, this effect was found to be negatively impacting this relationship. Moreover, sensitivity analysis using different radii showed that the negative impact of green space on the effect of NO2 increases in size as a larger surrounding area of a property is considered. Industrial land use, on the contrary, had no significant effect on the relation between property values and air quality.

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Urban, Port and Transport Economics
September 2018

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1 Introduction

The European Commission plans to discipline member states that violate European Union (EU) rules on air pollutants. Several countries, including the largest European countries of France and Germany within the EU, have failed to meet air quality deadlines (Reuters, 2018). The EU air quality targets are, supposedly, not strict enough resulting in 12,000 deaths per year according to the Governmental advisory body of the Netherlands[1]. The same advisory body advises to use the stricter targets of the World Health Organization (WHO) to decrease the health risks resulting from poor outdoor air quality (NOS, 2018). These examples show that good air quality is essential for our health.

Moreover, poor air quality is shown to also affect the environment negatively. The effects of air quality on both the environment and human well-being, in turn, creates economic consequences. These can range from major costs of lost work days to premature deaths (MFE, 2014). These costs alongside the fact that housing fulfills a key element in people's lives, makes the relation between these subjects all the more important. The main question, when discussing this relationship between air quality and property value is, usually, whether air quality affects property values. This question is, nonetheless, investigated by myriad studies and it is generally agreed upon that air quality and property values are positively related.

Everybody wants to breath clean air, yet quantifying and measuring air quality is challenging. This is especially true for the general public. For instance, one can have a perception of good air quality when being in an urban park, however the actual air quality is probably not much different to the air quality of nearby urban areas. The perception of air quality could therefore be as relevant to property values as the air quality itself. This perception can be influenced by land use of nearby areas. So a more nuanced question when discussing the relationship between air quality and property values is: to what degree is the effect of air quality on house prices mediated by land use?

1.1 Previous Literature

Literature on the relationship between property value and air quality suggests, unsurprisingly, a positive association. Previous studies have investigated this relationship, however the measures of air quality differ greatly among them. Boyle & Kiel (2001), give an overview of the results of twelve studies on the relationship between air quality and property values. Several studies find a statistical significant relationship between property values and air quality (Ridker & Henning, 1967; Deyak & Smith, 1974; Harrison Jr & Rubinfeld, 1978; Murdoch & Thayer, 1988). However, other reviewed studies found mixed results. Not all of the examined pollutants, by which air quality is approximated (e.g. NO_2, SO_2 or TSP[2]), have been found to have significant association with property values in these studies Nelson (1978); Palmquist (1982, 1983); Graves et al. (1988); Zabel & Kiel (2000). Meanwhile, several studies failed to find any significant relationship at all (Wieand, 1973; Smith & Deyak, 1975; Li & Brown, 1980).

Following on from the review study of Boyle & Kiel (2001), Azmi et al. (2012) find a positive correlation between air pollution and property values. This positive correlation, as the writers note, is inconsistent with previous theory. However, the study does show that air quality and property values have a relationship. On the other hand, the results of the study of Sullivan (2015) affirms the theory by finding a positive relation between property values and air quality.

There are studies that suggest that the perception of air quality can differ greatly among individuals. Liao et al. (2015), for instance, show that highly educated parents younger than 40 years old that have international travel experience, have a higher level of air quality awareness. This higher awareness can translate into a stronger effect of air quality on property values.

1.2 Academic Relevance

There are several arguments that address the relevance of this study. First of all, there is little to none literature on the effect of air quality on property values mediated by land use. This fact is

[1]de Gezondheidsraad
[2]Total Suspended Particles

naturally the first and foremost argument to show the academic relevance of this study. Moreover, data on land use is readily available by the Dutch Central Agency for Statistics[3] (CBS).

Secondly, there is limited evidence on the impact of air quality when considering the results of previous studies, despite the ample literature. Boyle & Kiel (2001) in their review paper note that studies on air quality have often statistically insignificant results. There is a possibility that the measures of air quality used are not relevant to homeowners, therefore causing statistically insignificant results. Therefore, examining the mediation effect of land use can help in understanding how air quality and property values are related.

Thirdly, Boyle & Kiel (2001) also state that only a few studies include multiple environmental goods (e.g. water and noise quality). Considering the fact that including multiple environmental goods should reduce omitted variable bias (OVB), makes including these goods all the more important. There is ample data available that can help address OVB. Using another environmental good, such as noise quality, can help in reducing OVB when this environmental good affects both air quality and property values.

1.3 Problem Statement

This study will examine how the effect of air quality on property values is mediated by land use. Furthermore, this study will use multiple measures of air quality, as recommended by Boyle & Kiel (2001). Noise pollution, measured in average $dB(A)$ will be added to this study as a second environmental good. The metric $dB(A)$ gives an indication of the loudness of noise simultaneously considering human hearing. It is expected that noise pollution affects both air quality and property values. Therefore, adding noise pollution into this study should help in reducing the OVB.

To encapsulate the above mentioned subjects, a research question will be compiled. The research question of this study will be as follows:

To what degree is the effect of air quality on property values mediated by land use?

This study will use data from the Dutch National Institute for Public Health and the Environment[4] (RIVM). The RIVM provides data on air quality and noise pollution. Moreover, data on property characteristics and transaction prices will be obtained from the Dutch Association of Realtors and Appraisers in real estate[5] (NVM). Furthermore, neighborhood characteristics and data on land use will be retrieved from the CBS.

Furthermore, this study will use a hedonic estimation model. The rationale of this estimation is that with the purchase of a house, the buyer also receives its environmental and neighborhood characteristics (Boyle & Kiel, 2001). So, this estimation makes the assumption that a buyer alongside his house, also buys implicitly some environmental and neighborhood goods. Furthermore, this study will use a multilevel approach where the property values will be related to individual property characteristics on a lower level and neighborhood characteristics on a higher level. Multilevel models are appropriate when the units of analysis, property values in this case, are nested within neighborhoods (Luke, 2004).

It is expected that land use will significantly affect the relationship between air quality and property values. As stated earlier, the expectation is that the effect of air quality on property values will differ between, for example, green and industrial land use.

1.4 Paper Outline

This paper will proceed with chapter 2 where relevant academic literature will be examined. Data needed for quantitative research will be described in chapter 3. Chapter 3 will continue with explicating the methodology. Chapter 4 will present the results of the quantitative analysis. This chapter will be followed up with chapter 5, where the key findings will be discussed alongside the limitations and some recommendations for future studies. Chapter 6 will present the final conclusion.

[3]Centraal Bureau voor de Statistiek
[4]Rijskinstituut voor Volksgezondheid en Milieu
[5]Nederlandse Vereniging van Makelaars en Taxateurs in onroerende goederen

2 Literature Review

In this chapter the literature on air quality and property values is reviewed. This chapter starts with literature on the relation between air quality and property values specifically and will continue with analyzing perceived air quality. The role of land use in perceived air quality will also be touched upon alongside noise pollution. The chapter concludes by setting up 4 hypotheses that will help in answering the main research question.

2.1 Air Quality and Property Value

Literature on the relationship between property value and air quality suggests, unsurprisingly, a positive association. Pollutants are often regarded as detrimental for property and health of the occupants. The direct effect of pollutants on property is described by one of the earliest studies on air quality by Ridker & Henning (1967). They argue that pollutants such as SO_2[6] and H_2S can cause damage to freshly applied paint, resulting it to flake off more rapidly, therefore making maintenance needed more often. H_2SO_4 can cause corrosion of metal and stone. These compounds can also cause damage to vegetation and irritate the nose, eyes, and throat.

There is a great deal of qualitative research on the relationship between air quality and property values. A survey on the impact of environmental externalities conducted by Boyle & Kiel (2001) partly examines house price hedonic air quality studies. Twelve studies are reported in total. Ridker & Henning (1967); Deyak & Smith (1974); Harrison Jr & Rubinfeld (1978); Murdoch & Thayer (1988) find a statistically significant relationship between property values and air pollution. Ridker & Henning (1967); Deyak & Smith (1974); Harrison Jr & Rubinfeld (1978) use different pollutants; sulfates, total suspended particulates (TSP), and NO_2[7] respectively. Meanwhile, Murdoch & Thayer (1988) use several measures of visibility. They demonstrated with their study that simple means are not enough to get unbiased models. Therefore, more complete measures of environmental quality are to be considered to improve hedonic models. Boyle & Kiel conclude their survey with observing that the signs on air quality coefficients are oftentimes sensitive to changes when other variables are included and statistically insignificant. A possible explanation is that the measures that are included in the reviewed studies are not significant to homeowners. It is unclear what homeowners value most in terms of air quality. For example, particulates are presumably the easiest observable pollutant measure. Results of studies using particulate measures should, therefore, be most likely to give a clear conclusion. However, results of the reviewed studies using particulates are also inconclusive.

Including neighbourhood variables are crucial in studies on the relationship between air quality and property values (Li & Brown, 1980; Graves et al., 1988). Considering that the possibility of neighbourhood characteristics being correlated with air quality measures makes the inclusion of these variables crucial. Chay & Greenstone (2005), use an increase in air quality produced by regulatory changes to study the effect of air quality on property values using TSP. They include several neighbourhood characteristics (e.g., number of doctors per capita and crime rates) in their study. Their results show a robust significant negative relation between air quality and property values. A decrease of one $\mu g/m^3$ of TSPs increases mean property values with 0.2-0.4 percent. The areas where the regulatory changes were implemented experienced a 45 billion dollar aggregate gain for homeowners in the mid-70s.

One of the more recent studies, by Le Boennec & Salladarré (2017) uses a database containing certain attributes of houses that have been sold from 2002 to 2008 in addition to some location attributes, to study the impact of air pollution and noise on the real estate market of Nantes, France. They fail to find an effect of air pollution on property values citing two possible arguments, that are the following. Firstly, air quality is by and large intangible and invisible by nature. Secondly, air quality is mostly seen as ephemeral. In other words, low air quality is short-lived; air pollutants dissipate quickly after coming in contact with the air. However, Le Boennec & Salladarré continue with observing that when homeowners are willing to accept lower air quality as a byproduct of living closer to specific facilities (e.g., proximity to a commercial zone or the city center), then there might be no need for property values to be affected by air quality.

The results of Le Boennec & Salladarré in contrast to studies such as Chay & Greenstone may indicate a dichotomy between the U.S. and Europe. The preferences of residents are highly

[6]Sulphur dioxide.
[7]Nitrogen dioxide

important in the relationship between property values and air quality. Furthermore, regulation and actual air quality rates can differ greatly between the U.S. and Europe. Europe, compared to the U.S., uses a different air quality index (AQI) to convey pollution levels to the public (EEA, 2017; EPA, 2016).

Kim et al. (2003) developed a hedonic housing model to measure the benefits of air quality improvement for the Seoul metropolitan area. They show that a small change in the air quality can induce a substantial increase in property values using a spatial-lag model. Their results indicate that a permanent 4 percent (1 ppb[8] change) improvement of air quality can increase the willingness to pay for property by 2,333 dollars. This increase in property value is equal to 1.43 percent of the mean property value of their data set.

2.2 Perceived Air Quality

Air quality is gaining more importance in the public consciousness, through increasing attention from the public debate over the effectiveness of air regulation (Brody et al., 2004). While air quality effects on property values have been studied thoroughly, the perception of air quality at the local level has enjoyed little empirical research. A number of recent studies suggest that local characteristics are important in the perception formation.

Le Boennec & Salladarré (2017) note in their study that taking perception of property buyers in consideration, should contribute toward a better understanding of the impact of environmental variables, such as air quality, on the real estate market

2.2.1 Perceived and Actual Air Quality

There is evidence from several sources that there is a dichotomy between measured air quality by monitoring systems and levels of air quality perceived by the public. Studies focusing on this dichotomy between actual and perceived air quality are partly inconsistent. While some studies (Elliott et al., 1999; Oglesby et al., 2000) find that perceived air quality matches measurements from monitoring stations, others (Johnson, 2002; Dworkin & Pijawka, 1982; Bickerstaff & Walker, 2001) find that the public is not conscious of pollution levels in their neighbourhood. Deguen et al. (2017) cite the diversity and variability of the characteristics of individuals (e.g., gender or stage of life) as an explanation of these conflicting results. Menz & Welsch (2010), find that the relation between the preference for air quality and age is U-shaped. In other words, older people appear to be more sensitive to air quality. However, literature on the relation between actual and perceived air quality generally agrees that perception does play a large part in the response of people to environmental exposure (Elliott et al., 1999; Hillier, 2016).

For example, environmental research shows that the possible links between health, in a broad sense, and air quality are mediated by the perception of exposure to air quality and other contextual and individual factors (i.e., the presence of a household member with asthma increases concerns with regard to air pollution) (Elliott et al., 1999). The proximity of industry, through environmental effects and the identity of neighbourhoods, influences residents' views about the links between health and air pollution. This contrast was found by comparing neighbourhoods nearby and faraway from industry (Howel et al., 2003; Lercher et al., 1995). Lercher et al. (1995) found in their study on perceived air pollution that although the measured air quality was above guidelines set by the World Health Organization (WHO), a considerable portion of the respondents were annoyed by black soot[9] exposure, visible dust or car fumes.

Brody et al. (2004) show that there is indeed a difference between scientifically measured air pollution and perceived air pollution. They find based on a three phase analysis, including a correlation analysis and an ordinary least squared (OLS) multiple regression, that perception of the local air quality does not match the actual air quality readings. However, the local perception of air quality seems to be affected by factors such as sense of place, proximity and neighbourhood setting. This is unsurprising given that a casual observer cannot feel or see most air pollutants. So, mental constructs or perceptions of air quality are not necessarily based upon scientific understanding.

[8]parts per billion

[9]carbon particles that are formed after fuel combustion (Omidvarborna et al., 2015)

2.2.2 Role of Land-use in Perceived Air Quality

Results from a number of studies (Oltra & Sala, 2016; Deguen et al., 2017) show that perceived air quality differs greatly between and within cities. Oltra & Sala (2016) found that there are significant differences between cities in aggregated levels of distress, physical symptoms, and annoyance due to air pollution. They used four cities in their behavioural study on air pollution perception, finding considerable differences in the perception of local air quality between them. The cities in question had contrasting NO_2 levels, and at the same time similar PM_{10} levels.

Deguen et al. (2017), examine if neighbourhood characteristics influence perceived air quality, using individual and neighbourhood characteristics. A variable used in this study, relevant in the case of land-use, is the variable *Green Space*. This variable includes different types of natural areas (e.g., forests, parks), specified as the percentage of green spaces in the total area. Results showed that the respondents living in an area with a higher density of green spaces were more significantly more satisfied with their place of residence, when compared to those with a lower density of green spaces. In other words, more green spaces in close proximity appears to have a positive effect on the air quality perception.

Brody et al. (2008), note that previous studies have rarely included local physical and geographical variables. These studies mostly include attitudinal, demographic and social contextual variables. Brody et al. (2004), argue that land-use patterns can affect air quality perceptions. They explain the air quality perception difference between the cities of Houston and Dallas in terms of land development. This difference is generated by the fact that Houston has a sprawling patter of land development (due to the absence of zoning regulation in the city of Houston). The proximity to sources of air pollution also affects residential concern on air quality (Elliott et al., 1999). The proximity to industrial areas could therefore generate a negative perception of the local air quality.

2.3 Noise Pollution

Noise pollution is often used as an indicator for the quality of the environment. This noise exposure includes noise from several sources (e.g., industry, railway and road traffic) (Deguen et al., 2017). Moreover, noise pollution is considered to be an environmental variable that has an effect on the health of citizens. Noise pollution can be overlooked with respect to air pollution, as the latter has increasingly played a larger role in the public consciousness (Brody et al., 2004). However, there is ample evidence suggesting that noise pollution can lead to hypertension, hearing deterioration, decreased school performance, and sleep disturbance (Passchier-Vermeer & Passchier, 2000). Noise pollution is mainly a negative side effect of transport and is especially felt near main road cross-sections (Schwela, 2001). A study of the European Commission in 2011 showed that the social costs of road noise resulted in 40 billion euros linked to premature deaths and noise related diseases (EC, 2011).

A recent study that examines the relation between noise pollution and property values is that of Le Boennec & Salladarré (2017). Le Boennec & Salladarré find a significant relation between noise pollution and property values in Nantes *Métropole*. However, their results indicate that a 1 percent increase in dB(A) decreases property values around 0.035 percent.

Another study on noise pollution is that of Łowicki & Piotrowska (2015). Łowicki & Piotrowska examine the monetary valuation of noise pollution, road noise in particular, in Poznan County, Poland. They use a hedonic pricing method to estimate the benefits of reducing noise levels. Their data includes several property, neighbourhood, environmental and accessibility characteristics. The main sources of noise in the Poznan County turned out to be industrial plants and the transport network, with transport network being the largest component of the two. Their results suggest that properties located in zones with exceeding noise levels at night were 57 percent cheaper than properties not located in these zones.

Wilhelmsson (2000) examines the impact of traffic noise on single-family property by analyzing a sample over a period of 10 years, in Stockholm. Wilhelmsson uses several structural and locational attributes in his analysis. The results of the empirical analysis suggest that property values decrease on average by 0.6 percent per dB. A total discount of 30 percent is found, when comparing properties located in quiet and noisy neighbourhoods.

2.4 Hypotheses

It has been established in the previous paragraphs that environmental quality affects property values. Air quality as well as noise exposure have been found to affect property values by several studies. However, the role of land use in the relationship between air quality and property values seems not studied extensively in the literature. This study, therefore, aims to examine how the relationship between air pollution and property values is mediated by land use. Thus, the main research question is:

To what degree is the effect of air quality on property values mediated by land use?

Results on the relationship between air quality and property value seem to indicate some disagreement in light of the reviewed literature above. However, there is no discourse on the notion that this relationship should be positive. In other words, property values are expected to be higher when air quality is high and thus air pollution levels are low. The following hypothesis is formulated to test the relationship between air quality and property values.

Hypothesis 1: Air pollution has a negative effect on property values

Furthermore, it is apparent that the public has a perception of air quality that does not correspond with its actual levels, as noted by several studies (Johnson; Dworkin & Pijawka; Bickerstaff & Walker). It is, therefore, argued that the relationship between air quality and property values is mediated by the perception of air quality. An argument can be made that this perception can be affected by proximity of green land use. The second hypothesis is formulated to test whether more nearby green space eliminates or decreases the negative effect of air pollution on property values.

Hypothesis 2: Green land use has a positive effect on the perception of air quality

Another land use type that is being tested is that of industrial land use. Industrial land use is found to decrease property values (De Vor & De Groot, 2011). It is also expected that more nearby industrial land use will exacerbate the negative effect of air pollution through public perception, as industry is seen as a major polluter. The third hypothesis is formulated to test whether more nearby industrial land exacerbates the negative effect of air pollution on property values.

Hypothesis 3: Industrial land use has a negative effect on the perception of air quality

3 Data and Methodology

Statistical analysis is used to analyze the effect of land use measures on the relationship between air quality and property values. Multilevel modelling will be used as the estimation method. This method alongside data collection and description will be explained in this chapter.

3.1 Data

The dataset from which the analysis is conducted from consists of two parts. These are concerning residential properties and neighbourhoods in which these properties are located.

3.1.1 Level 1: Properties

The information on property sales' prices and corresponding structural attributes, was provided by the NVM. The data provided by the NVM concerns transactions done in the provinces North Holland, South Holland and Utrecht between 1 January 2015 and 31 December 2017. Initially, the number of observations was 251,451. However, the NVM did not provide any coordinates. For this reason, geocoding was computed using the PDOK BAG plugin within QGIS[10] desktop 2.18.9. This plugin provided the coordinates[11] by using house numbers, postcodes and city names. Ultimately, 248,696 valid observations were left after the elimination of non-residential buildings and incorrectly geo-referenced observations[12].

3.1.1.1 Property Values The dependent variable of the analysis is property value. This variable is retrieved from the NVM dataset in the form of the final sales' price. There are two transformations performed on the dependent variable.

Firstly, in order to reduce the effect of the extreme values of property values (especially the more expensive properties) a winsorization is applied of 99 percent. This means that the extreme values are replaced by $0.5th$ and $99.5th$ percentiles values[13] (Barnett & Lewis, 1974; Tukey, 1962). Rosen (1974) indicated that that the hedonic price structure is considered not to be linear. The second transformation involves a log transformation of the dependent variable, making the models in this study log-linear.

3.1.1.2 Structural Attributes The dataset provided by the NVM contains a considerable number of basic attributes of the properties, such as when the property was constructed and number of square metres. A selected number of structural attributes are being used in the analysis as the dataset provided by the NVM comprises of 80 variables. A selection is made mainly based on the studies of Sirmans et al. (2006) and Malpezzi (2002). The used structural characteristics are: type of property, sales quarter, age of property, square metres, number of rooms, number of isolation types, garage and balcony. The relationship between property value and a number of the used variables is expected to be non-linear. Therefore, a number of variables are divided into dummy variables. These variables are: type of property, age of property, number of rooms, number of isolation types, garage and balcony. Also, the number of square metres is not expected to be linearly correlated with the property value, so this variable is included in a log form.

3.1.1.3 Locational Attributes The NVM dataset provided also a geographical attribute for each property. This was the relative location to the centre. This variables will also be included as a dummy variable.

Additionally four variables are created using QGIS. These are: (1) percentage green land use within a certain radius, (2) percentage industrial land use within a certain radius, (3) the Euclidean distance to the nearest airport and (4) the Euclidean distance to the port of Rotterdam. The port of Rotterdam is specifically included as the port is a major source of pollution in the three provinces which make up the geographical setting of this study. The data on the locations of every airport, the port of Rotterdam, green space and industrial site are retrieved from the CBS, in the form

[10] QGIS is an open-source GIS software application

[11] The coordinate reference system this plugin uses is EPSG:28992 Amersfoort/RD New.

[12] 132 incorrectly geo-referenced observations and 2,623 non-residential buildings removed.

[13] Winsorizing is preferred over trimming as trimming would discard the extreme observations of property values, resulting in the loss of valuable data

of shape-files[14]. Land use, just like properties are geo-referenced, which enables to create new variables by using QGIS (Figure 1).

Selecting Area Size Producing GIS metrics for the Euclidean distances to an airport and the port of Rotterdam is straightforward. These variables are generated by simply calculating the distance from a property to the nearest airport and the port of Rotterdam. The same cannot be said about the variables percentage green land and industrial land use. The first step in determining these variables is choosing an appropriate area size. These areas will have circular form, by which the area size is calculated by the following equation: $\pi \cdot r^2$, where r is the radius. However, selecting an appropriate r is problematic, since a slightly larger or smaller r can affect the relationship between property values and pollutants (Parenteau & Sawada, 2011). This problem is called the modifiable areal unit problem (MAUP). MAUP is a major challenge for studies with a geographical dimension and remains an unresolved problem to this day (Dark & Bram, 2007). Therefore, the variables percentage green space and industrial areas will be calculated for 3 different radii. The first radius that is used is 500 metres. This radius is selected since it is used several papers using including Czembrowski & Kronenberg (2016); Kong et al. (2007). The second radius being considered is 800 metres. 800 metres is usually considered a 10 minute's walk. There is a major parks advocacy movement in the US that uses this radius to advocate for high quality green space for everyone, associating greater access to parks with a lower Body Mass Index (BMI)(10minutewalk, 2018). The third and main radii will be the mean of the previous two, thus 650 metres. The radii of 500 and 800 metres will be used to test the robustness of the 650 metre results.

Classification of Green Space Determining which areas to consider as green space is complicated, since green space can be characterized in many ways. Green space is in most cases regarded as a uniform good. However, green space is more a heterogeneous good, since green space has various dimensions. Consider, for example, that man-made parks and nature can both be seen as green land use. However, there are most definitely great differences between these two examples. Green space can vary in size, space density, or even vegetation concentration (Panduro & Veie, 2013). There are, therefore, two percentage green space variables generated with GIS software. The first green space variable includes forest, allotment gardens, parks and public gardens and shrub-land. The second variable includes only forest and can be seen as a restricted form of the first variable. The latter green space variable will be used to test the robustness of the former variable.

3.1.1.4 Environmental Attributes A nationwide pollution map was needed to find the air pollution levels for every property. These pollution maps were retrieved from the RIVM and used with GIS software to generate a new variable that quantifies the pollution levels. This process is done for several pollutants. These are: NO_2, PM_{10}, and SO_2[15]. NO_2 is known to be a good tracer of pollution generated by traffic and other sources (main sources of pollution in many metropolitan areas). This pollutant has also been recognized to have a greater spatial variability compared to other pollutants, such as PM_{10} which will also be used in the analysis Deguen et al. (2017). PM_{10} will be included in the analysis as this is one of the more observable pollutants (Le Boennec & Salladarré, 2017). However, NO_2 is the main air pollutant that will be used throughout this study. SO_2 is chosen, since this pollutant usually follows a different spatial pattern from NO_2 (Kim et al., 2003). SO_2 an PM_{10} will be used when assessing the robustness of the NO_2 results. It is also important to include noise exposure when studying the effects of air quality, as these environmental variables often have overlapping sources. Industry, railway and road traffic are substantial sources of noise and air pollution. Including noise pollution will alleviate any OVB that it would cause if omitted from the analysis. The variable noise is generated likewise to the air pollution variables by retrieving a nationwide noise shape-file from the RIVM. However, noise is divided into several categories as the relation of noise and property values is not expected to be linear. These categories range from "Excellent" to "Very Poor" noise quality.

[14] Calculating the percentage green space and industrial sites within a certain radius was carried out, in the Python Console plugin of QGIS, using a python script largely drafted by Jeroen van Haaren

[15] It was considered to make an index called Year Average Common Air Quality Index (YACAQI). This index would give a broad sense of the air quality levels of a city, by indicating if it exceeds or fails EU-guidelines in terms of air quality. However, this index is not found to be accurate enough to give an indication on air quality levels and will therefore not be utilized(van den Elshout et al., 2005).

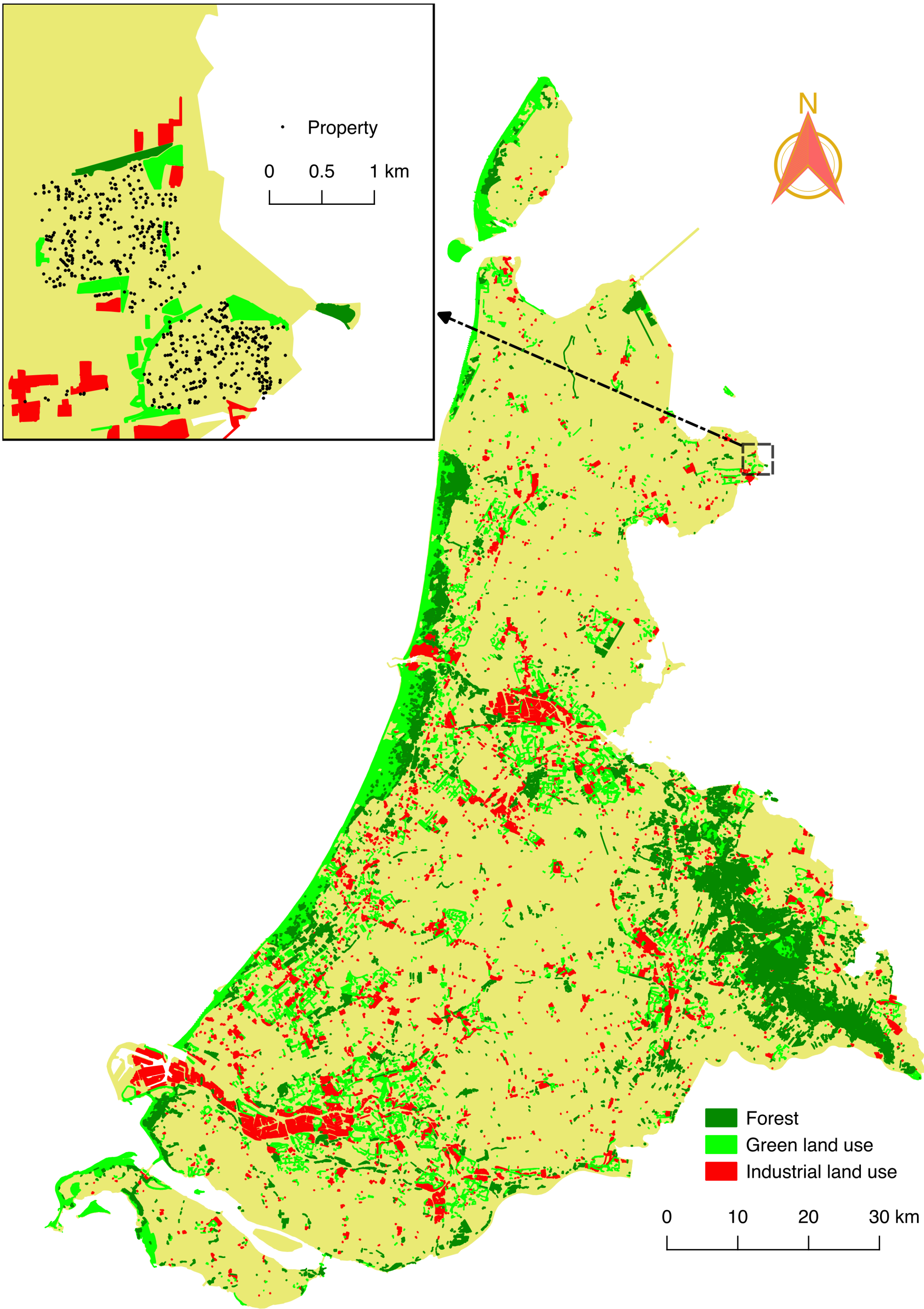

Figure 1: Land use in North Holland, South Holland and Utrecht (Source: CBS)

3.1.1.5 Interaction Effects Several interaction variables are generated using Stata between the air pollutants and the percentages green and industrial areas. Interaction effects are simply generated by a multiplication of the two main effect. These interaction variables will indicate whether nearby land use influences the relationship between air quality and property values.

3.1.2 Level 2: Neighbourhoods

The dataset on the neighbourhoods, in which individual properties are located, was provided by the CBS. The CBS provides many variables on all neighbourhoods in the Netherlands. The selection of variables was based on their possible relation with both property value and air quality, in order to minimize a possible OVB. The neighbourhood variables are the following: average income per capita, population density, total amount of cars, and number of schools within 3 kilometres[16].

A full list of the variables used in the analysis, along with a concise description and summary statistics can be found in table 1. The interaction variables used in this study are combination of the pollutants NO_2, SO_2 and PM_{10}, and the land use variables for all radii. Summary statistics of the interaction variables can be found in the Appendix.

[16] There is also controlled for average distance to doctors, convenience stores, day cares, urbanity, electricity and gas consumption, however excluding these neighbourhood variables caused no meaningful differences in the model.

Table 1 Summary statistics.

Name	Description	Mean	Expected sign	Source
Level 1				
LNPRICE	Log of sales' price	12.435	n/a	NVM
TYPE	Type of building	0.8159	+	NVM
QUARTER	Quarter the transaction took place in	6.6216	+	NVM
BUILD_PER	Building construction period	3.612	-	NVM
LNM2	Log of living area in square metres	4.6422	+	NVM
NROOMS	Number or rooms	4.223	+	NVM
ISOL	Number of isolation types	2.1592	+	NVM
GARAGE	Garage dummy	0.1535	+	NVM
BALCONY	Balcony dummy	0.3638	+	NVM
LOCATION_C	Location relative to the centre	1.798	-	NVM
DIST_AIRPORT	Euclidean distance to the nearest airport in metres	13013	+	CBS*
DIST_PORT	Euclidean distance to the port of Rotterdam	48455	+	CBS*
NOISE	Degree of noise pollution	3.5039	-	RIVM**
NO2	Yearly average of NO_2 measured in $\mu g/m^3$	22.368	-	RIVM**
SO2	Yearly average of SO_2 measured in $\mu g/m^3$	1.3507	-	RIVM**
PM10	Yearly average of PM_{10} measured in $\mu g/m^3$	18.959	-	RIVM**
GR500	Percentage green land use in a radius of 500 metres	0.0822	+	CBS***
GR650	Percentage green land use in a radius of 650 metres	0.0888	+	CBS***
GR650_R	Percentage forest in a radius of 650 metres	0.0168	+	CBS***
GR800	Percentage green land use in a radius of 800 metres	0.0934	+	CBS***
BN500	Percentage industrial land use in a radius of 500 metres	0.0453	-	CBS***
BN650	Percentage industrial land use in a radius of 650 metres	0.0514	-	CBS***
BN800	Percentage industrial land use in a radius of 800 metres	0.0562	-	CBS***
Level 2				
AVG_INC	Average income per capita in thousends	27.25	+	CBS
POP_DENS	Population density per square kilometre	7664.2	+	CBS
CARS_TOT	Total number of cars	1657.6	-	CBS
SCHOOL_3KM	Number of schools within 3 kilometres	17.075	+	CBS

*Generated by using CBS land-use maps through QGIS.
**Generated by joining RIVM pollutant maps and properties through QGIS.
***Generated using the Python Console plugin.

3.2 Methodology

3.2.1 Hedonic Pricing Model

The housing hedonic pricing model (HPM) is a model that used to estimate the value of a property by using a range of its attributes (e.g. type of house, number of balconies, or its distance to an amenity, etc.)(Rosen, 1974). HPM is one of the most basic tools used within spatial sciences, as it takes into account that a property is made up of numerous attributes. These attributes do not only involve structural attributes but also attributes concerning accessibility of the house, as well as contextual variables (e.g. population density and levels of income) and urban amenities (e.g. air and noise quality)(Chasco & Gallo, 2013).

Rosen (1974) derived the basis of hedonic pricing modeling from the consumer behaviour theory of Lancaster (1966). Lancaster argued that the good itself did not create utility for its consumer, rather the individual characteristics of the good creates utility. Since then, HPM has been used frequently in studies estimating property values (Suparman et al., 2014). The HPM is traditionally estimated by using ordinary least squares (OLS) (Orford, 2000). However, using OLS to estimate a housing HPM has several drawbacks, caused by spatial effects.

Spacial effects can broadly be split into two categories: spatial dependence and spatial heterogeneity (Anselin, 2001). Spatial dependence occurs with spatial data whenever the value of one observation is correlated with the value of an adjacent observation. Spatial heterogeneity, on the other hand, occurs when the relationship between a property's price and its individual attributes vary over space. OLS estimators are inefficient, with the presence of spatial effects. Making the statistical inference of models using OLS invalid (Dubin, 1998). Furthermore, demographic and socioeconomic characteristics of households, just like structural attributes, are spatially diverse (Helbich et al., 2014).

3.2.2 Multilevel Modelling

An alternative to OLS modelling is multilevel modelling (MLM). A MLM, also known as a hierarchical linear model, allows variables to vary at more than one spatial level. Additionally, MLM allows for observations to be spatially clustered (Jones, 1991). A MLM is more flexible than its OLS counterpart as it allows relationships to vary from area to area. Moreover, MLM outperforms OLS even when OLS estimates are corrected for clustering (Cheah, 2009). The relaxation of the independence assumption along with the explicit modeling of the spatial dependency, increases the number of efficient estimates that are obtained, thusly making inference with MLM more reliable (Glaesener & Caruso, 2015).

A two-level random intercept model is chosen to analyze property values within neighbourhoods. Properties and neighbourhoods form the two levels. Properties form the lower level units and neighbourhoods form the higher level units, meaning that properties are nested within neighbourhoods (Figure 2.).

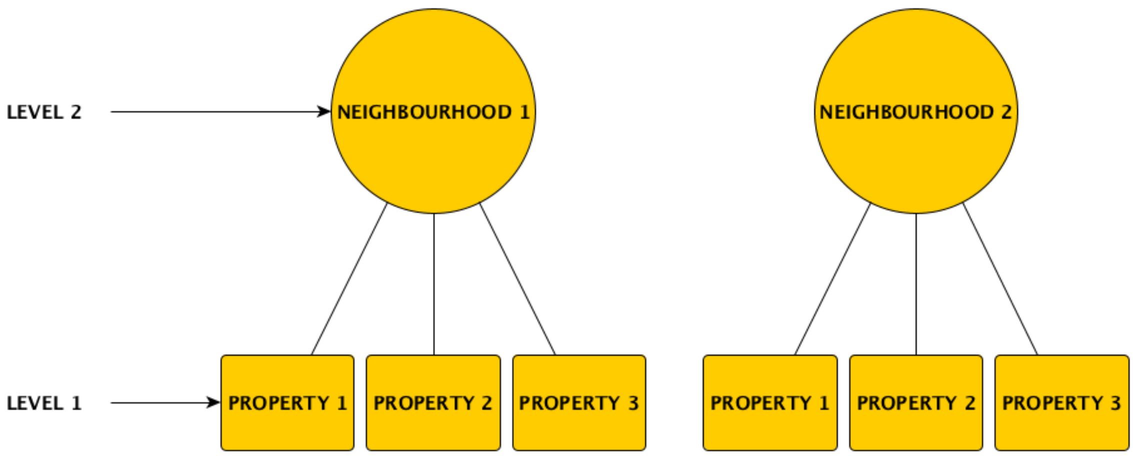

Figure 2: Unit diagram of two-level nested structure; properties in neighbourhoods

Figure 2 shows the non-independent or correlated nature of the data, in the sense that properties in the same neighbourhood will often correlate. MLM expects this correlation and explicitly models for it.

3.2.2.1 MLM Estimation Strategy MLM is usually starts with the unconditional model (UM) (Glaesener & Caruso, 2015). Later models will step-by-step include first more lower level structural variables and next the remaining lower level and higher level independent variables. With the UM only the dependent variable is regressed without any independent variables, only allowing for neighbourhood differences in the mean of property value. This two level model makes two segments, matching with the two previously defined levels.

The intra-class correlation coefficient[17] (ICC) estimates the portion of the total variance that as a result of the differences between neighbourhoods. The ICC is between 0 and 1, where 0 indicates no neighbourhoods differences and 1 no within neighbourhood differences. Thus, an ICC larger than 0 indicates that there are neighbourhood effects, making MLM the appropriate model. The likelihood ratio (LR) test will be used to test for neighbourhood effects. With LR one can test if there are no neighbourhood differences by comparing the UM with its linear counterpart[18]. The difference between these models is that UM is multilevel whereas the linear counterpart will be a one level regression.

The next steps involve adding independent variables in the following way. The first step involves adding all structural attributes. These attributes will be assessed and thereafter will not be displayed in the subsequent models. However, these models will still be controlled for the structural attributes. The next model will be the benchmark model, including the now non-displayed structural attributes, locational attributes, environmental attributes, interaction effects and lastly the neighbourhood variables.

The results of the benchmark model will be assessed for their robustness. Firstly, this is done by regressing the benchmark model with SO_2 and PM_{10} instead of NO_2. Secondly, regressing the benchmark model with only forest land use, to assess the green land classification. Thirdly, regressing the benchmark model with the alternative radii, in order to assess the effect of proximity of land use on the results.

To summarize, the first model will give the overall mean property value across all neighbourhoods and the portion of variance that each level contributes to the total variance in property values (Orford, 2000). u_j is the neighbourhood level variance and e_{ij} is property level variance. These variances can also be interpreted as the between-neighbourhood (level 2) variance and within-neighbourhood between-property (level 1) variance, respectively. The second model will by including all structural attributes estimate the impact of these attributes on the property value. The third model will be the benchmark by including the locational, environmental, interaction and neighbourhood variables. The results of the benchmark model will be assessed on their robustness.

[17]Some use the variance partition coefficient (VPC) is used to measure neighbourhoods effect, however this coefficient is equal to ICC in two-level models.

[18]The null hypothesis with the LR test is as follows; H_0; $\sigma_u^2 = 0$.

4 Results

This chapter will give the results of the MLM regressions in the order as discussed in the MLM estimation strategy section of the previous chapter. Table 4 to 7 do not display every regressed variable. The full regressions can be found in the appendix.

4.1 Benchmark Model

The results for the UM are given in table 2. The mean property value in the provinces of North Holland, South Holland and Utrecht, between the years 2015 and 2017, is 283,943 euros[19]. The variation of the observed property values around the mean property value is split into two components. These components are the between neighbourhood variance and the within neighbourhood variance. The ICC indicates that the between variance is larger than the within variance (0.190 compared to 0.149). Thus, approximately 56 percent of the variance of property values can be attributed to differences between neighbourhoods. Additionally, the LR test of the UM in contrast to its linear counterpart is highly significant. Hence, the null hypothesis of no neighbourhood differences is rejected. Therefore, signifying the existence of neighbourhood effects. This implies that there is strong evidence suggesting that a multilevel approach is relevant and necessary.

Table 2 UM

	Coefficent	Std. Err.
Intercept	12.557***	0.007
u (Level 2)	0.190***	0.004
e (Level 1)	0.149***	0.000
ICC	0.561	
LR test vs. linear model	1.60+05***	

Significance: * 0.05; ** 0.01; *** 0.001.

[19]Calculated by $e^{12.55653}$, since the model is log-linear.

Table 3 presents the results for the structural attributes model. This model includes all structural attributes. All of these attributes display their expected sign and are strongly significant at a 0.1 percent significance level, apart from having a house with two rooms compared to one room. In other words, increasing the amount of rooms from one to two does not provide a significant increase in property value, *ceteris paribus.* However, there are a number of interesting remarks that can be made with regard to the significant results.

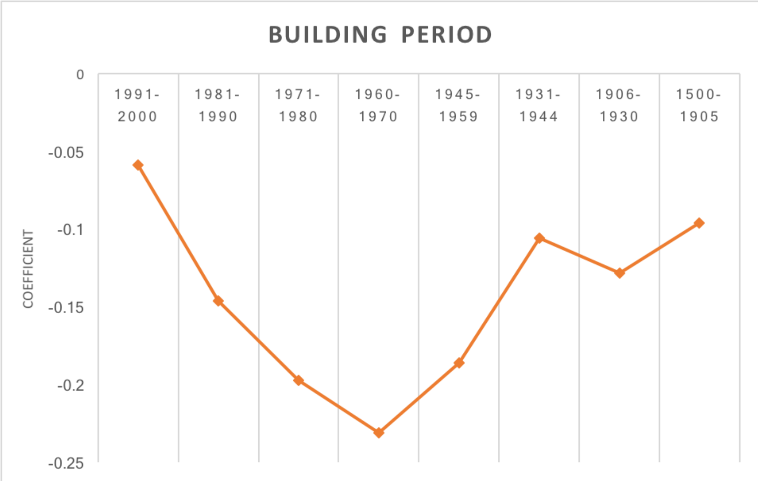

Figure 3: U shaped effect of building period

The type of building has a significant effect on the property values, as the terraced, semi-detached and detached houses yield a positive price premium over apartments[20]. Detached houses have the highest premium of all categories. Properties of the detached housing type have an 38.7 percent higher property value compared to apartments, *ceteris paribus.* Furthermore, the effects of building periods have an u shape as seen in Figure 3. The reference period is 2001 or later. Properties build before 2001 are found to have increasingly lower property values, with a turning point between the 70's and 60's. Lastly, the positive price premium from having more types of isolation plateaus after two types of isolation and up.

Property level variance compared to the UM has declined by the inclusion of the structural attributes. This decrease is due to the fact that property value differences between individual properties are caused by differing structural attributes. The ICC indicates that 79.7 percent of the variation is now occurring between neighbourhoods.

[20]Apartments is the reference category.

Table 3 Structural attributes model

	Category	Coefficient	Std. Err.
Intercept		8.835***	(0.011)
TYPE			
	Terraced-house	0.108***	(0.002)
	Semi-detached	0.233***	(0.002)
	Detached	0.387***	(0.002)
QUARTER		0.023***	(0.000)
BUILD_PER			
	1991-2000	-0.059***	(0.002)
	1981-1990	-0.146***	(0.002)
	1971-1980	-0.197***	(0.002)
	1960-1970	-0.231***	(0.002)
	1945-1959	-0.186***	(0.002)
	1931-1944	-0.106***	(0.002)
	1906-1930	-0.128***	(0.002)
	1500-1905	-0.096***	(0.003)
LNM2		0.721***	(0.002)
NROOMS			
	2	-0.008	(0.004)
	3	0.033***	(0.004)
	4	0.045***	(0.004)
	5	0.062***	(0.005)
	6	0.089***	(0.005)
	7 or more	0.128***	(0.005)
ISOL			
	1	0.013***	(0.001)
	2	0.067***	(0.002)
	3	0.074***	(0.002)
	4	0.068***	(0.002)
	5	0.073***	(0.002)
GARAGE		0.092***	(0.001)
BALCONY		0.005***	(0.001)
u (level 2)		0.106***	(0.012)
e (level 1)		0.034***	(0.002)
ICC		0.758	
LR test vs. linear model		2.70E+05***	

Significance: * 0.05; ** 0.01; *** 0.001.

Table 4 presents the results for the full housing attributes model. This model includes the structural attributes from the previous model and the locational attributes, environmental attributes, interaction effects, and the neighbourhood variables. This model enables the examination of the environmental variables.

Table 4 Benchmark model

	Category	Coefficient	Std. Err.
Constant		8.108***	(0.033)
Structural attributes		(YES)	
LOCATION_C			
	Residential	-0.029***	(0.004)
	Out urban-area	0.086***	(0.011)
DIST_AIRPORT		-5.71e-06***	(4.55e-07)
DIST_PORT		1.21e-06***	(1.26e-07)
NOISE			
	Very Good	-0.015*	(0.006)
	Good	-0.024***	(0.006)
	Fair	-0.028***	(0.007)
	Poor	-0.044***	(0.007)
	Very Poor	-0.066***	(0.008)
GR650		0.382***	(0.074)
IN650		0.098	(0.091)
NO2		5.46e-04	(0.001)
NO2xGR650		-0.013***	(0.003)
NO2xIN650		-0.003	(0.004)
AVG_INC		0.020***	(0.001)
POP_DENS		7.24e-06***	(1.21e-06)
CARS_TOT		1.11e-05**	(3.61e-06)
SCHOOL_3KM		0.005***	(0.001)
u (Level 2)		0.030***	(0.001)
e (Level 1)		0.030***	(0.000)
ICC		0.507	
LR test vs. linear model		29829***	

Significance: * 0.05; ** 0.01; *** 0.001.

The locational attributes and neighbourhood variables appear to have a highly significant relationship with property values. Locational attributes have several interesting features, especially property location. The reference category is a property located in the city centre. Properties located in residential areas yield a negative price premium of 2.9 percent, whereas properties outside urban-areas have a positive price premium associated with them of 8.6 percent, *ceteris paribus*. Furthermore, distance to airport appears to have an unexpected sign. Properties located nearby airports have higher property values than properties faraway from airports. These results suggest that advantages in terms of accessibility by being located nearby an airport outweigh the disadvantages in terms of noise and pollution[21]. The maximum negative price premium of distance to airports within this dataset is approximately 27 kilometres, which would result in a negative price premium of 15.4 percent, *ceteris paribus*. A possible explanation for this negative coefficient could be that this relationship is not linear. Notably, the total number of cars appears to have a positive

[21] This effect persists after controlling for urbanity and distance to nearest highway

relationship with property values. This positive relationship may be due the possible two-sided relationship of these variables, as areas with a higher property values on average presumably have more cars.

Noise unsurprisingly, affects property values negatively, confirming their expected relationship. Properties located in an area with very poor noise quality compared to excellent, appear to have 6.6 percent lower property values, *ceteris paribus.* Levels of NO_2 are not found to be significantly affecting property values. Furthermore, only percentage green space appears to be significant of the two land use measures that have been tested. Interestingly enough, the interaction effect between yearly average $\mu g/m^3$ of NO_2 and percentage green space is highly significant. Testing for joint significance indicates that these measures and their interaction effect jointly affect property values significantly.

The positive coefficient of NO_2 is unexpected, as it suggests a positive relation with property values. However, the level of green space needs to be considered when discussing the partial effect of NO_2, as the interaction effect between NO_2 and green space is highly significant. The partial effect of NO_2 on property values can be found in Figure 4. The line of this graph represents the effect of NO_2 given the percentage of green space[22]. Green land use ranges from 0 to approximately 100, which corresponds with the starting and end point of the line. NO_2 affects properties gradually more negatively as the percentage green within a radius of 650 metres rises. This decline of the positive effect of NO_2 reaches a turning point at approximately 4 percent green space, where after the effect turns negative. Therefore, NO_2 affects the average property negatively in this dataset, considering that the mean of green land use (9 percent) is larger than the turning point of 4.2 percent.

To summarize, the sign of the effect of NO_2 on property values depends on the percentage green space. The positive part of this effect constitutes only a small part of the relationship. NO_2 affects property values negatively with 4.2 percent or more nearby green space.

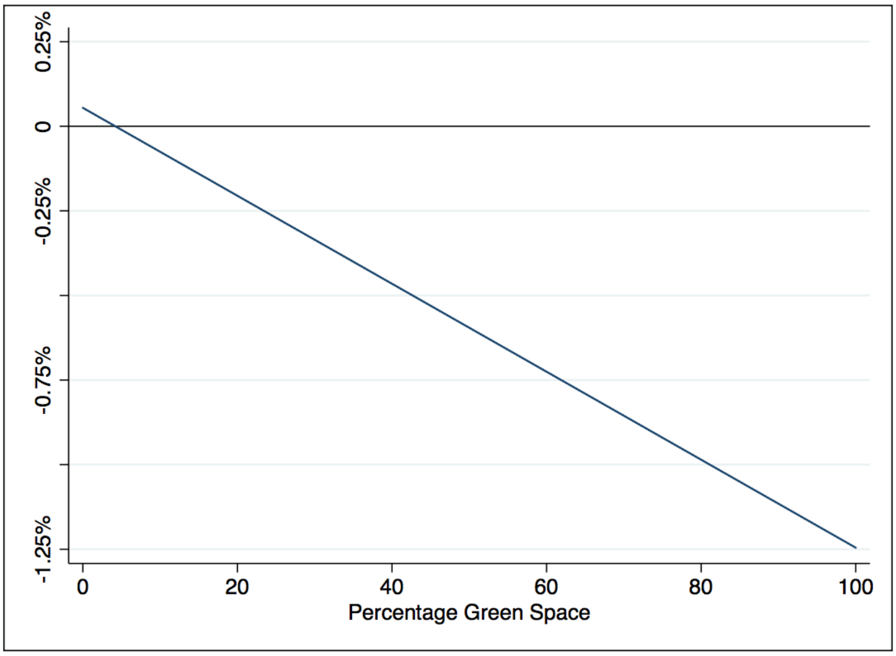

Figure 4: Partial effect of NO_2 on property values

The positive coefficient of green space suggests a positive relationship with property values. However, the interaction effect between green space and NO_2 needs to be considered when discussing the effect of green space. This interaction effect has a negative coefficient and therefore weakens the positive effect of green space. The partial effect of green space on property values is visually depicted in Figure 5. The line in the graph represents the effect of one percentage point increase of green space. The range of NO2 is between 8 and 44 $\mu g/m^3$ in this dataset. Percentage

[22]The plotted equation which gives the partial effect of green space on property values is as follows: $\Delta(Property\ Value)/\Delta(NO_2) = 0.000546 - (0.013/100) \cdot (Green\ Land\ use)$ (dividing by a 100 to get the coefficient for a 1 percentage point increase of green land use).

green space affects properties positively, since it has a positive coefficient. However, this positive effect decreases gradually for each unit increase of NO_2. This decline reaches a turning point at approximately 30 $\mu g/m^3$ of NO_2, where after the effect turns negative.

In other words, more nearby green space with low levels of NO_2 affects property values positively. However, properties located nearby green space with average yearly levels of NO_2 higher than 30 $\mu g/m^3$ are affected negatively by green space, *ceteris paribus.* Therefore, NO_2 affects property values also indirectly through nearby green space.

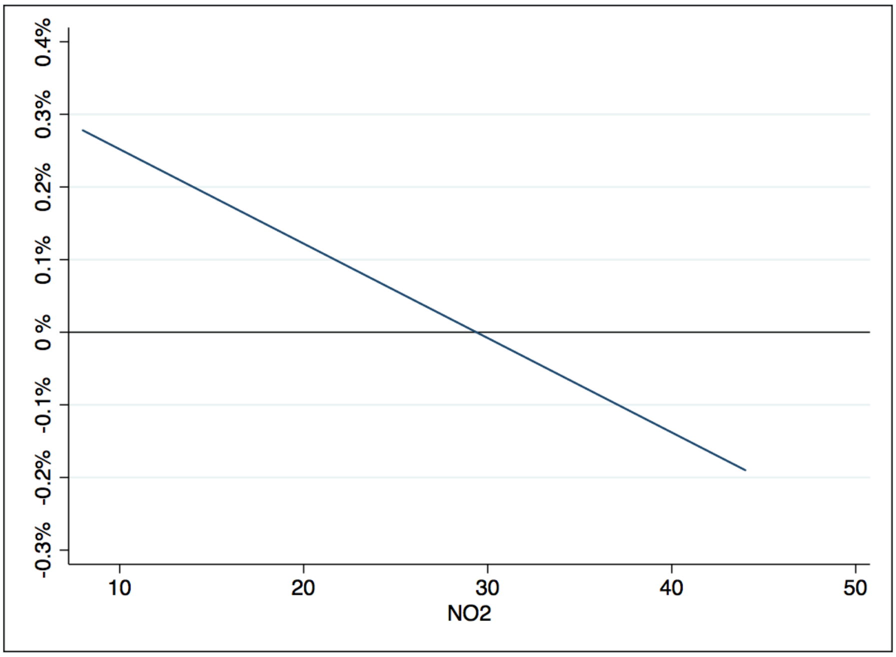

Figure 5: Partial effect of green space on property values

4.2 Sensitivity Analysis

The sensitivity analysis will start by examining the benchmark model with the other proxy's for air quality. These are: SO_2 and PM_{10}. The sensitivity analysis will continue with the alternative classification of green land, in which only forest is classified as green land. The last sensitivity analysis will regard the radius by which the land use measures are generated. The benchmark model will be compared to two models. The first model will include the percentage green and industrial land use within a radius of 500 metres and the second model 800 metres. The results for the locational and neighbourhood variables will hereafter be suppressed, as the main goal of the sensitivity analysis is to test the robustness of the environmental results.

The full models can be found in the appendix. The results of the benchmark model along with SO_2 and PM_{10} results can be found in table 5. The coefficients of the noise pollution categories between NO_2, SO_2 and PM_{10} bear to large extend resemblance, with minimal differences, to each other in terms of magnitude and significance. Percentage green space coefficients across the three models is highly significant and indicates a positive relationship with property values. However, the magnitude of the coefficients differs greatly. These differences may be due to the differing sources of these pollutants. Percentage green space in the PM_{10} model has an unusually large coefficient. This may be due to the fact that PM_{10} can be positively correlated to vegetation (Wesseling et al., 2011). Nonetheless, the significance of the percentage green space results over all three models indicate a strong robust relationship. The percentage industrial land use, on the other hand, is insignificant in all three models. SO_2, unlike NO_2, has direct negative impact on property values and no significant interaction with green space. SO_2 ranges from 0 to 8 in this dataset, what translates to a maximum decrease of property values of 26.4 percent, *ceteris paribus.* Interpreting the results of PM_{10} is a bit more challenging. The interaction effects between PM_{10} and both land use measures are significant. The effect of PM_{10} on property values is positive, however decreases with as the percentage green space and industrial land use increases. The positive effect of PM_{10} on property values, nonetheless, stays positive even for the higher levels of green space and industrial land use. Percentage green space affects property values positively in the PM_{10} model as mentioned above, yet this positive effect decreases as PM_{10} levels rise, as was the case with NO_2.

Table 5 Sensitivity analysis of NO2 results

Model:	NO2		SO4		PM10	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Constant	8.108***	(0.033)	8.207***	(0.031)	7.845***	(0.058)
Structural attributes	(YES)		(YES)		(YES)	
Locational attributes	(YES)		(YES)		(YES)	
NOISE						
Very Good	-0.015*	(0.006)	-0.015*	(0.006)	-0.016*	(0.006)
Good	-0.024***	(0.006)	-0.023***	(0.006)	-0.025***	(0.006)
Fair	-0.028***	(0.007)	-0.028***	(0.007)	-0.030***	(0.007)
Poor	-0.044***	(0.007)	-0.043***	(0.007)	-0.045***	(0.007)
Very Poor	-0.066***	(0.008)	-0.067***	(0.007)	-0.067***	(0.007)
GR650	0.382***	(0.074)	0.168***	(0.036)	1.630***	(0.244)
IN650	0.098	(0.091)	0.049	(0.037)	0.540	(0.255)
NO2	5.46e-04	(0.001)				
NO2xGR650	-0.013***	(0.003)				
NO2xIN650	-0.003	(0.004)				
SO2			-0.033***	(0.005)		
SO2xGR650			-0.042	(0.023)		
SO2xIN650			-0.018	(0.022)		
PM10					0.015***	(0.003)
PM10xGR650					-0.081***	(0.013)
PM10xIN650					-0.028*	(0.013)
Neighbourhood	(YES)		(YES)		(YES)	
u (Level 2)	0.030***	(0.001)	0.029***	(0.001)	0.030***	(0.001)
e (Level 1)	0.030***	(0.000)	0.030***	(0.000)	0.030***	(0.000)
ICC	0.507		0.495		0.501	
LR test vs. linear model	29829***		28501***		29556***	

Significance: * 0.05; ** 0.01; *** 0.001.

Table 6 shows the sensitivity analysis involving the restricted classification of green land use. The results of noise, NO_2, and industrial land use seem to be robust for both classifications of green land use. The effect of green land use on property values seems to depend on the classification as the restricted form, using only forest areas, has no significant effect on property values. The insignificance of the percentage forest areas may be due to the fact that only a small subsection of the dataset is near forested areas and differences within said subsection lack in diversity. However, the coefficient of the nearby forest variable is despite its insignificance noticeably positive.

Table 6 Sensitivity analysis of green land use results

Model:		GR650		GR650_R	
	Category	Coefficient	Std. Err.	Coefficient	Std. Err.
Constant		8.108***	(0.033)	8.160***	(0.035)
Structural attributes		(YES)		(YES)	
Locational attributes		(YES)		(YES)	
NOISE					
	Very Good	-0.015*	(0.006)	-0.015*	(0.006)
	Good	-0.024***	(0.006)	-0.024***	(0.006)
	Fair	-0.028***	(0.007)	-0.028***	(0.007)
	Poor	-0.044***	(0.007)	-0.044***	(0.007)
	Very Poor	-0.066***	(0.008)	-0.066***	(0.008)
IN650		0.098	(0.091)	0.076	(0.091)
NO2		5.46e-04	(0.001)	-0.001	(0.001)
NO2xIN650		-0.003	(0.004)	-0.002	(0.004)
GR650		0.382***	(0.074)		
NO2xGR650		-0.013***	(0.003)		
GR650_R				0.203	(0.129)
NO2xGR650_R				0.002	(0.007)
Neighbourhood		(YES)		(YES)	
u (Level 2)		0.030***	(0.001)	0.31***	(0.001)
e (Level 1)		0.030***	(0.000)	0.30***	(0.000)
ICC		0.507		0.509	
LR test vs. linear model		29829***		30026***	

Significance: * 0.05; ** 0.01; *** 0.001.

The results of the sensitivity analysis on the radii are found in table 7. Noise is again highly significant in all three models, with minimal differences in magnitude of the coefficients of each category. The percentage industrial land use has no significant effect on property values in any of the tested radii. The percentage green space and its interaction effect with NO_2 is also significant for all three radii levels. Moreover, the results indicate that the effect of green space on property values increases as a larger area is considered. However, the negative impact of the interaction effect also increases with radii length. The variables percentage green space, NO_2 and their interaction effect are tested for their joint significance for the radii of 500 and 800 metres. The results of the joint significance test indicate that these variables affect property values significantly at a 0.1 percent level.

Table 7 Sensitivity analysis of radii

Model:	500 Metres		650 metres		800 metres	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Constant	8.125***	(0.033)	8.108***	(0.033)	8.088***	(0.034)
Structural attributes	(YES)		(YES)		(YES)	
Locational attributes	(YES)		(YES)		(YES)	
NOISE						
Very Good	-0.016*	(0.006)	-0.015*	(0.006)	-0.015*	(0.006)
Good	-0.024***	(0.006)	-0.024***	(0.006)	-0.024***	(0.006)
Fair	-0.029***	(0.007)	-0.028***	(0.007)	-0.028***	(0.007)
Poor	-0.044***	(0.007)	-0.044***	(0.007)	-0.043***	(0.007)
Very Poor	-0.067***	(0.008)	-0.066***	(0.008)	-0.066***	(0.08)
GR500	0.293***	(0.067)				
IN500	0.047	(0.080)				
NO2	-2.56e-04	(0.001)	5.46e-04	(0.001)	1.54e-03	(0.001)
NO2xGR500	-0.009**	(0.003)				
NO2xIN500	-0.000	(0.003)				
GR650			0.382***	(0.074)		
IN650			0.098	(0.091)		
NO2xGR650			-0.013***	(0.003)		
NO2xIN650			-0.003	(0.004)		
GR800					0.476***	(0.100)
IN800					0.156	(0.141)
NO2xGR800					-0.018***	(0.004)
NO2xIN800					-0.007	(0.004)
Neighbourhood	(YES)		(YES)		(YES)	
u (Level 2)	0.031***	(0.001)	0.030***	(0.001)	0.030***	(0.017)
e (Level 1)	0.030***	(0.002)	0.030***	(0.000)	0.030***	(0.004)
ICC	0.508		0.507		0.506	
LR test vs. linear model	29965***		29829***		29679***	

Significance: * 0.05; ** 0.01; *** 0.001.

The effect of NO_2 on property values for each radius can be found in Figure 6. More green space decreases the effect of NO_2 as the interaction variable is negative in all the models. Moreover, the interaction effect increases in magnitude as the radius length increases. Thus, more green space measured in an greater area seems to increase the negative effect of NO_2, which can be seen in the form of steeper lines in Figure 6.

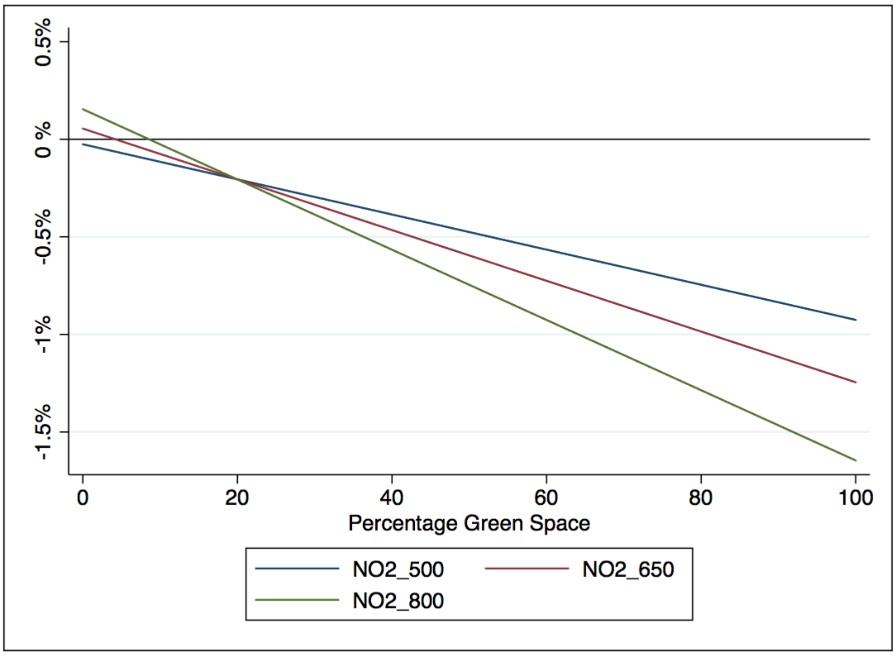

Figure 6: Partial effect of NO_2 on property values for different radii

Table 8 shows the effect of an one unit increase of NO_2 on property values for high and low levels of green space[23]. The effect of NO_2 varies greatly between the three radii models and between low and high levels of green space. The table indicates that NO_2 affects property values positively, with low levels of green space measured in a radius of 800 metres. However, this positive effect constitutes a limited section of the relation between NO_2 and property values, as was the case with the 650 metre radius model. The turning point of the 800 metres model is approximately 8.5 which is still smaller than the mean green land use of 9 percent. Thus, NO_2 affects the value of the average property negatively, even when a greater area is considered. Furthermore, the negative effect of NO_2 with high levels of green space increases in magnitude as a greater area is considered (from -0.93 to -1.65).

Table 8 Coefficient of NO_2

Perc. Green Space		Low	High
Radius:	500	-0.03	-0.93
	650	0.06	-1.25
	800	0.15	-1.65

The effect of green space for each radius can be found in Figure 7. The negative effect of NO_2 through the interaction effect can again be substantial enough to flip the sign of the coefficient of green space. This negative effect of pollution can dominate the positive effect of green space, so much so, that having more green space can decrease property values, because of the high air pollution. This decrease becomes greater as more polluted green areas are in close proximity to a property, as can be seen in Figure 7. The effect of NO2 on the relation between green space and property values intensifies as a greater area is considered, which is visually displayed in the form of steeper lines and earlier turning points in Figure 7.

[23]The maximum and minimum observed green space levels are used as high and low.

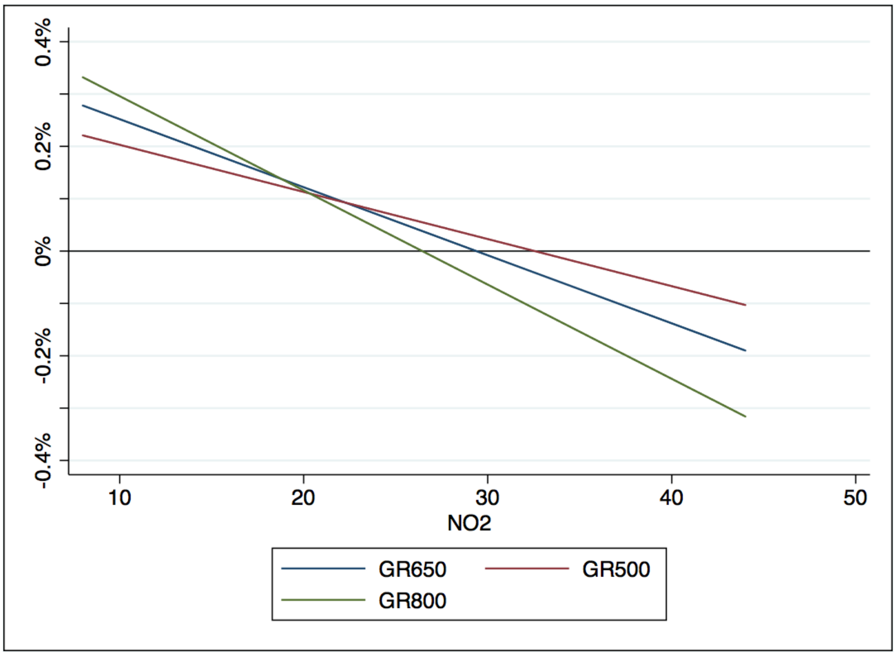

Figure 7: Partial effect of green space on property values for different radii

Table 9 shows the effect of an one percentage point increase of green space on property values for high and low levels of pollution[24] per radius. The effect of percentage green space varies greatly between high and low levels of pollution. The table shows that the pollution levels and the size of the area under consideration have a large impact on how green space affects property values.

Table 9 Coefficient of green space

NO2 levels:		High	Low
Radius:	500	-0.10	0.21
	650	-0.20	0.27
	800	-0.31	0.33

[24]The maximum and minimum observed NO_2 levels are used as high and low.

5 Discussion, Limitations and Recommendations

This chapter will discuss the key findings of the results and answers the hypotheses set up in section 2.4. This chapter concludes with a number of limitations of this study and recommendations for future studies.

5.1 Discussion

The first hypothesis was:

Hypothesis 1: Air quality has a negative effect on property values

A number of air pollution measures have been used in the previous chapter that can help in determining an appropriate answer to this hypothesis. The main air pollution measure was NO_2. This measure was found to affect property values negatively despite its initial positive coefficient. The initial positive coefficient was found to turn negative with relatively little nearby green space. NO_2 was also found to affect property values negatively through its interaction effect with percentage green space. The positive effect of percentage green space on property values was found to diminish gradually for each unit increase of NO_2. High levels of NO_2 can even result in an negative relationship between green space and property values. Furthermore, SO_2 and PM_{10} also have significant relationship with property values. SO_2 displayed the expected negative relationship. However, PM_{10} was found to affect property values positively. This unexpected positive relation may be due to the fact, as discussed in chapter 4.2, that PM_{10} is highly correlated with vegetation (Wesseling et al., 2011). Wesseling et al. describe that trees and plants can have a detrimental effect on the amount of PM_{10} in the air. Trees and plants can reduce the wind in areas where PM_{10} is produced, such as a high intensity roads. This would result in a higher concentration and little to none dispersion of PM_{10}.

Based on these results there is partial support for hypothesis one. The main pollutant of this study NO_2 did affect property values negatively for the most part. Furthermore, NO_2 was found to affect property values also indirectly through green land use. SO_2 and PM_{10} were found to affect property values directly. PM_{10} was found to have a positive relation, whereas SO_2 was found to have a negative relation.

The second hypothesis put forth that green land use will decrease the negative impact of air pollutants. The second hypothesis was as follows:

Hypothesis 2: Green land use has a positive effect on the perception of air quality

The interaction effects for three pollutants were tested on their relationship with property values. None of these interaction effects were found to decrease the negative impact of air pollution. On the contrary, more green land use was found to increase the negative impact of NO_2. Furthermore, this negative impact of green land use increased in size when an greater area was considered. It is unclear why green land use should exacerbate the negative effect of NO_2 on property values. The interaction effect between green land use and PM_{10} also showed the same negative impact. The effect of SO_2 on property values was not found to be significantly affected by green land use. Hypothesis two is rejected as the sign of the interaction effects was negative for both NO_2 and PM_{10} models.

The third hypothesis stated that industrial land use has a negative effect on the relationship of air quality. The third hypothesis was as follows:

Hypothesis 3: Industrial land use has a negative effect on the perception of air quality

The results of the percentage nearby industrial land use indicate that this variable does not affect property values. The results of industrial land use were robust over all sensitivity analyses. The insignificance of industrial land use may be due to insufficient capturing of underlying processes. De Vor & De Groot (2011), for example, splits industrial land in heavy industry and regular industry which yield different results. They argue that heavy industry affects property values differently than regular industry. The third hypothesis is rejected as industrial land use did not show any significance in the results and sensitivity analyses.

5.2 Limitations and Recommendations

A major limitation is the fact that the used land use measures were quite broad, as discussed earlier. Industrial land can, for example, be divided into several categories (i.e., heavy industry and light industry). Deyak & Smith (1974), finds different results for heavy industry than regular industry, as the former is expected to be of greater nuisance in terms of pollution and noise. The same argument can be made of green land use. Green space is, as discussed in section 3.1, a heterogeneous good. It can vary in intensity, or vegetation concentration. This study tried do test for two types of green space. These were: green space in a general sense and green space classified as forest only. However, green space can be further divided into more sub categories. Future research could, therefore, study the effect of air pollution with different green land use measures.

Another limitation is that of MAUP. MAUP are, as discussed in section 3.1, problems regarding the selection of the graphical dimension. The sensitivity analysis regarding different radii for the land use measures indicated that there are indeed differences in results. The significant effect increased in magnitude when a larger area is considered. It is possible that this increase in magnitude will attenuate for radii greater than 800 metres.

Another drawback of the data that has been used is the relative low resolution of the pollutants grid. The pollution maps retrieved from the RIVM had a resolution of one kilometre by one kilometre. It is safe to assume that air pollution can vary greatly between two points in the same grid. However, the interpolation assigns said points with the same pollution level. This naturally affects the study results. Therefore, using air pollution maps with a higher resolution would yield superior results.

Furthermore, data of the pollutants were measures in terms of in yearly average $\mu g/m^3$. These measures can give a distorted view of the air quality. An area which experiences a lot of days with high levels of pollution can have low levels of yearly average pollution, as long as there are more days with very low levels of pollution in the air. A different approach would be to measure air pollution in terms of the amount of days an area experiences very high levels of pollution.

Future research could also include subjective measures of air quality. This data can be collected in the form of surveys. Chasco & Gallo (2013) also found counter intuitive signs for pollutant measures. They state that models based on perceptions could outperform models using objective measures. Including subjective air quality measures can therefore be highly beneficial and needed. Furthermore, authorities might find subjective air quality measures a better guideline when assessing the possible impact of projects with the goal of improving air quality. Future research could also use a different geographical setting. This study used the provinces of North Holland, South Holland, and Utrecht. One could use different provinces that have more variation in pollution levels to add explanatory power to the models and improve results.

6 Conclusion

This study set out to examine the effects of land use on the relationship between air quality and property values. This was done by using a multilevel analysis with variables on property and neighbourhood level. Data from several sources were taken into account and several variables were generated with GIS in order to answer the main research question.

The multilevel model used several housing characteristics. These were of structural, locational, environmental nature. Structural attributes were retrieved from the NVM and included type of property, sales quarter, age of property, square metres, number of rooms, number of isolation types, garage and balcony. Locational attributes included data from the NVM, in the form of the relative location to the city centre. Furthermore, several variables created using QGIS. The data needed to create these variables were retrieved from the CBS and were the following: (1) percentage green land use within a certain radius, (2) percentage industrial land use within a certain radius, (3) the Euclidean distance to the nearest airport and (4) the Euclidean distance to the port of Rotterdam. Environmental attributes were created by using data retrieved from the CBS and RIVM and included green and industrial land use, and air and noise pollution levels. The multilevel model also included four neighbourhood variables. The used neighbourhood variables were: (1) average income, (2) population density, (3) total cars and (4) the number of schools within 3 kilometres. Moreover, a number of sensitivity analyses were conducted to study the robustness of the multilevel model results.

The main research question asked to what degree the effect of air quality on property values is mediated by land use. Industrial land use had no significant effect on the relationship between air quality and property values. This non-existing relationship was robust in all of the sensitivity analyses. However, green land use was found to significantly affect the relation between air quality and property values. Green land use had an unexpected negative effect on the relation between air quality and property values for the pollutants NO_2 and PM_{10}. Furthermore, the sensitivity analysis using different radii showed that the negative impact of green space on the effect of NO_2 increases in size as a larger surrounding area of a property is considered.

Furthermore, a number of interesting observation can be made. Firstly, it was found that the effect of air quality, in terms of the level of pollutants in the air, differs from pollutant to pollutant. NO_2 was found to have a positive effect on property values. However, the positive effect was only the case with very low levels of green space. The average property within the used dataset was found to be negatively affected by NO_2. SO_2 was also found to affect property values negatively, whereas PM_{10} exhibited a positive relation. Furthermore, NO_2 was found to also indirectly affect property values through green land use. Green space on its own yielded a property price premium. However, polluted green space was found to affect property values negatively. The same phenomenon was the case with PM_{10}. This indirect effect of NO_2 was found to increase when the considered surrounding area is greater. Lastly, noise pollution was found to have a negative relationship with property values, robust for different pollutants, classifications and radii of green space.

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7 Appendix

Variable	Obs	Mean	Std. Dev.	Min	Max
LNPRICE	248,696	12.43482	.5455498	11.08214	14.22098
TYPE	248,696	.8159319	.8945416	0	3
QUARTER	248,696	6.621558	3.358012	1	12
BUILD_PER	248,696	3.611719	2.5782	0	8
LNM2	243,636	4.642165	.3821988	3.258096	6.287858
NROOMS	248,696	4.222529	1.379423	1	7
ISOL	248,696	2.159235	1.816408	0	5
GARAGE	248,696	.1534966	.3604663	0	1
BALCONY	248,696	.3638659	.4811117	0	1
LOCATION_C	190,166	1.798013	.6326903	0	3
DIST_AIRPORT	248,696	13012.57	7541.305	21.76673	36972.78
DIST_PORT	248,696	48455.43	27618.02	114.2456	141524.5
NOISE	248,346	3.503902	1.130946	1	6
NO2	248,696	22.36777	4.768984	8	44
SO2	248,696	1.350717	.828569	0	8
PM10	248,696	18.95878	1.237205	13	32
GR500	248,696	.0821785	.0892722	0	.9765142
GR650	248,696	.0887506	.088489	0	.9672264
GR650_R	248,696	.0167765	.0570345	0	.9665818
GR800	248,696	.093421	.0882107	0	.9726223
IN500	248,696	.0453486	.0715492	0	.886682
IN650	248,696	.0514169	.069348	0	.8432879
IN800	248,696	.0561916	.0672376	0	.7547882
AVG_INC	78,155	27.2498	7.299001	10.6	105.5
POP_DENS	248,643	7664.19	5512.266	2	35720
CARS_TOT	248,655	1657.563	1452.451	0	27190
SCHOOL_3KM	165,755	17.075	12.69909	0	62.4
NO2xGR650	248,696	1.975533	1.9208	0	17.91733
NO2xIN650	248,696	1.224653	1.733095	0	22.53599
SO2xGR650	248,696	.1241393	.1614373	0	3.537543
SO2xIN650	248,696	.0737887	.1330657	0	3.004798
PM10xGR650	248,696	1.678219	1.655737	0	19.71019
PM10xIN650	248,696	.9879689	1.339008	0	16.02247
NO2xGR650_R	248,696	.3281399	1.082632	0	15.46531
NO2xGR500	248,696	1.828971	1.964404	0	19.4265
NO2xIN500	248,696	1.079852	1.77886	0	23.88678
NO2xGR800	248,696	2.078804	1.890284	0	16.63962
NO2xIN800	248,696	1.338711	1.695114	0	22.60052

LNPRICE	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
TYPE						
terraced-house	.1103924	.0028294	39.02	0.000	.1048468	.115938
semi-detached	.234532	.0039974	58.67	0.000	.2266972	.2423667
detached	.3812452	.0051908	73.45	0.000	.3710714	.391419
QUARTER	.014748	.0006653	22.17	0.000	.013444	.016052
BUILD_PER						
1991-2000	-.0647597	.0036706	-17.64	0.000	-.071954	-.0575654
1981-1990	-.1564473	.0041299	-37.88	0.000	-.1645418	-.1483528
1971-1980	-.2077791	.004423	-46.98	0.000	-.2164479	-.1991102
1960-1970	-.2368569	.0043489	-54.46	0.000	-.2453807	-.2283331
1945-1959	-.1836095	.0048078	-38.19	0.000	-.1930327	-.1741863
1931-1944	-.1028782	.0047932	-21.46	0.000	-.1122727	-.0934837
1906-1930	-.1185123	.0043797	-27.06	0.000	-.1270964	-.1099282
1500-1905	-.0956945	.0050818	-18.83	0.000	-.1056548	-.0857343
LNM2	.7303805	.0039112	186.74	0.000	.7227147	.7380462
NROOMS						
2	.0608418	.0100613	6.05	0.000	.041122	.0805616
3	.088143	.0101113	8.72	0.000	.0683251	.1079608
4	.0968777	.0103482	9.36	0.000	.0765957	.1171598
5	.1177622	.0106083	11.10	0.000	.0969704	.1385541
6	.140621	.0109292	12.87	0.000	.1192001	.1620419
7 or more	.1864599	.011545	16.15	0.000	.163832	.2090878
ISOL						
1	.0120899	.0023067	5.24	0.000	.0075689	.0166109
2	.0683809	.0030264	22.60	0.000	.0624494	.0743125
3	.0717686	.0035254	20.36	0.000	.064859	.0786782
4	.0573795	.0037759	15.20	0.000	.0499788	.0647802
5	.0684817	.0030188	22.68	0.000	.0625649	.0743985
GARAGE	.0905988	.0026086	34.73	0.000	.0854861	.0957116
BALCONY	.0012496	.0018841	0.66	0.507	-.0024432	.0049424
LOCATION_C						
Residential	-.0284618	.0036097	-7.88	0.000	-.0355366	-.0213869
Out urban-area	.0863464	.0111451	7.75	0.000	.0645024	.1081904
DIST_AIRPORT	-5.71e-06	4.55e-07	-12.55	0.000	-6.60e-06	-4.81e-06
DIST_PORT	1.21e-06	1.26e-07	9.60	0.000	9.66e-07	1.46e-06
NOISE						
Very Good	-.015407	.0062926	-2.45	0.014	-.0277402	-.0030737
Good	-.023791	.0063557	-3.74	0.000	-.0362479	-.0113341
Fair	-.0283647	.0064826	-4.38	0.000	-.0410704	-.015659
Poor	-.0436692	.0066887	-6.53	0.000	-.0567787	-.0305597
Very Poor	-.0663177	.0074497	-8.90	0.000	-.0809189	-.0517165
GR650	.3815364	.0734746	5.19	0.000	.2375288	.5255441
IN650	.098395	.0908884	1.08	0.279	-.079743	.276533
NO2	.0005463	.0007484	0.73	0.465	-.0009206	.0020132
NO2xGR650	-.0130059	.0033507	-3.88	0.000	-.0195733	-.0064386
NO2xIN650	-.0033375	.0038569	-0.87	0.387	-.0108968	.0042218
AVG_INC	.020195	.0005184	38.96	0.000	.019179	.0212109
POP_DENS	7.24e-06	1.21e-06	5.99	0.000	4.87e-06	9.61e-06
CARS_TOT	.0000111	3.61e-06	3.09	0.002	4.07e-06	.0000182
SCHOOL_3KM	.0049482	.0004971	9.95	0.000	.0039739	.0059225
_cons	8.107615	.033397	242.76	0.000	8.042158	8.173072

Random-effects Parameters	Estimate	Std. Err.	[95% Conf.	Interval]
bu_code: Identity				
var(_cons)	.0304409	.0009346	.0286632	.0323288
var(Residual)	.0296061	.0001786	.029258	.0299583

LR test vs. linear model: chibar2(01) = **29829.80** Prob >= chibar2 = **0.0000**

Variable	benchmark	so2	pm10
LNPRICE			
TYPE			
terraced-~e	.11039242***	.11018103***	.11028906***
semi-deta~d	.23453195***	.23432312***	.23452494***
detached	.38124523***	.38092949***	.38165325***
QUARTER	.014748***	.01472346***	.01475698***
BUILD_PER			
1991-2000	-.06475969***	-.06488752***	-.06477624***
1981-1990	-.1564473***	-.1564404***	-.15619939***
1971-1980	-.20777906***	-.2075495***	-.20790272***
1960-1970	-.2368569***	-.23668266***	-.23676366***
1945-1959	-.18360946***	-.18277186***	-.18333105***
1931-1944	-.10287818***	-.10251813***	-.10254953***
1906-1930	-.11851228***	-.11787534***	-.11851325***
1500-1905	-.09569453***	-.09534456***	-.09587214***
LNM2	.73038046***	.73047311***	.7303406***
NROOMS			
2	.06084183***	.06077022***	.06085302***
3	.08814295***	.08798948***	.08819586***
4	.09687771***	.09647831***	.09698659***
5	.11776223***	.11734037***	.117852***
6	.14062103***	.14023751***	.14075615***
7 or more	.18645992***	.18596042***	.1867165***
ISOL			
1	.01208993***	.01195025***	.01210954***
2	.06838091***	.06836287***	.06846773***
3	.07176863***	.07178419***	.07190207***
4	.05737953***	.05736938***	.05740191***
5	.06848173***	.06817305***	.06839698***
GARAGE	.09059884***	.09069441***	.09070793***
BALCONY	.00124961	.00136937	.00137387
LOCATION_C			
Residential	-.02846179***	-.02914238***	-.02821465***
Out urban..	.08634639***	.07884534***	.08810706***
DIST_AIRPORT	-5.705e-06***	-6.033e-06***	-5.381e-06***
DIST_PORT	1.214e-06***	6.520e-07***	1.371e-06***
NOISE			
Very Good	-.01540696*	-.01486881*	-.01592843*
Good	-.02379102***	-.02314024***	-.02475644***
Fair	-.0283647***	-.0278124***	-.02967888***
Poor	-.04366921***	-.04335058***	-.04515487***
Very Poor	-.06631773***	-.06665799***	-.06730646***
GR650	.38153641***	.16825692***	1.6285364***
IN650	.09839499	.0514189	.53937009*
NO2	.00054631		
NO2xGR650	-.01300591***		
NO2xIN650	-.00333753		
AVG_INC	.02019498***	.01998613***	.02014083***
POP_DENS	7.241e-06***	7.684e-06***	6.930e-06***
CARS_TOT	.00001114**	8.897e-06*	.00001172**
SCHOOL_3KM	.00494819***	.00481523***	.00451168***
SO2		-.03256863***	
SO2xGR650		-.04191225	
SO2xIN650		-.01919931	
PM10			.01463278***
PM10xGR650			-.08138468***
PM10xIN650			-.02749804*
_cons	8.1076148***	8.2065318***	7.8431909***
lns1_1_1			
_cons	-1.7459843***	-1.7702183***	-1.7581065***
lnsig_e			
_cons	-1.759887***	-1.7593432***	-1.7595739***

legend: * p<0.05; ** p<0.01; *** p<0.001

Variable	benchmark	restricted
LNPRICE		
TYPE		
terraced-~e	.11039242***	.11066128***
semi-deta~d	.23453195***	.23435554***
detached	.38124523***	.38070136***
QUARTER	.014748***	.01474657***
BUILD_PER		
1991-2000	-.06475969***	-.06458239***
1981-1990	-.1564473***	-.1561696***
1971-1980	-.20777906***	-.20716665***
1960-1970	-.2368569***	-.23649934***
1945-1959	-.18360946***	-.18319393***
1931-1944	-.10287818***	-.10265972***
1906-1930	-.11851228***	-.11836331***
1500-1905	-.09569453***	-.09546357***
LNM2	.73038046***	.73015489***
NROOMS		
2	.06084183***	.06070664***
3	.08814295***	.08808423***
4	.09687771***	.09685022***
5	.11776223***	.11788849***
6	.14062103***	.14064807***
7 or more	.18645992***	.18636292***
ISOL		
1	.01208993***	.01203844***
2	.06838091***	.06835438***
3	.07176863***	.07170034***
4	.05737953***	.05732504***
5	.06848173***	.068442***
GARAGE	.09059884***	.09042004***
BALCONY	.00124961	.00134923
LOCATION_C		
Residential	-.02846179***	-.02846549***
Out urban..	.08634639***	.08284808***
DIST_AIRPORT	-5.705e-06***	-5.662e-06***
DIST_PORT	1.214e-06***	1.147e-06***
NOISE		
Very Good	-.01540696*	-.01517571*
Good	-.02379102***	-.02342553***
Fair	-.0283647***	-.02808103***
Poor	-.04366921***	-.04337472***
Very Poor	-.06631773***	-.06623472***
GR650	.38153641***	
IN650	.09839499	.07660496
NO2	.00054631	-.00081419
NO2xGR650	-.01300591***	
NO2xIN650	-.00333753	-.00243788
AVG_INC	.02019498***	.01993896***
POP_DENS	7.241e-06***	7.458e-06***
CARS_TOT	.00001114**	.00001147**
SCHOOL_3KM	.00494819***	.00518301***
GR650_R		.20295994
NO2xGR650_R		.00163591
_cons	8.1076148***	8.1462845***
lns1_1_1		
_cons	-1.7459843***	-1.7421493***
lnsig_e		
_cons	-1.759887***	-1.7602661***

legend: * p<0.05; ** p<0.01; *** p<0.001

Variable	small	benchmark	large
LNPRICE			
TYPE			
terraced-~e	.11025885***	.11039242***	.11046861***
semi-deta~d	.23441891***	.23453195***	.23458508***
detached	.38118871***	.38124523***	.38135626***
QUARTER	.01476552***	.014748***	.01473944***
BUILD_PER			
1991-2000	-.06471156***	-.06475969***	-.06480407***
1981-1990	-.15655875***	-.1564473***	-.15640448***
1971-1980	-.20770668***	-.20777906***	-.20783711***
1960-1970	-.23671484***	-.2368569***	-.23689771***
1945-1959	-.18328991***	-.18360946***	-.1836297***
1931-1944	-.1025877***	-.10287818***	-.10298993***
1906-1930	-.11825055***	-.11851228***	-.11861339***
1500-1905	-.09543298***	-.09569453***	-.09577161***
LNM2	.73021083***	.73038046***	.73041439***
NROOMS			
2	.06119994***	.06084183***	.06055996***
3	.08847131***	.08814295***	.08796529***
4	.09717748***	.09687771***	.09671979***
5	.11814567***	.11776223***	.11761364***
6	.14108248***	.14062103***	.14042571***
7 or more	.18694179***	.18645992***	.18626655***
ISOL			
1	.01207274***	.01208993***	.01210762***
2	.06828331***	.06838091***	.06844127***
3	.07176895***	.07176863***	.07177124***
4	.05718207***	.05737953***	.05750755***
5	.06832999***	.06848173***	.06856956***
GARAGE	.09053366***	.09059884***	.09056746***
BALCONY	.00129877	.00124961	.00122512
LOCATION_C			
Residential	-.02874196***	-.02846179***	-.02803168***
Out urban..	.0856138***	.08634639***	.08698005***
DIST_AIRPORT	-5.781e-06***	-5.705e-06***	-5.634e-06***
DIST_PORT	1.198e-06***	1.214e-06***	1.232e-06***
NOISE			
Very Good	-.01556029*	-.01540696*	-.01537547*
Good	-.02401101***	-.02379102***	-.02364619***
Fair	-.02870489***	-.0283647***	-.02809175***
Poor	-.04412656***	-.04366921***	-.04331976***
Very Poor	-.06712071***	-.06631773***	-.06560549***
GR500	.29348761***		
IN500	.04668232		
NO2	-.00025641	.00054631	.00153526
NO2xGR500	-.00869801**		
NO2xIN500	-.0003901		
AVG_INC	.02025651***	.02019498***	.02014087***
POP_DENS	7.383e-06***	7.241e-06***	7.118e-06***
CARS_TOT	.00001108**	.00001114**	.00001126**
SCHOOL_3KM	.00496565***	.00494819***	.00491253***
GR650		.38153641***	
IN650		.09839499	
NO2xGR650		-.01300591***	
NO2xIN650		-.00333753	
GR800			.47628794***
IN800			.15612778
NO2xGR800			-.01785036***
NO2xIN800			-.00695448
_cons	8.1245748***	8.1076148***	8.0882164***
lns1_1_1			
_cons	-1.7441058***	-1.7459843***	-1.7485757***
lnsig_e			
_cons	-1.7600488***	-1.759887***	-1.7597952***

legend: * p<0.05; ** p<0.01; *** p<0.001