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Thesis

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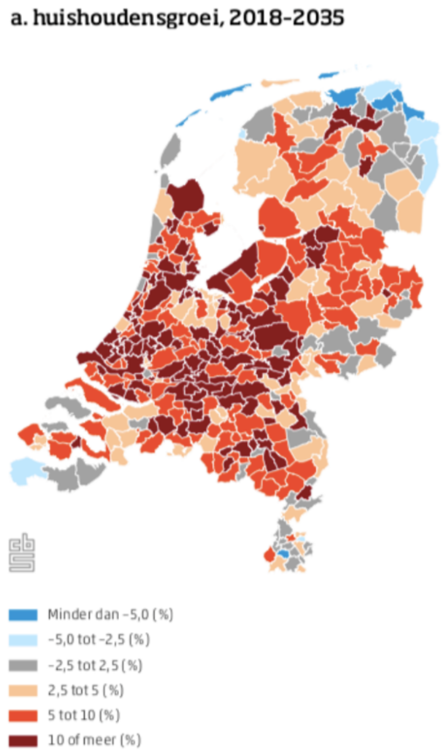
"What influence have different sustainability policy forms per municipality on the housing price trends and resulted these different policies into interregional price differences for the metropoolregio Amsterdam?"

Content

1. Introduction

Housing prices have gone through the roof in Western Europe in recent decades. In the Netherlands, house prices have inflated by 78% in real terms since 2012 (CBS). In the last year alone (2020 – 2021) the average transaction prices have increased between 3.90% in France to 10.81% in the Netherlands (Deloitte, Property Index). The average increase in transaction prices for major cities within Western Europe is even more marked, doubling the national growth rates (figure 17, appendix). The inflation of house transaction prices can be attributed to several key factors. Significant drivers are stagnating construction, a constrained supply, and an increasing population (Maydou, Monfort, Morley, 2021). The house price boom has been fueled by the Covid-19 pandemic, influenced by record-low interest rates, a rise in savings (FT, pandemic house price boom) and a supply demand imbalance in housing inventory as global supply chains have come under pressure and the cost of building materials has increased. These trends have exacerbated the shortage of affordable housing across Europe: for example, the Netherlands, Germany and the United Kingdom have an estimated shortfall of 331.000 units, 1.000.000 units, and 3.500.000 units respectively (State of Housing in EU, 2021). Easing the housing crisis has become a top priority for governments across Western Europe (NOS). but they face the challenge of balancing building affordable housing with sustainability goals. Indeed, research has demonstrated that buildings and construction and are one of the single largest contributors to climate change. According to the Global Status Report for Buildings and Construction 2020 report from the United Nations Environment Programme, the building sector accounts, directly or indirectly, for 38% of global energy-related carbon emissions. Construction accounts for 5-12% of total national greenhouse gas emissions in Europe according to the European Commission Buildings and Construction department. Housing stock contributes to the climate change crisis: residential buildings are often energy inefficient and account for one 20% of greenhouse gas (GHG) emissions (Economist World, 2022, p.94) To combat climate change it is essential to make housing stock more sustainable. Sustainable housing' is defined as housing with a minimum negative environmental impact in terms of climate change (greenhouse effect); the quality of the air, water, and soil; noise; stench the stock of nonrenewable materials; and biodiversity (Priemus, 2005). Numerous policies on both an international and national level have been enacted to focus on mitigate the negative impact of the building sector on climate change and encourage the create sustainable housing stock. For example, the European Cohesion Policy lists in top five objectives for 2021-2027 'supporting sustainable urban development across the EU' and has allocated 8% of the European Regional Development Fund in support of sustainable and affordable housing. In the Netherlands, The Dutch Climate Agreement stipulates that by 2030, one and a half million existing homes should have been made sustainable, and that by 2050, 7 million homes must have ceased using natural gas. The Netherlands Energy Performance Certificate (EPC) system, implemented in 2008, requires that houses and apartments have an energy label (which rates the energy efficiency of the property) when they are bought or sold. The Netherlands also encourages sustainable housing through subsidy schemes: for example, the Energy-Efficient home scheme provides extra credit of 9000 euro in a mortgage if a home has a valid energy label of at least A++, and the Sustainable Energy Investment Subsidy (ISDE) provides subsidies for the purchase of solar boilers and heat pumps. Despite the many policies to encourage more sustainable housing (the International Energy Agency lists 31 policies from 1992 to 2022 in the Netherlands specifically addressing this objective), it is not yet entirely clear how effective these policies are, and to what extent households include sustainability in their purchasing decisions (Stiglitz, 1979).

This research investigates to what extent home buyers in the municipalities around Amsterdam, The Metropoolregio Amsterdam, take into account sustainability as a criteria in their property search, and whether sustainability policies and subsidies play a role in their purchase decision. Several research papers have analysed the effect of sustainability on the housing price trends. The sustainability development of office buildings lead to a 2% higher profitability on rental price and a 6% to 9% more effective rent policy for so called "Green buildings" (Eichholtz, Kok and Quigley, 2010). These different sustainability factors per building lead to a differential in the price development. Nevertheless, in the beginning of the 21st century there was an abstinence of the investment activity by real estate investors to invest in sustainability developments due



to the lack of evidence for the expected positive long-term returns. The proof of the added value in terms of IRR was not a given (Kok & Jennen, 2010). This trend resulted to be more present in political discussion and was built up from 2010 onwards. The Metropoolregio Amsterdam has been chosen as it represents a microcosm of several of the key trends described: it faces a major housing shortage, a significant sustainability change and has many subsidies at a municipal level. However, the latest efforts from the Dutch government this housing shortages is still surging. The government's public housing policy has strongly promoted the current housing shortage. ABF research, a by the government appointed research body, researches scenario's focusing on the Dutch populations, number of households and the real estate market. In their latest report the researchers founded two main factors amongst others that play a major role in the creation of this problem. The Dutch government has systematically underestimated population growth and there is a continuing decline in the average size of a household in the Netherlands. To combat the housing shortage, an average of 80,000 additional homes need to be built each year. This paper will be focused on the involvement of the different stakeholders, the tradeoff between personal gains and municipality goals and the influence of sustainability policies on the transaction prices. To research these stakeholders and involved factors there is the following research question defined:

"What influence have different sustainability policy forms per municipality on the housing price trends and resulted these different policies into interregional price differences for the metropoolregio Amsterdam?**"**

2. Literature review

It is estimated that the construction sector is currently reliable for 40% of the world's emissions (as stated in the latest report by the Global Alliance for Buildings and Construction). The indirect and direct pollution from residential housing accounts for 17% on a pro rata basis. In addition, 55% of the wood that is not used for fuel is consumed in construction. The design and operation of real estate can play a major role in energy conservation. These operational decisions are made by real estate investors whilst being monitored by the governments. (Eichholtz, Kok and Quigley, 2009). For example, concrete contributes 8% of the global emissions. It is identified that taking actions in the construction sector and especially in the residential and office sector is amongst one of the most cost effective. Opposed to more costly and complicated issues such as the transition period to renewable energy. The International Energy Agency forecasted the global building stock to increase from the current 223 billion sqm to an estimate of 415 sqm needed in 2050. This means that all global, national and local initiatives can have a major impact on the improvement of climate change. These concerns have globally been expressed in many concrete commitments. The latest major initiative was the foundation of the Net-Zero Asset Owner Alliance. Several national pension funds and insurers committed directly $2.4 trillion of their assets to be carbon neutral by 2050 of which a major part are real estate portfolios.

Investors are one of the three main stakeholders that are part of the decision making concerning the pollution intensity coming from real estate properties and developments. The three main stakeholders are individuals (property owners), companies (investors & real estate developers) and (national & local) government bodies. For individuals is climate change thus sustainability of their real estate properties a secondary problem. Property owners care about the price of a house transaction above anything else. There are a few problems that cause this possible short-term ignorance of the environmental side of the transaction, namely the hidden costs of energy efficiency investments, principal-agent problems and behavioral failures such as inattention (Aydin, Brounen & Kok, 2020). The inattention is primarily caused by the fact that individuals can't see the immediate consequences of their positive sustainability measures. Individuals don't solve the climate change by putting solar panels on their roof. Why would I make this extra investment and not my neighbours? Which results in (on purpose) inattention from individuals. The consequences of their actions will occur in the future and will not be seen in a short-term period (in a few years). The distance between an action and its outcome confirms an uncertainty factor over the long-term future compared to the present (Why people aren't motivated to address climate change - Harvard Business Review, 2018). This created ignorance is also a problem for investors and developers. The management of large investors / developers rotate frequently. This means that they have a direct incentive to maximize their own benefits, which are shown short term, instead of focusing on long term measures such as sustainability policies or costly measures against climate change. Own self-interest and short-term goals coming from the previously prescribed stakeholders lay a responsibility at the last stakeholder. The national and local government bodies have the obligation to pursue (most of the time) a long-term future plan for their country. The governments have to guide the short-term needs and goals from the other stakeholder by putting up rules and regulations. This is the only way feasible way to make an attempt to achieve the long-term goals needed. Especially in the past 10 years the importance of environmental and sustainability policies became increasingly relevant and important. The trend started especially in the beginning of this decade when many Governments choose to support the heavily polluting industries (like automotive, oil & gas). Because these companies accounted for a big part of the employment. Therefore, an easy choice to support the companies who are supposed to be the engines in the world's economy. Since then, the scientific and social perspective of these matters have changed thus the political perspective. What are these environmental and sustainability policies?

There are different approaches and opinions to define these two different policies. One of the first researchers that made a distinction between sustainability and environmental policies was Stiglitz in 1979 in its research: A Neoclassical Analysis of the Economics of Natural Resources. The environmental policy described is the time path of all incentives, such as emission taxes and resource conservation subsidies, with which the government can intervene in decentralised markets to internalise the costs that a single agent (property owners) treats as external to her private maximization of intertemporal welfare. Sustainability policies by the municipalities are the time path of incentives which persuade agents to achieve a collectively desired "sustainability" goal. The individuals need an external factor that motivates and align their own incentive, maximizing welfare, with the collective desire: reaching sustainability goals. Most individuals will never voluntarily choose to not maximize their welfare to contribute to the collective goals. That confirms the essence of the environmental and sustainability policies. Another important environmental definition would be the emissions tax and a resource stock subsidy combined, each equal to the respective external cost or benefit (Pezzey, 2004). These environmental policies are partly based on the substitution possibilities. Are there any existing limits to sustainability? If so, mankind needs to look into the most suitable policy matched with moral standards as response to such an uncertainty (Howarth, 1992). These substitutability limits between the different sectors where the policies have an influence (e.g. real estate vs. heavy industry) are direct related with the amount of sector specific policy measures (Asheim, Buchholz and Tungodden, 2001). For the real estate and construction industry these policies are mainly the sustainability policies. The sustainability policies compromise a forced trade-off between immediate consumption of capital or the incentive to investment for long term benefits. The sustainability policies exist to strongly incentive consumers to choose for the latter. The sustainability policies can include consumption tax, capital subsidies or investment subsidies (or a combination). These capital subsidies can be arranged by the national or the local governments (the municipalities). The sustainability policies are therefore not solely focused on environmental aspects. It is important to encouraging more savings and hence capital investment to substitute for some degree of future environmental resource depletion. Pezzey used a neoclassical theory to analyse the drivers behind the sustainability policies. The neoclassical economic theories are known for their focus on the explanation of the drivers between supply and demand (Stiglitz, 1979). The definition starts with the sustainability policy defined by the general consumer tax τ^C correlated with the personal and general discount rates ρ and σ :

$$-\frac{\tau^C}{1+\tau^C} = \rho - \sigma$$

This equation shows the impact of the consumer tax implemented through a sustainability policy to the individual's effective utility move from ρ to σ. This individual's intuition can be seen when the discount rate σ is less than ρ , showing stronger concern for future generations. Which means that the personal benefits are greater than the added value created by the sustainability policies. This results in the τ^C(t) being a falling consumption tax or a rising consumption subsidy. This creates an incentive to delay consumption and bring forward productive investment. By implementing the sustainability policies the "translation" has been created from elusive long term benefits towards short term visible benefits. E.g. a 20% tax return on buying solar panels. These measures differ from time to time and are often correlated with the volatility of the economic cycles. Countries in the middle of an economic crisis tend to reserve less for sustainability goals. Other matters will have priority during these periods such as unemployment or health crisis's (Covid-19). The sustainability policy is a dynamic governmental intervention method to maximise the social present value by internalising the social values of environmental decisions which individuals tend to ignore when they privately maximise the present value.

Sustainability policies exist to incentivize people to build sustainably by providing concrete benefits. Sustainability policies exist on both and international and national level. The international Energy Agency, an organization geared towards the promotion of renewable energy, has identified over 3000 initiatives and agreements focused on mitigating climate change since 1972. Policies are encouraged by climate change activism on a global scale, such the United Nations Climate Change Conference (COP26), which brought together over 20 governments united in pact to keep global warming at 1.5 degrees Celsius above pre-industrial levels. What does decarbonization policies look like in the residential real estate sector? It can involve low carbon development and construction by purchasing lower-emission building materials; building retrofits to improve energy efficiency; upgrades to heating and cooling systems. China has made energy efficiency a cornerstone of its 5-year plan and aims to retrofit 4 million square feet of non-residential space. In a European context this is exemplified by the new Green Deal and pursuit of climate neutrality by 2050 (Lambrechts & Co, 2020). The EU has required member states to produce energy performance certification schemes for residential buildings since 2009. International sustainability policies put pressure on local governments to create their own policies. (Kok, 2020) For example, although the US does not have a federal policy for energy efficient building, under California's Global Warming Solutions Act, 50% of commercial buildings will be retrofitted to be net zero energy by 2030. In order for sustainability policies to become truly effective, there needs to be uptake on the consumer side. But do western consumers care about buying sustainable housing? Research seems to indicate that consumers increasingly factor sustainability into their purchasing decisions as a result of a growing awareness of climate change and rising energy prices. A survey conducted by the Building Research Establishment in the UK reported that "more than two two-thirds of respondents listed sustainable features such as high levels of insulation, triple glazing, solar panels would be very important or quite important". A 2019's study by NIBUD found that 57% of Dutch people intended to make their homes more sustainable. Does this positive sentiment towards sustainability translate into willingness to pay for consumers in the residential real estate market? The implications of research are mixed so far. The research of Chegut, Eichholtz & Kok, (2009) found that 'green housing' creates a gentrification effect, meaning that average rental and sales prices in the neighbourhood rose. However, the prices of non-green housing in the neighbourhood also rose, limiting the extent to which the importance of sustainability was factored into purchase decisions. The willingness to pay for a more sustainable neighbourhood, after gentrification, can sum up to 50% (Hong, 2011). It could be theorized that there would be an increased uptake in sustainability subsidies for residential real-estate if it was proven to be a good investment decision. The findings of research so far seem to indicate that there is a positive relationship between sustainability and commercial real estate, but the results are more mixed for residential real estate (Eichholtz et al., 2010, 2013). This could be because the commercial sector is more heavily regulated: indeed, from 2023 onwards every office in the Netherlands over 100 square meters will be required to have a minimum of C energy label. Brounen and Kok found that the consumers pay a 4 percent premium for homes labelled as efficient. Their research uses energy efficiency labels as a proxy for gauging sustainability, with homes labelled A, B or C considered to be 'efficient' and thus sustainable. Dasptrup et al. (2012) studied the residential real estate market in California and found that homes with solar panels sold at 3.5 percent premium. Despite growing interest in sustainability and rising costs of energy bills it can be observed that these premiums are quite marginal. There is a possibility of an "attitude-behaviour" gap: meaning that although sustainability is said to be increasingly important to all stakeholders, people are not willing to pay for sustainable products and services (McKinsey, 2021). Research by Alcott and Greenstone (2012) has demonstrated that the uptake of subsidies for energy investments has been limited. Kok suggests that consumers are reluctant to invest in energy efficiency upgrades due to their perceived undervaluation on the market, the length of payback time and the nuisance of retrofit work (2021).] Bernet theorises that in the investment rental market, there is little incentive to retrofit homes as investors believe that the benefits (such as lower heating costs) will mainly pass on to the tenants instead of the investors (Bernet and co., 2010).

3. Data Analysis

3.1. Objectives

In order to analyse the MRA housing market, it is first necessary to explore and understand the data. The NVM dataset obtained represents 291,137 house listings over the course of 10 years. After the cleaning of the data (described in the method section) 205,422 data points will be used for this research. The dataset consists out of 65 variables available for each listing. 20 of these hedonistic variables are used as control variables in this paper:

m^2	m^3	year	score	insulation
construction period	parking	# floors	garden m^2	location 1*
location 2*	location 3*	garden location	garden quality	inside maintenance
outside maintenance	# balcony	# rooms	# toilets	quality workmanship

**Location variables are related to the quality, busyness and centralized location*

The relative distribution of the overall transactions is concentrated mainly in Amsterdam followed by the middle large cities such as Haarlem, Haarlemmermeer, Hilversum and Zaanstad. The dataset didn't include the transaction data for Almere and Lelystad, which are officially part of the MRA. The distribution of the transaction type is quite balanced: 56% of the transactions are apartments and 44% are houses (named Single family in the dataset). The floor area for the apartments where on average smaller then for houses (figure 18, appendix). Moreover, the majority of houses in the plot size distribution ranges

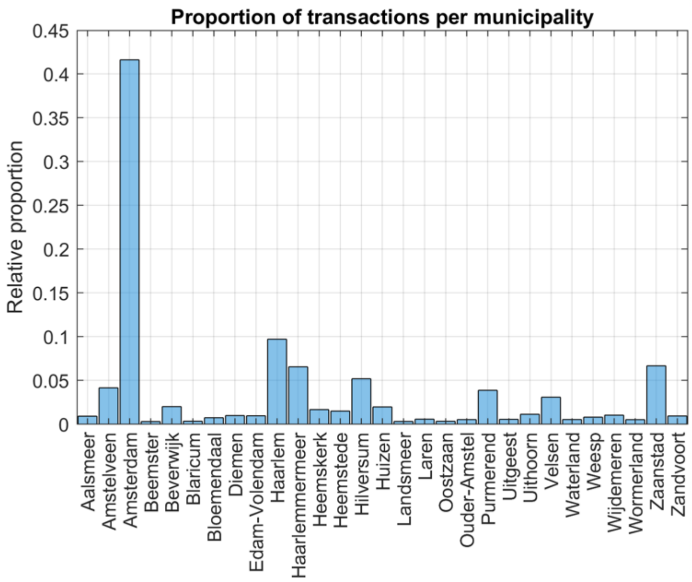


Figure 1. Proportion of transactions per municipality

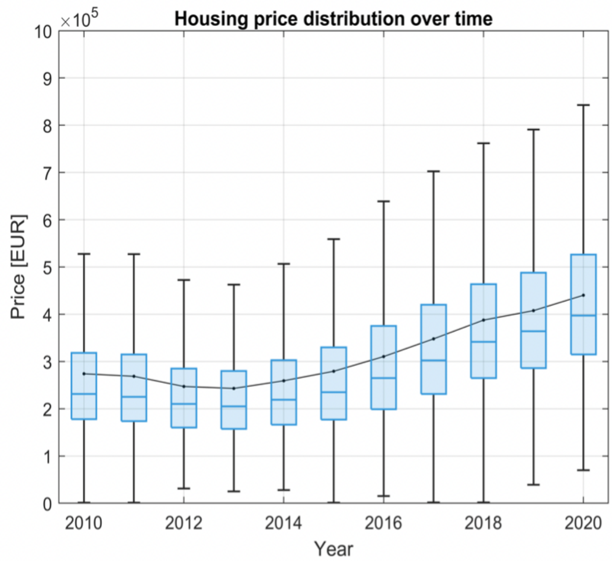


Figure 2. Housing price distribution over time

from $100^2 – 300m^2$ (figure 19, appendix). Over the past 10 years the increased price volatility has led to a wider range of minimum and maximum transaction prices in the region as seen in the boxplot above. This trend came along with increasing average transaction prices for the municipalities. The average transaction price per municipality and the ranges are quite widespread. The more expensive municipalities tend to have a wider range of property values than the on average cheaper once's. However, the size of the municipality doesn't have any influence on the range of transaction prices in the 25% most expensive municipalities. The top 10 most expensive cities include both large (e.g. Amsterdam) and small (e.g. Laren) cities with quite similar ranges as shown in the boxplot below. On the other hand, if a comparison is made between the larger expensive cities and the cheaper smaller (lowest 25%) municipalities, than there is an upward trend in the price range volatility for the larger expensive municipalities and a stable trend for the cheaper smaller once's. (figure 20, appendix)

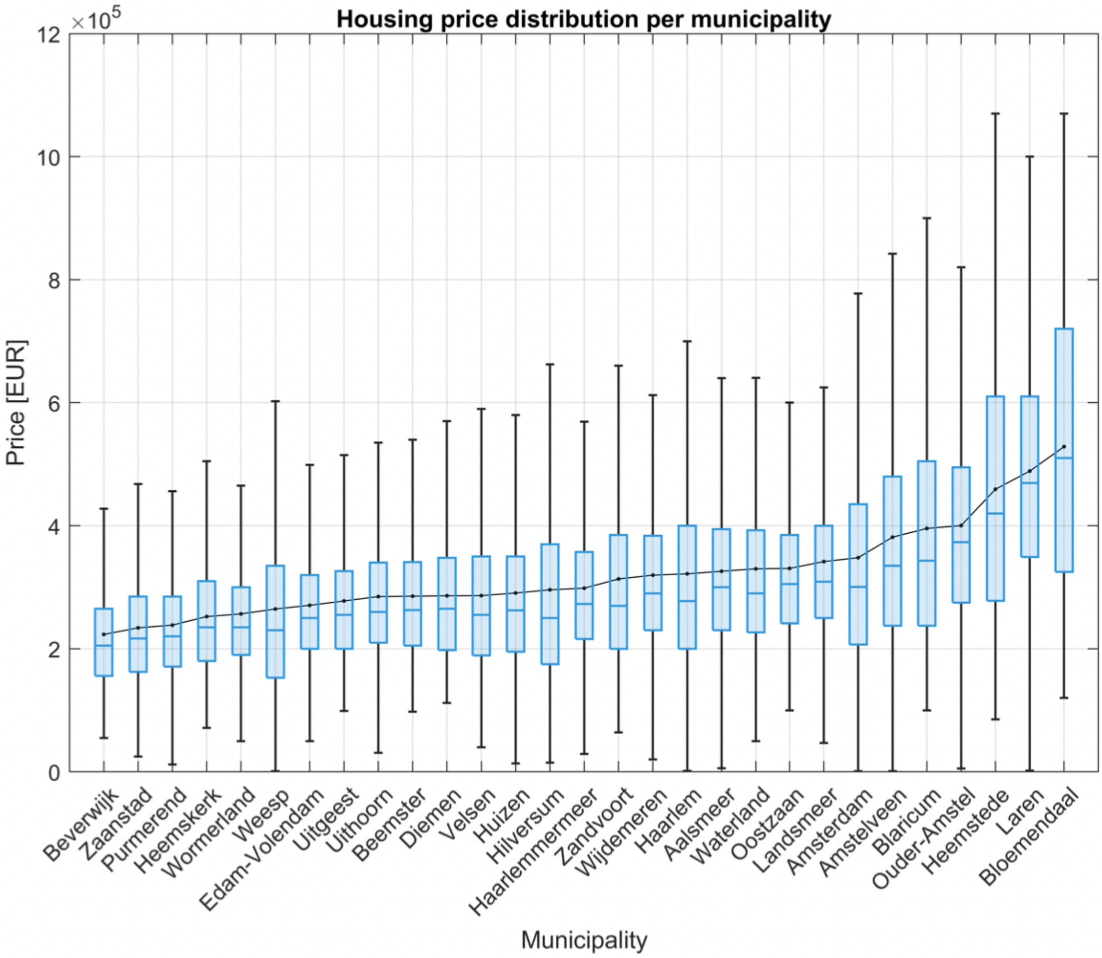


Figure 3. Housing price distribution per municipality

The data analysis shall be guided by three questions:

1) What for influence has the degree of insulation on the average transaction price?

2) How is the price of housing affected by the sustainability policies of different municipalities?

3) How accurately can we predict the transaction housing prices?

Before proceeding with the methodology and the regression models it's necessary to understand how the different control variables are distributed and what the different values mean. Via Brainbay I was able to get a hold of the definitions of the data. Underneath is an example of the distribution of a few variables. There is not a pattern in the distribution of the values of the specific variables. Some have a particular high concentrated distribution of values which make them less attractive as a control variable in the dataset. The wideness of the distribution influences the information about the different areas that the control variable can provide.

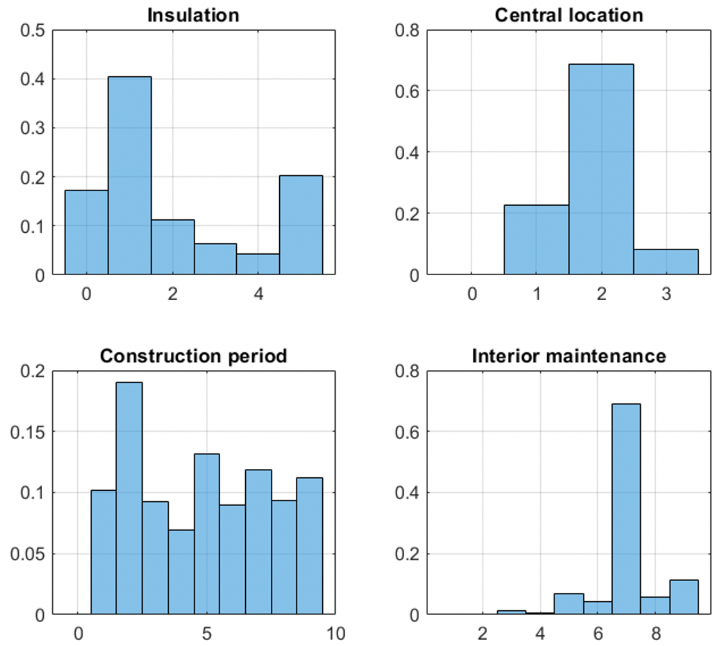


Figure 4. Category range examples of some of the hedonistic variables

3.2. Research Scope

The metropoolregio Amsterdam is an agglomeration of 32 municipalities. The current regions cumulated together have a population of approximately 2.5 million inhabitants. The region currently accounts for 18.7% of the Dutch GDP. The metropoolregio Amsterdam is the biggest financial district of the Netherlands. One of the greatest current challenges in the area is the housing shortage. The local governments are focused on developing as much as possible houses in a short time frame. The MRA made a construction deal with the national government to have 100.000 additional houses constructed in the region before 2025, the "Woondeal" was implemented by our previous minister of real estate Ollogren in 2019.

The leading program to realise this goal would be the Actieprogramma woningproductie MRA 2018 – 2025. This program has been realized to boost the number of houses in the most sustainable way possible. Part of this program is the year program living (Jaarprogramma wonen MRA). This program describes the yearly concrete goals for every stakeholder. It is important that the underlying programs are flexible to prevent difficulties by unforeseen problems such as the Covid-19 pandemic. These guidelines are used by local municipality governments to establish their own expectations and local goals for the construction of new build houses as well as transformational projects. The programs are an important source of information for the commercial stakeholders to manage their expectations for the building license process. Another national motivation example is that every local municipality must have written a “warmte visie” by the end of 2021. This future policy is there to describe which timelines are existing per municipality to focus on transforming parts of the local community into more CO_2 neutral environments. By for example giving out specific subsidies to inhabitants of specific areas to upgrade their isolation or to place solar panels on their property.

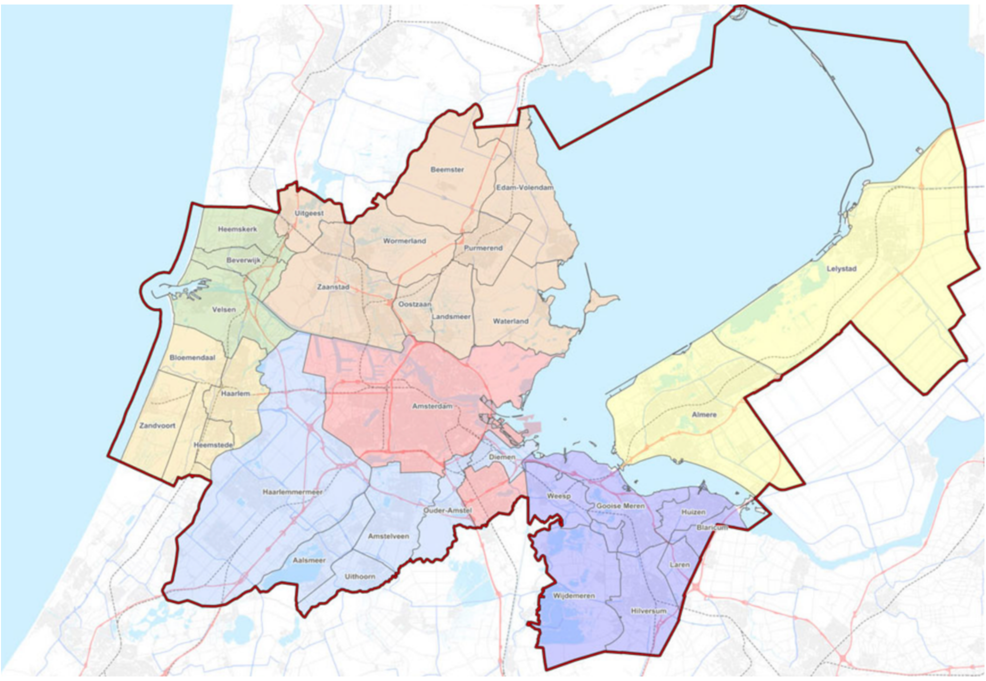


Figure 5. Metropoolregio Amsterdam

The key real estate developers, investors and governmental department of real estate minister Hugo de Jonge are the groups of companies and governmental bodies that are the key decision makers in the substantial growth of sustainable residential developments. The pace of the CO_2 reduction as well as the housing shortage is depending on the negotiations and decisions by these different groups. However these different stakeholders have a different goal and agenda. The national government wants to solve the housing shortage in the most sustainable way. To work towards a CO_2 neutral country in 2050. The local municipalities want to attract big multinationals to generate local job opportunities. This creates a need to have a local attractive property market. In terms of differentiation in property types and overall availability. Therefore attracting the best real estate developers and investors is key for the development of a viable and future prove municipality. On the other hand the real estate developers and investors are looking for the best investment opportunities. The two main drivers to evaluate these opportunities are the speed of the construction licenses and the expected house price developments per region. There is a clear trend of international real estate investors to stick to the large city names. This is one of the reasons why the Amsterdam prices have relatively increased a lot compared to the neighboring municipalities. The valuation measure to buy a real estate property is a yearly rental multiple. The average bid for a property currently lies between 22x – 30x the annual rent. In a region like Zaandam this range varies from 14x – 22x. This huge difference cause highly competitive processes for high quality development locations. The real estate developers and investors are depending on the construction material regulation implemented by the national government. For their building licenses and building mix of different properties they are depending on the local government. For example most of the different municipalities have a 30% social housing requisite. This means that a real estate developer who has a construction project of 100 apartments needs to build at least 10 social housing apartments. It is a difficult process through all these interconnectivities and different workstreams between the different stakeholders. Some industry experts claim that the pace of the issuance of a building license is currently way to slow. In that way, real estate investors and developers are not willing to work together with certain municipalities where this process is too slow. Moreover the national government is not able to reach its construction goals if every municipality is doing all it can to help solve this housing problem. A causation of the strict licensing process are the regulations established by the national government. It seems that the Dutch real estate sector as entered a vicious circle.

3.3. Method

This section shall detail the method used for the data analysis, guided by the questions listed above. The used programming language for all the data analysis methods used in the paper will be MATLAB.

3.3.1. Sustainability scorecard

I have created a sustainability scorecard using a combination of three different criteria to define a sustainability score per municipality. The three different factors are: 1) subjective opinions from investment professionals on the "sustainability focus" of the municipality, 2) the average percentage of properties with solar panels per municipality, 3) the # of insulation subsidies giving out in the last few years / the # citizens per municipality. In order to create a combined score, a weighting factor needs to be include for each score. The easiest method to use in practice was to use the MAX and MIN options in Excel to recalculate the different values back to a normalized score between 1 – 5. Using this weighting system with a maximum score of 15, gives a direct insight in which factors have the biggest influence per municipality. The first factor, the so called Elfi score, includes several subjective experiences from local real estate acquisition managers (N=5). I gathered a score per municipality per acquisition manager on how they have experienced the easiness of the workflow of the different municipalities. For every municipality there is a trade-off between the speed of issuing new building permits and the intensity of the sustainability policies. More implemented rules means a longer permit issuance process. This means that the focus on the sustainability policies of a municipality can be often determined by looking at how strict the policies are concerning the issuing of building permits. I sat down with every acquisition manager individually and had a conversation about all the municipalities individually asking them to provide a score between 1 – 5 for the easiness and speed of the issuance of permits. After conducting these interviews, I took the average per municipality to have a subjective indicator of their focus on sustainability. The second sustainability factor I took into account was the use of the "subsidie energiebesparing eigen huis". This is a governmental initiative to stimulate the energy transition. I found the data on the website waarstaatjegemeente (see sources). This database gives insights into different subsidy segments: Floor insolation, soil insolation, double glazing, façade insolation and roof insolation. A score will be created by dividing the number of given subsidies / inhabitants per municipality to get an energy transition score. This number will also be normalized to a score between 1 – 5. The last factor is the percentages of houses with solar panels in the municipalities which I found in the CBS database. The average price of a house / apartment with a WOZ – value between €200.000 – €400.000 increases with €5000 - €7000. This means that the number of solar panels and the potential of having subsidy can have an influence on the price development. Again a score between 1 – 5 is giving to every municipality by comparing the different solar panels penetration rate per municipality and how they perform compared to the average. All scores combined gives a score between 0 – 15 to rank the different municipalities on intensity of sustainability policies:

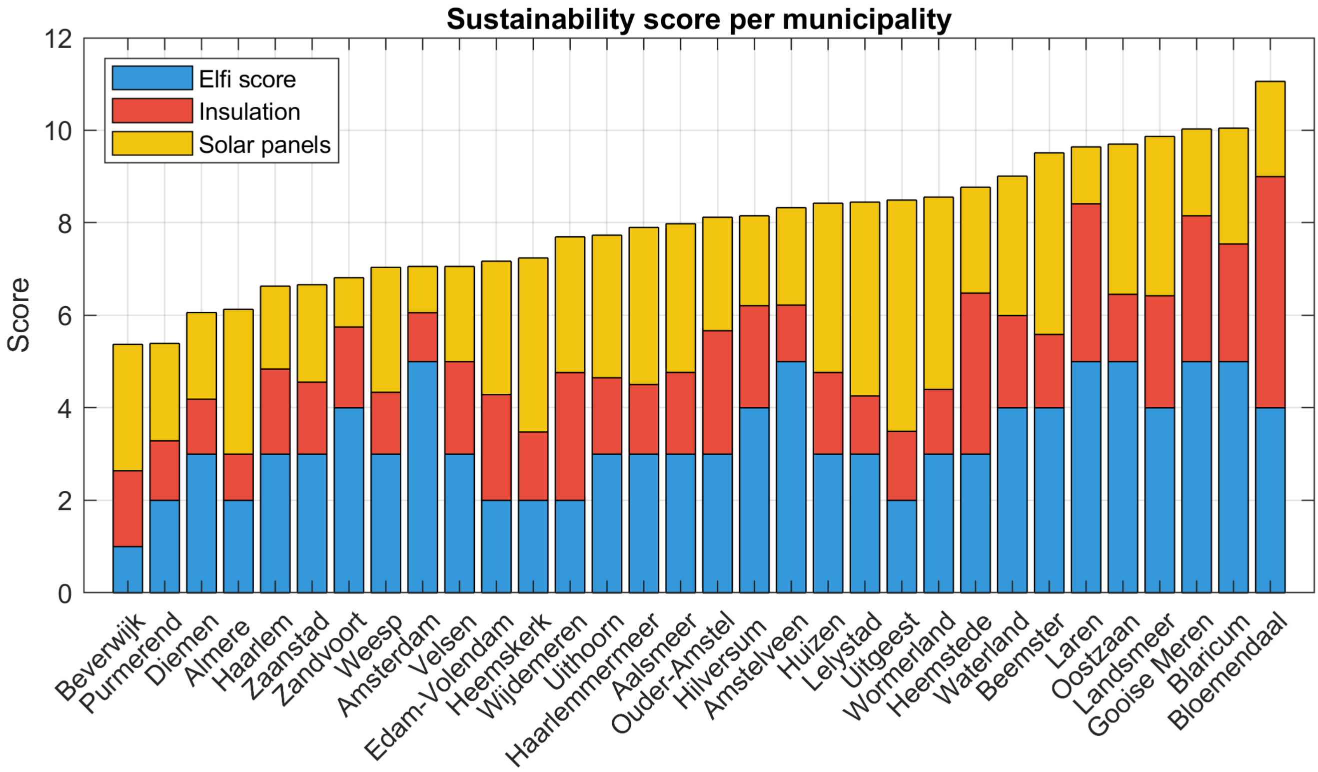


Figure 6. combined sustainability score per municipality

3.3.2. Clean the data & Segment the data

In order to perform an analysis, it is necessary to clean and segment the data. Cleaning the data will involve recoding columns, remove outliers & mistakes in the data, adjusting the scorecard to a workable format for MATLAB and selecting the useable part of the dataset by segmenting the data. First of all, the outliers are removed by putting a maximum on the housing transaction prices of €5 million per transaction. Followed by the use the quartile method to exclude any weird prices (e.g. = 999.999.999) or zero values. Any value in the dataset with 1.5X IQR above the upper or lowest quartile was removed. An example of the clean dataset can be found in Figure 20 in the appendix. To analyse the impact of sustainability policies on housing prices and desirability it is necessary to compare like to like (thereby controlling variable factors). I will therefore divide the dataset into two data frames: one representing houses in each municipality, and the other representing apartments in each municipality. As can be found in the results section there is a significant difference between house listings and apartments as they must be separated (Figure 22, appendix). Thereafter a few of the variables are removed from the dataset to have a clearer overview, e.g. province or province number. The data is a cross sectional time series. To create a consistent and reliable outcome of the research lognormal distribution is used for the transaction prices. Using a log minimize the time influence on the dataset (Leutkepohl, 2012). The next step is to test whether a log distribution will contribute to reliable results. There is a contradiction when we look at the usage of the logarithm. The following histograms / QQ plot look reasonable.

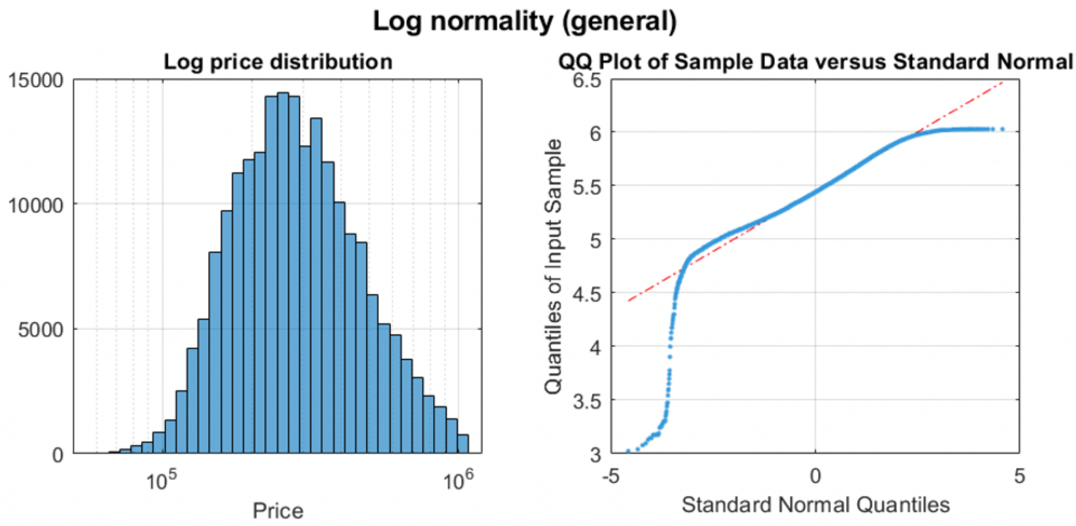


Figure 7. Log price distribution (see Figure 22 in the appendix for the separation between homes and apartments

However, when testing with different normality tests such as Lillieforts and Kolgomorov-Smirnov, the log distribution of the data fails. There are two main reasons for these failing test results. First of all, the skewness is too high for all the distributions (left leaning). Taking the log doesn't eliminate the skewness of the original price distribution. The tail of houses is too fat. Mostly this is a result from a bulk of transactions in the more expensive housing segment. There are not a lot of "expensive" transactions in the apartment segments (transaction price of >€2mn). Moreover, this means that the kurtosis is also too high. On the other hand prices are never perfectly lognormal. Therefore, the assumption is made to use the lognormal distribution for the further models and research in this paper.

3.3.3. Modelling

To start with, all the 3 different sub questions need a different statistical approach. I will elaborate on the used regressions and methods per sub question. For the descriptive statistics and graphs I have used linear regressions, histograms and boxplots to create an overview of the trends within the time series data.

1) What for influence has the degree of insulation on the average transaction price?

$$Regression\ 1: Logprice \sim m2 + m3 + year + isol + construction_{period} + parkeer + n_{verdiep} + tuin_{opp} + lig_{mooi} + lig_{drukw} + lig_{centr} + tuinlig + tuinafw + onbi + onbu + n_{balkon} + n_{kamer} + n_{WC} + verw;$$

There are a few key factors to consider in the research to find an answer to the first sub question. Using the above regression, the information is needed if there is a statistically significant difference. How big is this difference and what for implications gives this trend over time? To test for these differences the ANOVA analysis is the most suitable method to use. This model is used to control for the difference in the means of different variables. The ANOVA analysis is applicable for moderate deviations (Wold, 1989). Moreover I am using the bootstrap method to sample for an approximation of the distribution. This is a resampling method to iteratively check the data on its distribution. I have used mean log prices for the insulation variable and used 500 samples in the bootstrap. The time effect can be checked by using Log price distribution of the different insulation categories per two years.

2) How is the price of housing affected by the sustainability policies of different municipalities?

$$Regression\ 2: Logprice \sim m2 + m3 + year + isol + construction_{period} + parkeer + n_{verdiep} + tuin_{opp} + lig_{mooi} + lig_{drukw} + lig_{centr} + tuinlig + tuinafw + onbi + onbu + n_{balkon} + n_{kamer} + n_{WC} + verw + \boldsymbol{Scorecard}$$

After adjusted the scorecard to the right data fit, I composed the above regression. Using the same control variables as for regression 1. The regression partly consists out of categorical variables which are: construction period, onbi and onbu and quality maintenance (verw). I used an Ordinary Least Squares (OLS) regression including log prices. As described before the scorecard has a quite compact range of values. Therefore, it's important to remove as much outliers as possible, to have results from this sensitive data. The Cook distance method is the most commonly used method combined with OLS regressions. The Cook method identifies the outliers by creating an overview of the scaled change of the fitted data. I removed all the outliers with high leverage, meaning >3x the Cook distance. This resulted in removing approximately 11.000 datapoints (Figure , appendix)

3) How accurately can we predict the transaction housing prices?

Based on the extrapolation of the models including the scorecard it will be possible to have a prediction concerning the average house price in the area. This prediction will be based on the average trends for all the control variable in the dataset. The prediction's timeline is 4 years till 2026. The reason for a relatively short timeline is the uncertainty of macro-economic trends that can happen in unexpected waves e.g., the Russian – Ukraine war or the Covid-19 pandemic.

4. Results

The housing transaction prices are influenced by many factors, even a few that are not included in this paper. To answer the three hypothesis questions in the best way possible we need to look at a few different correlations and regressions over the 2010 – 2020 period. In general, both the WOZ value and the transaction prices of apartments and houses differ quite a lot over time (figure 22, appendix). It's essential for the understanding of the influence of different sustainability policies to know too which extent other variables influence the price. The starting point will be to research the influence of the degree of insulation to establish a solid framework for the main hypothesis question. The insulation variables refer to the number of different types of insulation present in the house. E.g. double-walled glass, roof insulation, wall insulation etc. The added value in terms of higher potential transaction prices can influence the decision making on the investment in the insulation options of a building. An important influence on the decision making for apartments is the influence of the so called VVE (Vereeniging van Eigenaren). This is a regulatory body within a complex to order the decision making for the building, such as paint the building or upgrade the isolation of the mutual hallways. Single family homeowners are responsible themselves whether to invest in isolation or not. The insulation variable is divided into 5 different categories with a certain distribution (see chapter 3.1. figure 4). The variable has a value between 1 and 5 in the dataset, 5 being the group with 5 different insulation types in their apartment / house.

To determine if there are any existing differences in price between low, medium and high insulation houses, they have been divided into three groups: Low isolation (value =<1) medium isolation (value = 3) and high isolation (= 5) for apartments and houses separately. This graph shows the average log price on a per year basis with a 95% confidence interval for the mean based on the 500 samples (bootstrap T-method) . The mean log prices between these three different categories varies consistently over the time period of the research. There is an average difference in transaction price between category 1 and 3 of 5.13% (€14.900). The difference between category 3 and 5 is even way bigger with an average difference of 9.16%

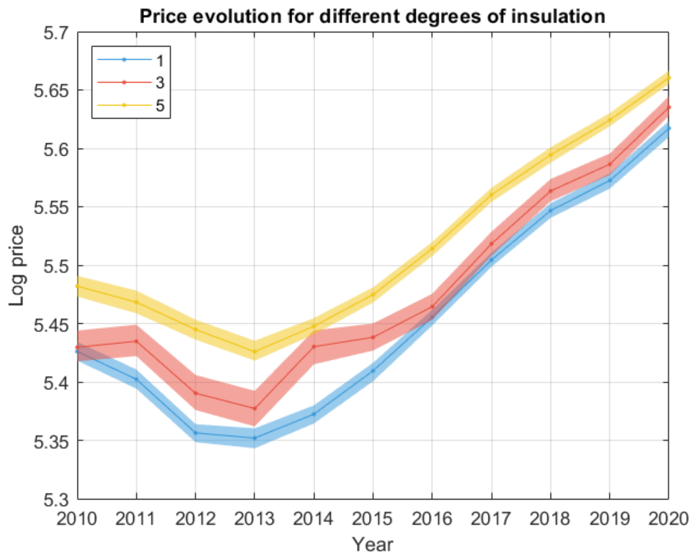


Figure 8. Different degrees of insulation

(€28.105) on average. Moreover, the conclusion can be made that there is an existing price difference between all of the 5 different insulation degrees (figure 25, appendix). The next step is to perform an ANOVA analysis on the house transaction prices.

	SS	df	MS	F	Prob>F
1 Groups	63.593	4	15.898	442.27	0
2 Error	2822.8	78526	0.035947		
3 Total	2886.4	78530			

Figure 9. Anova analysis on housing prices

The hypothese being the potential influence of the degree of insulation on the transaction price. Therefore the h_0 is that all insulation classes have the same house transaction prices. The results reject this h_0. With a large F value (442.27) and a p-value = 0 on a 5% significance level. The difference for the different degrees of insulation is statistically significant. The next step is to have a comparison between the correlation between the degrees of insulation on an individual basis. Is there a difference in price between the degrees separately? The ANOVA analysis points out a statistically significant difference between the various levels of insulation as seen in the graph (see figure 26 in the appendix for a mean with variance comparison plot). The differences are statistically significant with a significance value of 5% if the confidence interval does not include a 0. This means that for these values, there is only a 5% probability that the observed difference is coincidental. However not for all separately. Category 2 is overlapping with category 3 on the left side and category 4 on the right side. The differences in price level are relatively close to each other except for category 1. There is on average a ± €30.000 difference for average transaction prices for this category.

Cat_1	Cat_2	5%	Difference in mean	95%	p-value
1	2	-0.05492	-0.049683	-0.044446	9.9217e-09
1	3	-0.05141	-0.045139	-0.038868	9.9217e-09
1	4	-0.063688	-0.056332	-0.048975	9.9217e-09
1	5	-0.07264	-0.067889	-0.063138	9.9217e-09
2	3	-0.0023857	0.0045437	0.011473	0.38015
2	4	-0.014574	-0.0066488	0.0012764	0.14852
2	5	-0.023798	-0.018206	-0.012615	9.9217e-09
3	4	-0.019836	-0.011193	-0.002549	0.0037758
3	5	-0.02932	-0.02275	-0.01618	9.9217e-09
4	5	-0.01917	-0.011558	-0.0039447	0.00033332

Figure 10. Analysis on the correlation between different types of insulation

Was this difference always existing throughout the years? And what if there was a non-explainable difference or fluctuation? The dataset will be divided into 6 separate selections over time to see if this difference is existing and how big it might be.

The insulation degree comparisons over time show a less (or none) structural difference in the beginning years. In the year 2014, there was a major difference in price between category 1 and the rest of the insulation degrees. As time goes by the difference grows in a more logical and linear way. This could implicate some growing influence over time for the degree of insulation on the house transaction prices. Summarized if the lines of two insulation categories are not intersecting, it means that there is a statistical difference on a 5% level. This effect is significant however performing a 2-way Anova with an interaction between year and the insulations shows also statistical significance (Figure 27, Appendix). This means that there is a time fixed effect on the insulation which downgrades the statical significance from the first test. The next step is to determine which of the different variables in general have an overall

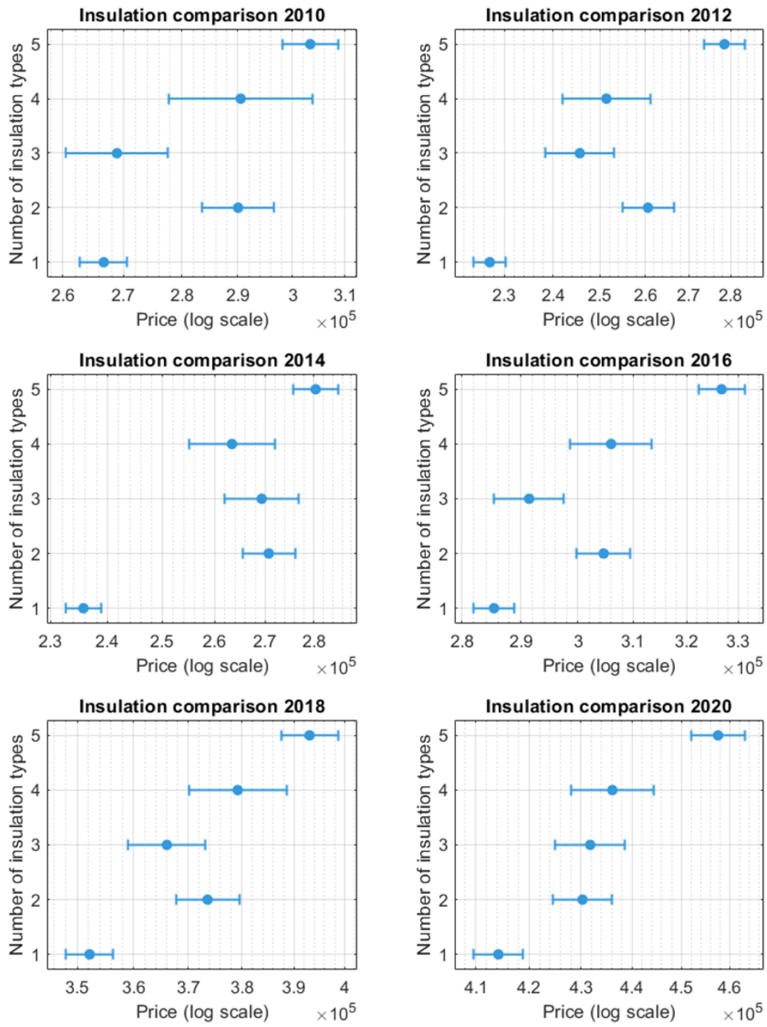


Figure 11. Insulation category comparison over time

influence on the data before the scorecard is added to the dataset. As expected, there is a difference on the average price concerning the municipalities. E.g. the municipality Purmerend has a negative effect on the price (below average) compared to the municipality Amsterdam which has a positive effect on the price (above average). All the variables have been tested on their fit with the transaction price dataset. The trends spotted in the first regression are the following. As expected, the year (0.026) has the greatest influence on the transaction price followed by m2 and construction period. These three are strong drivers: the WOZ value has been increased significantly + larger houses are more expensive. This seems a logical result and is confirmed by the pvalue = 0 which means these results are significant. These results match with the plots in the exploratory data. As well as the difference per municipality. The growth rates vary significantly between the different municipalities.

```
Number of observations: 194301
```

	Estimate	Standard error	t-statistic	p-value
(Intercept)	-47.937	0.16855	-284.41	0
year	0.026187	8.31E-05	314.95	0
m2	0.003089	1.20E-05	257.13	0
m3	1.91E-06	2.98E-07	6.4289	1.29E-10
construction_period_1	0.068883	0.01598	4.3105	1.63E-05
construction_period_2	0.022065	0.015972	1.3814	0.16714
construction_period_3	0.017017	0.015985	1.0646	0.28707
construction_period_4	-0.0559	0.015992	-3.4951	0.000474
construction_period_5	-0.10386	0.015979	-6.4997	8.07E-11
construction_period_6	-0.09933	0.015986	-6.2133	5.20E-10
construction_period_7	-0.07498	0.015977	-4.6928	2.70E-06
construction_period_8	-0.03111	0.01598	-1.9467	0.051569
construction_period_9	-0.03923	0.015975	-2.4558	0.014059
nverdiep	-0.00887	0.000495	-17.907	1.17E-71
nkamers	0.009747	0.000342	28.536	9.45E-179
nbalkon	0.008679	0.000559	15.518	2.83E-54
nwc	0.006449	0.000192	33.525	9.76E-246
parkeer	0.007481	0.00019	39.359	0
tuinlig	0.000907	0.000114	7.9422	2.00E-15
tuinafw	0.009282	0.000373	24.897	1.28E-136
onbi_2	0.016316	0.009078	1.7973	0.072292
onbi_3	0.024738	0.006574	3.7628	0.000168
onbi_4	0.032794	0.007079	4.6326	3.61E-06
onbi_5	0.03035	0.006421	4.7263	2.29E-06
onbi_6	0.037041	0.006497	5.7009	1.19E-08
onbi_7	0.066256	0.006401	10.351	4.22E-25
onbi_8	0.095428	0.006552	14.564	5.03E-48
onbi_9	0.10703	0.006509	16.444	1.02E-60
onbu_2	0.025738	0.012834	2.0055	0.044913
onbu_3	0.053912	0.009209	5.854	4.81E-09
onbu_4	0.052723	0.009995	5.2752	1.33E-07
onbu_5	0.085322	0.008857	9.633	5.86E-22
onbu_6	0.093793	0.008904	10.533	6.15E-26
onbu_7	0.10685	0.008815	12.121	8.42E-34
onbu_8	0.1174	0.008947	13.121	2.60E-39
onbu_9	0.11549	0.008918	12.95	2.43E-38
isol	0.002206	0.000185	11.897	1.26E-32
verw_1	-0.03647	0.002071	-17.604	2.57E-69
verw_2	0.001407	0.001255	1.1207	0.26242
verw_3	-0.04101	0.008439	-4.8601	1.17E-06
ligcentr	0.003968	0.000464	8.5563	1.17E-17
ligmooi	-0.00012	0.000163	-0.73684	0.46122
ligdrukw	-0.00648	0.000451	-14.362	9.43E-47
gemeente_Amstelveen	0.12489	0.002856	43.732	0

gemeente_Amsterdam	0.13714	0.002653	51.684	0
gemeente_Beemster	-0.0606	0.005079	-11.931	8.34E-33
gemeente_Beverwijk	-0.09096	0.003097	-29.373	3.00E-189
gemeente_Blaricum	0.040146	0.004881	8.2247	1.97E-16
gemeente_Bloemendaal	0.10695	0.00385	27.775	1.80E-169
gemeente_Diemen	0.069462	0.003581	19.4	9.22E-84
gemeente_Edam-Volendam	-0.04558	0.003589	-12.701	6.03E-37
gemeente_Haarlem	0.023859	0.002724	8.7595	1.98E-18
gemeente_Haarlemmermeer	-0.00535	0.002732	-1.9584	0.050188
gemeente_Heemskerk	-0.0404	0.003193	-12.655	1.09E-36
gemeente_Heemstede	0.08146	0.003272	24.893	1.41E-136
gemeente_Hilversum	-0.04165	0.002806	-14.843	8.16E-50
gemeente_Huizen	-0.03234	0.003113	-10.389	2.81E-25
gemeente_Landsmeer	0.063254	0.004981	12.699	6.16E-37
gemeente_Laren	0.098832	0.00413	23.932	2.11E-126
gemeente_Oostzaan	0.024515	0.004904	4.9994	5.76E-07
gemeente_Ouder-Amstel	0.1002	0.004219	23.749	1.66E-124
gemeente_Purmerend	-0.06425	0.002858	-22.481	8.78E-112
gemeente_Uitgeest	-0.05543	0.004154	-13.346	1.31E-40
gemeente_Uithoorn	-0.0029	0.003445	-0.84228	0.39963
gemeente_Velsen	-0.04526	0.002936	-15.415	1.40E-53
gemeente_Waterland	0.031864	0.004202	7.5829	3.39E-14
gemeente_Weesp	0.02423	0.00376	6.4438	1.17E-10
gemeente_Wijdemeren	-0.00709	0.003528	-2.0102	0.044411
gemeente_Wormerland	-0.05183	0.004219	-12.286	1.11E-34
gemeente_Zaanstad	-0.07598	0.002738	-27.749	3.72E-169
gemeente_Zandvoort	0.049437	0.003618	13.666	1.70E-42
tuinopp	0.000217	4.35E-06	49.911	0

Figure 12. Regression coefficients for the benchmark case.

As a next step, it is important to take a look at the regression diagnostics plots (underneath) to compare the difference of the base mode regression before and after the outliers are removed. Thereafter to analyse the difference between the municipality regression and the scorecard regression. As seen in the tables several large outliers are removed and a smooth table has appeared.

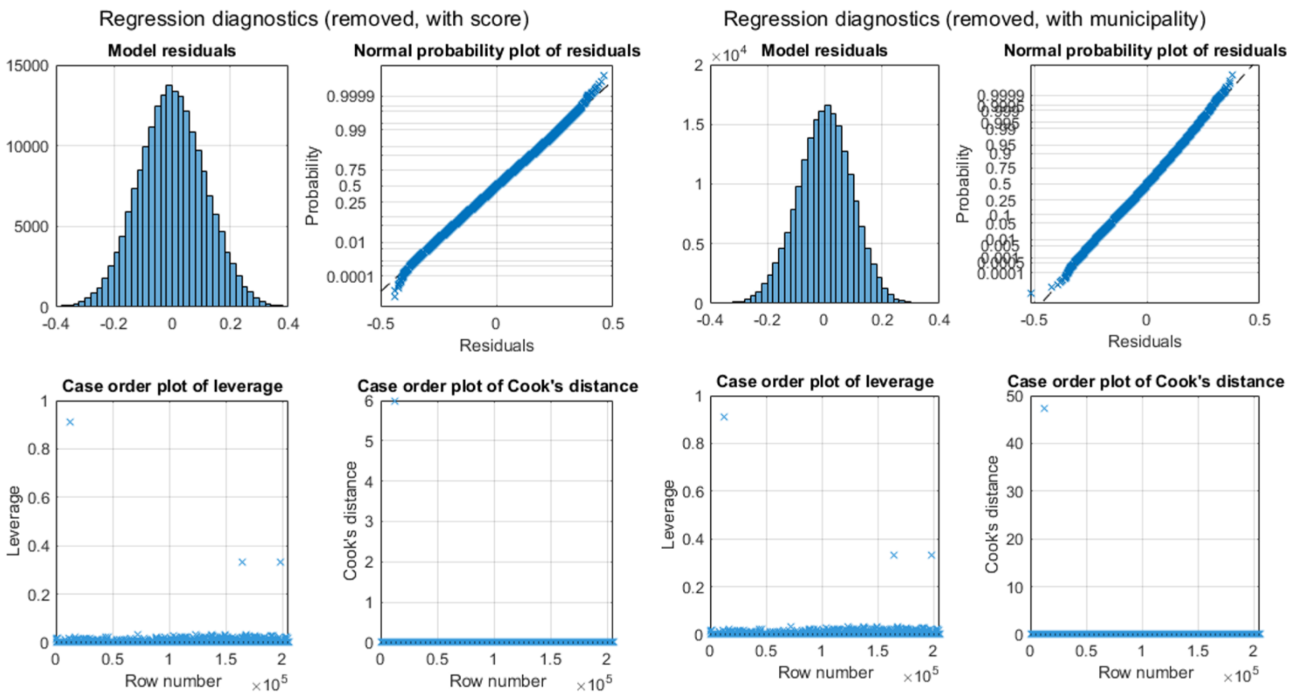


Figure 13. Regression diagnostics with score and with municipality

The most important conclusion that can be drawn from the scorecard ANOVA is that the score (0.27) has an influence on the transaction price. It changed slightly the values for the influence of the other variables however not too a certain extent that it changes anything to the outcome of the regression. Important to mention, the sustainability score does not yield the same predictive power as the municipalities do, but still the trend is clearly positive and the influence large. The R-squared value drops from 0.73 to 0.69, but this is acceptable and indicates that the model still has a lot of predictive power.

```
Number of observations: 194301
```

	Estimate	Standard error	t-statistic	p-value
(Intercept)	-4.75E+01	0.1902	-249.87	0
year	2.59E-02	8.84E-05	2.93E+02	0
m2	0.003539	1.36E-05	2.60E+02	0

m3	4.62E-06	1.10E-06	4.2073	2.59E-05
construction_period_1	0.2459	0.066348	3.7062	0.00021
construction_period_2	0.18798	0.066345	2.8334	0.004606
construction_period_3	0.17114	0.066349	2.58E+00	0.009898
construction_period_4	0.071576	0.066351	1.08E+00	0.28071
construction_period_5	0.008974	0.066348	1.35E-01	0.89241
construction_period_6	-0.00094	0.066349	-0.01419	0.98868
construction_period_7	0.058214	0.066347	0.87742	0.38026
construction_period_8	0.10808	0.066347	1.63E+00	0.10332
construction_period_9	0.082513	0.066345	1.24E+00	0.21362
nverdiep	-0.03425	0.00053	-6.47E+01	0
nkamers	0.01173	0.00037	3.17E+01	4.07E-220
nbalkon	0.018237	0.00059	30.889	5.36E-209
nwc	0.0045	0.000206	2.18E+01	2.46E-105
parkeer	0.008795	0.000206	4.28E+01	0
tuinlig	-0.00195	0.000122	-16.006	1.26E-57
tuinafw	0.008097	0.000398	20.366	4.15E-92
onbi_2	0.009992	0.015737	6.35E-01	0.5255
onbi_3	0.020166	0.011565	1.74E+00	0.081212
onbi_4	0.028712	0.012049	2.38E+00	0.017178
onbi_5	0.021273	0.011394	1.87E+00	0.061906
onbi_6	0.023775	0.011443	2.08E+00	0.03774
onbi_7	0.050146	0.011378	4.41E+00	1.05E-05
onbi_8	0.077039	0.011474	6.7145	1.89E-11
onbi_9	0.099974	0.011446	8.73E+00	2.46E-18
onbu_2	0.013766	0.024428	5.64E-01	0.57306
onbu_3	0.075441	0.017614	4.28E+00	1.85E-05
onbu_4	0.064227	0.018613	3.45E+00	0.000559
onbu_5	0.11167	0.017218	6.49E+00	8.85E-11
onbu_6	0.12743	0.017246	7.39E+00	1.48E-13
onbu_7	0.15483	0.017187	9.01E+00	2.11E-19
onbu_8	0.16356	0.017264	9.47E+00	2.72E-21
onbu_9	0.1652	0.017245	9.58E+00	9.83E-22
isol	-0.00185	0.000194	-9.5066	1.99E-21
verw_1	-0.06139	0.00233	-2.63E+01	1.09E-152
verw_2	-0.00267	0.001379	-1.94E+00	0.052488
verw_3	-0.05305	0.016312	-3.2522	0.001145
ligcentr	-0.00218	0.000496	-4.40E+00	1.08E-05
ligmooi	0.000752	0.000172	4.3757	1.21E-05
ligdrukw	-0.01771	0.000472	-37.494	1.47E-306
score	0.27095	0.003884	6.98E+01	0
tuinopp	-8.32E-05	4.71E-06	-1.77E+01	1.02E-69

Figure 14. Regression coefficients of the analysis with sustainability score.

In addition to this, to rule out the correlation between the score and the municipality score I did an additional regression with an interaction between the score and the municipalities

(Figure 28, appendix). When comparing the results there is not a significant difference between the outcome for the values compared to the other previous regressions.

3) How accurately can we predict the transaction housing prices?

To answer this question, we have to look into the trend of outbidding transaction prices. If this trend tends to become less obvious over the years, it tells the need for housing. As seen in the graph below the number of outbidding processes increased over time. The growing

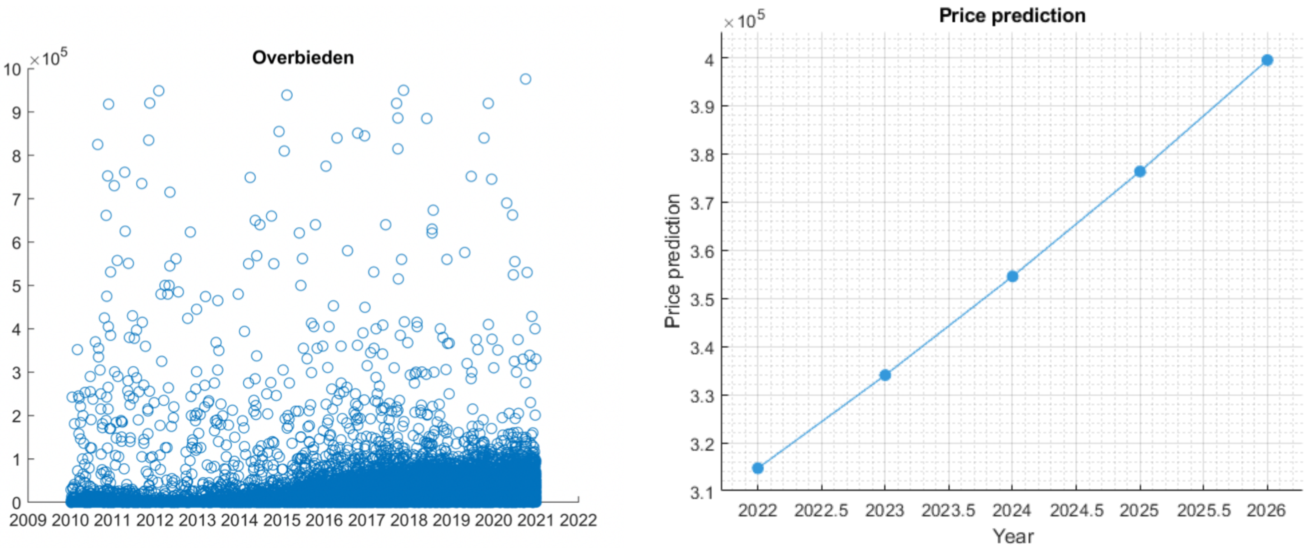


Figure 15. & 16. Overbidding on transactions & price prediction for the upcoming years

amount of outbidding prices gives us more uncertainty over the prediction of the housing prices. Overall, it's very hard to explain and to rationalize the premiums paid for a house transaction. If we extrapolate the latest trends of housing pricing over a period of 4 years, the average WOZ value will reach a €400.000 average transaction value by 2026.

5. Conclusion

The house transaction prices (and underlying WOZ-values) have increased substantially over the past decade. This research investigates the different hedonistic variables that have an influence on this upwards price trend. There are a few relatively obvious variables that have a major impact on the price such as year in which the transaction took place and the m2 of the house. The next step for the research is to explore the less obvious variables and to look for a correlation with the influence of the governmental policies (e.g. environmental and sustainability policies). One of these variables is the insulation degree. The sustainability policies include subsidies to stimulates the improvement of the insulation degree per house.

These subsidies have increased over the past 10 years. This trend matches the fact that the price difference became more visible in the recent years. There is a correlation between the amount of subsidy and the importance of insulation degree in a house transaction. To conclude, the municipalities with a higher average transaction price have a higher average degree of insulation. Moreover, the importance and difference became more clear over the past 5 years. There is a larger difference between the different degrees of insulation than in the beginning years (2010 – 2014). The next question to answer is whether the combined influence of the sustainability policies have an influence on the difference in transaction price between the different municipalities. The scorecard consists out of the score per municipality (interviews), degree of insulation and the % of solar panels in a municipality. The conclusion can be made that municipalities with a higher score on the scorecard have an average higher transaction price. This means that the regulations, subsidies, environmental policies and sustainability policies are important for the ongoing development of a rural area. However still the biggest influence on the price is the location and municipality itself concerning the price development.

6. Discussion

The performed research is meant to have an insight on the correlation between sustainability policies and prices in specific areas in the Netherlands. However, there are some limitations on the dataset and the number of variables taken into account. There are tons of variables that have an additional influence on a house price than the integrated dataset e.g., if the house is located to the south or the north (sun hours per day). Therefore, the further analysis for the effect of potential confounders is required. Next to that the research assumed the linear relation with time in order to perform extrapolation. There is no causal relation apart from (1) inflation and (2) interest rates, these are not taken into account in the regression. This means that there are quite some macro-economic factors that have influences as well. Next to these two factors the prices of construction supplies can play a bigger role in the future. The recent influence of Covid-19 pandemic and the Russian – Ukraine war shows the potential volatility of Oil, Wood and precious metals. These are all key materials for the construction of new houses. Another limitation is the number of interviewed real estate professionals (N=5). For further research a larger database of professionals is recommended. The dataset itself is reliable data. One outlier that has to be mentioned is the big influence of the price increase / drop in Amsterdam. This municipality is responsible for a large part of the house transactions.

Having in mind the scarcity of construction supplies, growing populations and growing house shortage I would suggest looking into the trade-off between using existing or new construction technologies for further research. How can mankind improve the construction pace whilst being environmental responsible? Does the government want to include new technologies like 3D printed houses? Which could mean a more CO_2 neutral score. Or would it rather focus on the current building technologies such as building with concrete?

7. Appendix

Figure 17 – EU housing transaction prices

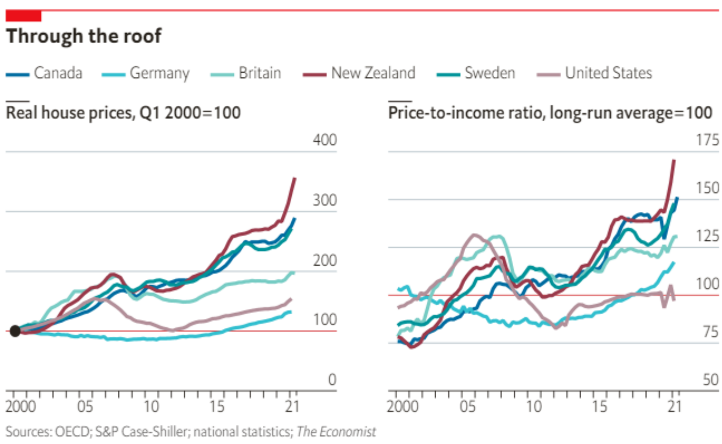


Figure 18 – Floor area distribution for single family homes & apartments

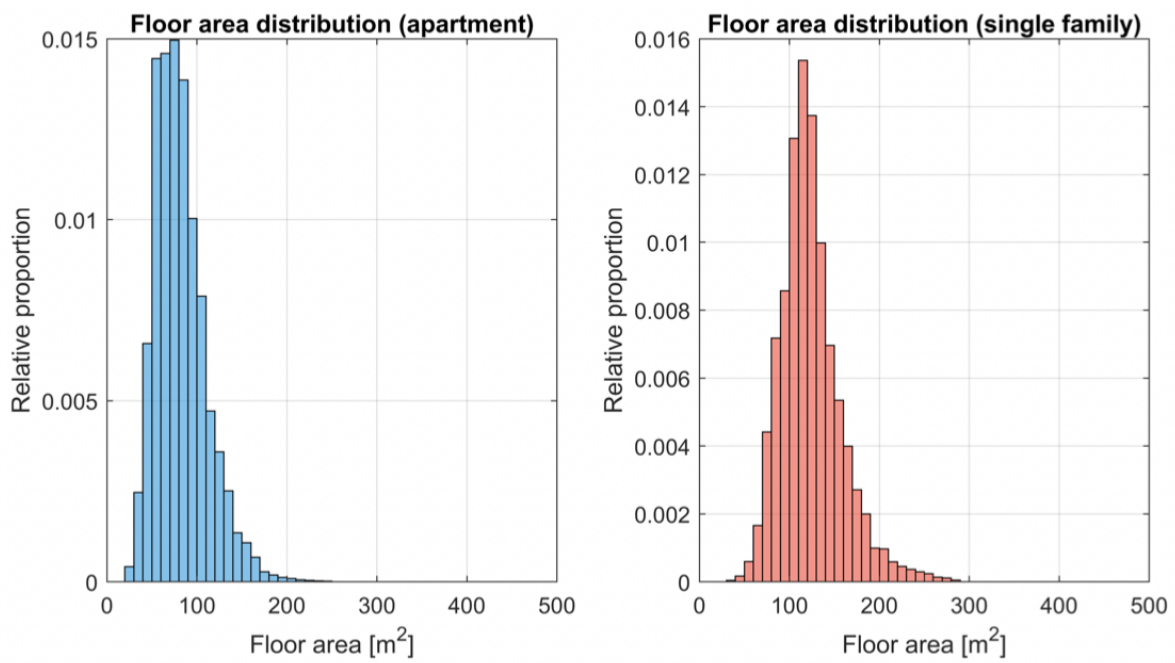


Figure 19 – Plot size distribution

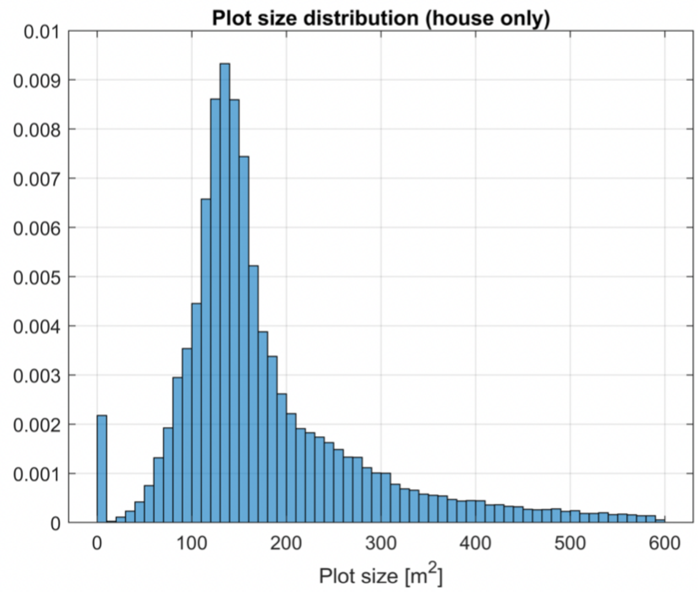


Figure 20 – Relative price increases per municipality

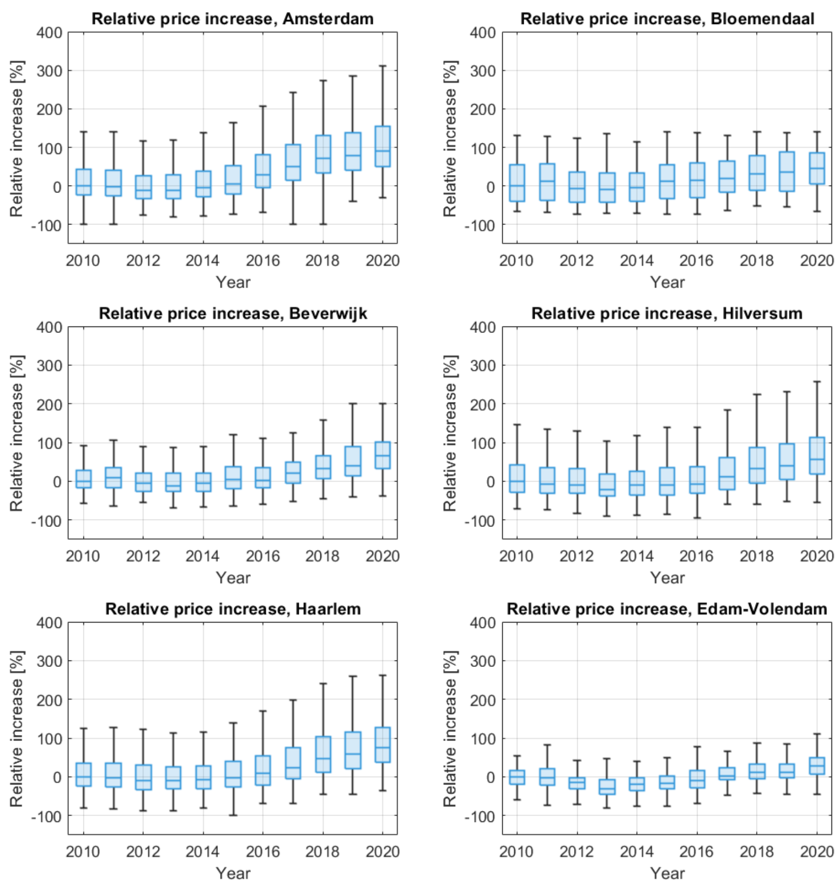


Figure 21 - Example of the clean dataset

	VarName1	uid	year	price	m2	list_date	date_delisted
8	7	5811467	2016	365100	59	2016-08-11	2016-08-30
9	8	6016030	2017	940000	123	2017-03-29	2017-05-10
10	9	6135191	2017	450000	61	2017-07-05	2017-08-25
11	10	6015935	2017	650000	87	2017-03-29	2017-04-20
12	11	6016000	2017	630000	80	2017-03-29	2017-05-10
13	12	6336665	2018	655000	137	2017-10-27	2018-05-23
14	13	6168040	2018	910000	80	2017-09-11	2018-03-22
15	14	6624540	2019	685000	137	2019-01-17	2019-04-10
16	15	7007789	2020	875000	118	2020-02-25	2020-04-17
17	16	4065005	2011	575000	100	2010-06-17	2011-02-04
18	17	4196583	2011	250000	65	2010-05-14	2011-07-06
19	18	4331237	2011	400000	100	2011-05-30	2011-07-28
20	19	4325724	2011	685000	150	2011-05-24	2011-06-17
21	20	4331246	2011	740000	165	2011-05-30	2011-10-05
22	21	5223610	2014	175000	39	2014-09-12	2014-11-13
23	22	4982718	2014	400000	203	2013-10-25	2014-06-13
24	23	5434925	2015	470000	116	2015-05-28	2015-08-17
25	24	5623017	2016	825000	158	2016-01-09	2016-01-18
26	25	5580350	2016	210000	0	2015-11-13	2016-01-12
27	26	5379769	2016	689000	142	2015-03-18	2016-03-21
28	27	6098996	2017	575000	119	2017-06-23	2017-10-11
29	28	5973995	2017	675000	164	2017-02-14	2017-03-03
30	29	6500792	2018	366000	86	2018-09-07	2018-09-21
31	30	6485131	2018	624500	77	2018-08-23	2018-09-21
32	31	6520382	2018	585000	103	2018-09-27	2018-11-16
33	32	6922292	2019	445445	62	2019-11-15	2019-11-27
34	33	7144665	2020	413001	68	2020-03-26	2020-07-16
35	34	4380516	2013	2800000	0	2011-08-02	2013-11-12
36	35	5093519	2015	285000	81	2014-03-27	2015-01-12
37	36	6442751	2018	860000	136	2018-06-29	2018-10-23
38	37	4561821	2012	395000	90	2012-03-20	2012-03-20
39	38	6201633	2017	510000	117	2017-10-11	2017-11-09
40	39	6456151	2018	770000	171	2018-07-13	2018-08-24
41	40	4679173	2014	412500	136	2012-08-28	2014-10-07

Figure 22 - Price distribution houses vs apartments over the past 10 years

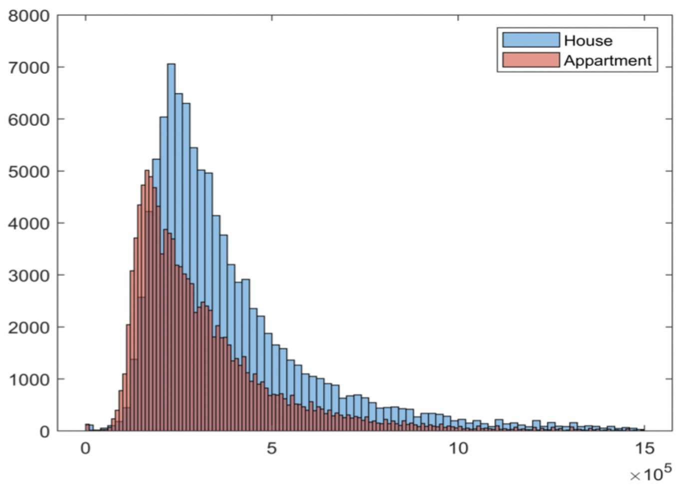


Figure 23 – Log price distributions & QQ's plot

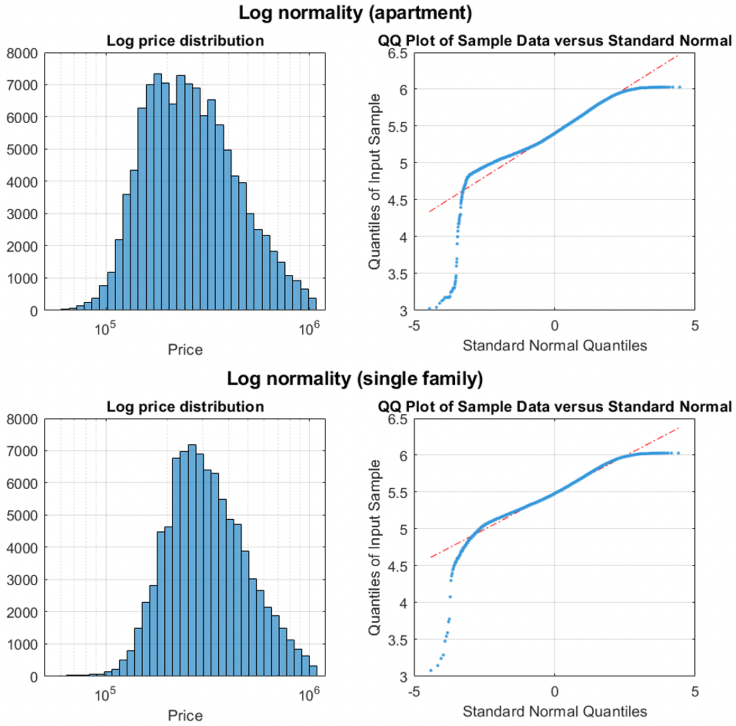


Figure 24 – Normal probability plot of residuals

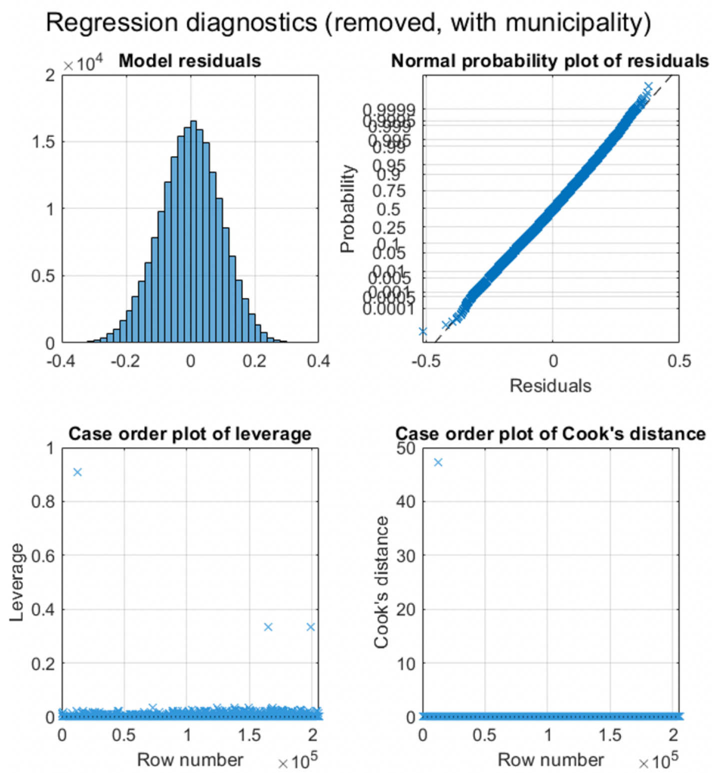


Figure 25 – Log price distribution per insulation type

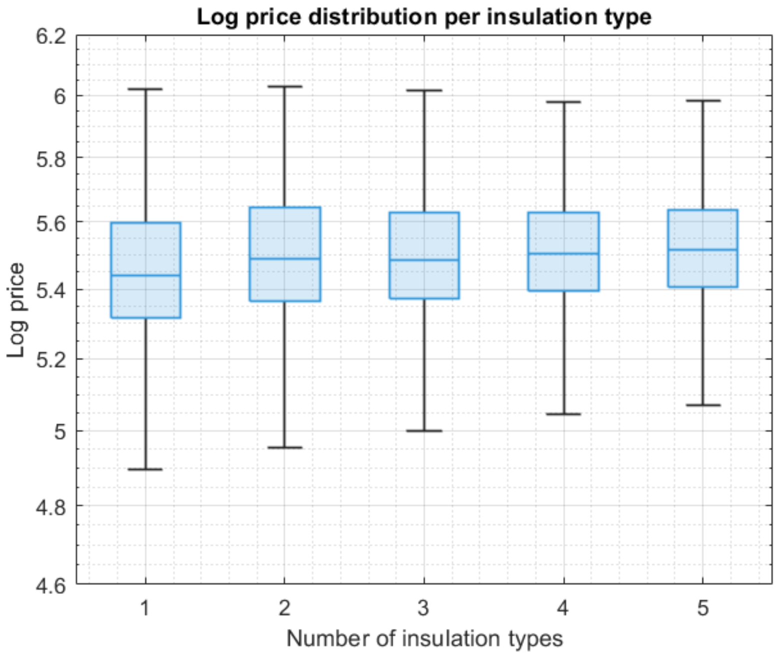


Figure 26 – Insulation spread comparison per category

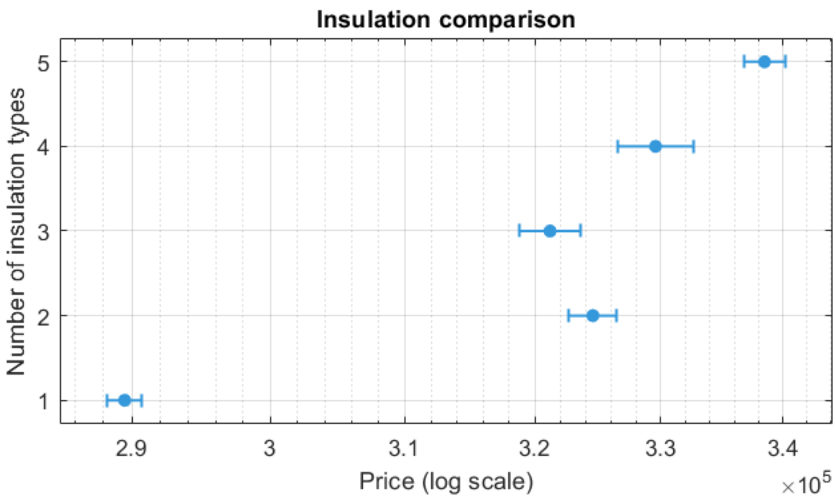


Figure 27 – Analysis on the Variance between Insulation and the compared year

Analysis of Variance

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
Insulation	45.92	4	11.48	389.66	0
Year	373.25	10	37.325	1266.91	0
Insulation*Year	4.18	40	0.1045	3.55	0
Error	2312.02	78476	0.0295		
Total	2886.37	78530			

Constrained (Type III) sums of squares.

Figure 28 – Regression with interaction between Score and Municipality

	Estimate	SE	tStat	pValue
(Intercept)	-49.297	0.15716	-313.68	
year	0.026845	7.3037e-05	367.56	
m2	0.0033302	1.13e-05	294.7	
m3	7.3272e-06	9.0693e-07	8.0792	6.5574e-16
construction_period_1	0.093575	0.05477	1.7085	0.087544
construction_period_2	0.045419	0.054767	0.8293	0.40693
construction_period_3	0.03785	0.054771	0.69107	0.48953
construction_period_4	-0.042521	0.054771	-0.77634	0.43755
construction_period_5	-0.092066	0.054768	-1.681	0.092763
construction_period_6	-0.086302	0.054769	-1.5757	0.11509
construction_period_7	-0.058414	0.054768	-1.0666	0.28617
construction_period_8	-0.017584	0.054768	-0.32106	0.74816
construction_period_9	-0.026674	0.054766	-0.48706	0.62622
nverdiep	-0.012595	0.0004443	-28.349	2.0014e-176
nkamers	0.0097531	0.00030617	31.856	4.1479e-222
nbalkon	0.0098463	0.0004907	20.066	1.8109e-89
nwc	0.0060986	0.00017066	35.736	8.8351e-279
parkeer	0.0072759	0.00017107	42.532	0
tuinlig	0.00088862	0.00010099	8.7988	1.3938e-18
tuinafw	0.0095411	0.00032908	28.993	1.9963e-184
onbi_2	0.018064	0.01299	1.3906	0.16435
onbi_3	0.020909	0.009546	2.1904	0.028498
onbi_4	0.033015	0.0099456	3.3196	0.00090178
onbi_5	0.027566	0.009405	2.9311	0.0033785
onbi_6	0.034385	0.0094452	3.6404	0.00027225
onbi_7	0.061892	0.0093914	6.5903	4.4017e-11
onbi_8	0.09125	0.0094708	9.6348	5.7639e-22
onbi_9	0.10295	0.0094474	10.898	1.2066e-27
onbu_2	0.020166	0.020163	1.0001	0.31725
onbu_3	0.062973	0.01454	4.331	1.4854e-05
onbu_4	0.055726	0.015364	3.627	0.00028686
onbu_5	0.091681	0.014213	6.4505	1.1172e-10
onbu_6	0.10024	0.014236	7.0408	1.9175e-12
onbu_7	0.11257	0.014188	7.9343	2.1286e-15
onbu_8	0.12177	0.014252	8.5438	1.3077e-17
onbu_9	0.1207	0.014236	8.4783	2.2998e-17
isol	0.0018244	0.00016173	11.281	1.669e-29
verw_1	-0.037993	0.0019268	-19.718	1.8399e-86
verw_2	0.0019974	0.0011388	1.7539	0.079447
verw_3	-0.04244	0.013466	-3.1517	0.0016237
ligcentr	0.0041676	0.00041089	10.143	3.6095e-24
ligmooi	-0.00021114	0.0001423	-1.4837	0.13789
ligdrukw	-0.0063442	0.00039401	-16.102	2.7093e-58
tuinopp	0.00017109	4.0768e-06	41.968	0
gemeente_Amstelveen:score	0.28148	0.0056972	49.407	0
gemeente_Amsterdam:score	0.3911	0.0069898	55.953	0
gemeente_Beemster:score	-0.10827	0.0091629	-11.816	3.3171e-32
gemeente_Beverwijk:score	-0.45127	0.013863	-32.552	8.3705e-232
gemeente_Blaricum:score	0.055168	0.0091356	6.0388	1.5552e-09
gemeente_Bloemendaal:score	0.16226	0.005396	30.07	3.4014e-198
gemeente_Diemen:score	0.28154	0.012403	22.7	6.3126e-114
gemeente_Edam-Volendam:score	-0.14815	0.0094404	-15.694	1.8075e-55
gemeente_Haarlem:score	0.0588	0.0079987	7.3512	1.9725e-13
gemeente_Haarlemmermeer:score	-0.0060713	0.0059335	-1.0232	0.3062

gemeente_Heemskerk:score	-0.1162	0.0079808	-14.56	5.3271e-48
gemeente_Heemstede:score	0.16891	0.0060829	27.767	2.3182e-169
gemeente_Hilversum:score	-0.099492	0.0058059	-17.136	8.8901e-66
gemeente_Huizen:score	-0.07922	0.0061032	-12.98	1.6476e-38
gemeente_Landsmeer:score	0.11053	0.008342	13.25	4.6748e-40
gemeente_Laren:score	0.18282	0.0069922	26.147	1.9607e-150
gemeente_Oostzaan:score	0.049747	0.0083808	5.9358	2.9292e-09
gemeente_Ouder-Amstel:score	0.23438	0.0090393	25.929	5.5719e-148
gemeente_Purmerend:score	-0.31339	0.012676	-24.723	9.8242e-135
gemeente_Uitgeest:score	-0.11616	0.0081894	-14.185	1.2003e-45
gemeente_Uithoorn:score	0.0017643	0.0077451	0.22779	0.81981
gemeente_Velsen:score	-0.13435	0.0077488	-17.339	2.7075e-67
gemeente_Waterland:score	0.058171	0.0080451	7.2306	4.8258e-13
gemeente_Weesp:score	0.067491	0.0101	6.6824	2.3566e-11
gemeente_Wijdemeren:score	0.0095426	0.0081918	1.1649	0.24406
gemeente_Wormerland:score	-0.097987	0.0084716	-11.567	6.2351e-31
gemeente_Zaanstad:score	-0.22349	0.0079663	-28.054	7.9432e-173
gemeente_Zandvoort:score	0.1519	0.010413	14.588	3.576e-48

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