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GENTRIFICATION IN ROTTERDAM

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Abstract

Gentrification is a striking phenomenon observed in numerous urban areas. Acquiring knowledge regarding the specific locations where gentrification occurs is crucial, as it enables the pursuit of a harmonious equilibrium between urban renewal and the preservation of social diversity. This thesis examines where gentrification is taking place in Rotterdam. Previous research shows that gentrification occurs most rapidly in neighborhoods adjacent to originally wealthy areas and in places with many amenities. Gentrification often results in a house price increase along with dispossession of the old neighborhood residents. Social housing and policies can greatly affect the degree of gentrification. The results of the hedonic pricing model and the residential sorting model revealed that households like to live next to originally wealthy neighborhoods and close to the city center. In addition, it is visible that some neighborhoods have become much more popular, based on house price, and that in some neighborhoods the average income has increased much more than in the other neighborhoods. These are all indications of gentrification. These indications are found particularly in the neighborhoods of Rotterdam Centrum, Delfshaven, Kralingen-Crooswijk and Noord.

Keywords: Gentrification, Hedonic pricing, Residential sorting, Housing market, Rotterdam

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Acronyms

CBS	Centraal Bureau voor de Statistiek
KW	Krachtwijken programma
KWB	Kerncijfers wijken en buurten
NPRZ	Nationaal Programma Rotterdam Zuid
NVM	Nederlandse Coöperatieve Vereniging van Makelaars en Taxateurs
WBMGP	Wet Bijzondere Maatregelen Grootstedelijke Problematiek / Rotterdamwet
WOON	Woononderzoek Nederland

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1. Introduction

There is an increasing number of households that is interested to reside within urban areas (Couture & Handbury, 2020). In many cities, this contributes to the process of gentrification. In this thesis, gentrification refers to the inflow of young and often well-educated households to inner-city neighborhoods that used to be inhabited by older and low-income households (Rouwendal et al., 2018). This phenomenon is observed across numerous cities in the Netherlands. This thesis specifically concentrates on a particular Dutch city, namely Rotterdam.

Gentrification is often a consequence of policies. For Rotterdam, this is very relevant. Indeed, many programs have been established in recent decades to upgrade the city's livability. Rotterdam is known for a large share of low-income households; namely 53%. However, the share of higher income households, as well as the share of higher educated households is increasing. Still, the city is behind the three other big cities, The Hague, Amsterdam, and Utrecht. In the city of Rotterdam, two types of programs have been implemented with the aim of urban development. One program is focused on attracting households commonly referred to as "strong shoulders" to the city center, while the other program seeks to uplift disadvantaged neighborhoods and provide support to households considered as "weak shoulders". Strong shoulders are characterized by having earned a college (HBO) or university degree (WO) (OBI Gemeente Rotterdam, 2022).

First of all, a program which focuses on bringing in strong shoulders. The 'Kansrijke wijken' program is a policy program in line with this plan. The program focuses on families with highly educated parents who live in a more expensive rental or owner-occupied house (Doff & van der Sluis, 2017). With this program the municipality tries to make the city center more attractive for families with children. They do so by increasing the livability in the neighborhoods, by providing suitable housing for families, ensuring good education, and strengthening initiatives of private parties and residents. This should not only boost the city's economic development, but also increase its social resilience.

Secondly, there are several programs dedicated to enhancing the quality of disadvantaged neighborhoods. In the pursuit of enhancing the overall livability of Rotterdam, the city recognizes the importance of not exclusively targeting the needs and the preferences of households categorized as strong shoulders, but also prioritizes addressing the concerns and challenges faced by the weak shoulders. There are several programs implemented for this purpose. The best-known programs are the WBMGP ('Wet Bijzondere Maatregelen Grootstedelijke Problematiek/Rotterdamwet'), the NPRZ ('Nationaal Programma Rotterdam Zuid') and the KW program ('Krachtwijken programma'). The main aim of WBMGP is to improve livability of distressed streets as well as neighborhoods by increasing social mixing and thereby avoiding high concentrations of disadvantaged households (Koster & van Ommeren, 2022). The NPRZ, aims are to improve school performance of children, labor market

opportunities of young workers as well as the livability of the neighborhood. An alternative program is the KW program. The main aim of this program is to improve quality of public housing units by demolition and renovation.

This thesis examines whether there are signs that there is a process of gentrification going on in various Rotterdam neighborhoods. Understanding the underlying factors that drive gentrification is crucial to find a balance in upgrading the neighborhood and maintaining a social mix. Indeed, Rotterdam is characterized by a high proportion of low-educated, low-income households. These households are not always eager for renewal of their neighborhoods. Transformations in shops and meeting places, and the nature of the local social structure and government interventions, can create a sense of loss of place even without physical displacement (Shaw & Hagemans, 2015). Gentrification of downtowns makes poor residents also worse off, as they are either displaced to the suburbs or pay higher rents for amenities that they do not value as much (Couture et al., 2021).

In the analysis there is made use of a combination of three datasets. The first one contains information about housing transactions collected by the Dutch Association of Real Estate Agents (NVM). One of the main advantages of the NVM data is the rich set of housing characteristics. The dataset covers a ten-year period, namely 2012-2021. This information will be used for the hedonic pricing model. For the residential sorting model there is made use of the WoON dataset ('Woononderzoek Nederland'), this triennial survey contains a lot of household characteristics obtained from the 'Ministerie van Binnenlandse Zaken en Koninkrijksrelaties'. This is combined with a dataset obtained from the Central Statistics Office (CBS). The dataset called key figures neighborhoods and districts (KWB) contains core figures on neighborhoods for instance on population, housing types and income by neighborhood for every year.

The initial step in the analysis involves the application of a hedonic pricing method. Making use of hedonic housing price analysis is a way to measure preferences and quantify the so-called marginal willingness to pay (MWTP) of people for location and housing characteristics. The hedonic pricing analysis requires information on many location choices, the prices of properties, as well as location and housing characteristics. Besides that, the data can show the price increase per neighborhood versus the initial price. This makes it able to look at which neighborhoods were initially not that expensive and then actually increased in price more than average. This is similar to how academics have looked at gentrification in Paris (Guerrieri et al., 2013) and the USA (Couture & Handbury, 2020).

The second model performed in the analysis concerns the residential sorting model. This model analyses the MWTP for factors that influence the residential location choice of households in Rotterdam. Therefore, the sorting model following the approach of Bayer, et.al. (2007) is estimated. The residential

sorting model is a discrete choice model that explains the residential location decision of heterogeneous households over a set of alternative locations. The alternative locations in this thesis are the 14 neighborhoods of Rotterdam. The model relies on the assumption that households choose a location that maximizes their utility. And allows that heterogeneous households have different preferences and therefore value different locational attributes differently.

The thesis proceeds as follows; first, there is an overview of the literature concerning gentrification, specifically what triggers gentrification and where it is likely to occur. Second there is a part of the literature that focuses specifically on the municipality of Rotterdam. Next, there is a description of the methods used and the specifications. In this section there is also a description of the data and an overview of the descriptive statistics. After the method, the results are presented. The thesis concludes with a conclusion including a summary, limitations of the thesis and implications for further research.

2. Literature review

The literature review consists of two parts. The first part focuses on the somewhat more general literature on gentrification, namely what triggers the process of gentrification and where it is likely to occur. This part largely corresponds to the eponymous research project. The second part focuses specifically on the municipality of Rotterdam, for instance which areas belong to the municipality and what kind of policies are in place.

2.1. Gentrification

2.1.1. Similarity

In contrast to previous decades, there is a significant contemporary interest among households in urban residency (Couture & Handbury, 2020). In many cities, this growing interest for urban living contributes to the process of gentrification. There are multiple definitions for the concept of gentrification. In this thesis gentrification refers to the inflow of young and often well-educated households to inner-city neighborhoods that used to be inhabited by older and low-income households (Rouwendal et al., 2018).

So, in the process of gentrification high-income households move to older and traditionally poorer neighborhoods. By doing so, they change the neighborhoods' demographic composition. This can further enhance neighborhood attractiveness. One of the reasons this phenomenon may simply works is because households like to interact with other households that are like them. This is also known as homophily (McPherson et al., 2001), which stands for similarity breeds connection. These preferences for neighbors, but also schools determine how households search in the housing market. This influences the degree of segregation and households' choice regarding schools. A heterogeneous housing choice model, which takes into account the endogeneity of school and neighborhood characteristics, shows the importance of these choices for household location decisions (Bayer et al., 2007). From the model comes that households are willing to pay less than 1% more in house prices when the average performance of the local school increases by 5%. Moreover, the willingness to pay for better-educated and richer neighbors is largely explained by the correlation of these socio-demographic measures with unobserved neighborhood quality (Bayer et al., 2007).

This positive externality, that high-income households like to live next to high-income neighbors, generates an equilibrium where households segregate based on their income. As a response to a citywide demand shock, higher-income households will choose to expand their housing by moving into the poorer neighborhoods immediately adjacent to the original richer neighborhoods (Guerrieri et al., 2013).

2.1.2. Amenities

Another driver of gentrification is the presence of amenities. Amenities may not only be crucial for the growth of cities, but also impact the urban spatial structure and are a critical factor in location choices of households within the city, notably because high-income households value amenities more than low-income households.

In large US cities there are similar sorting patterns as in the Netherlands, high-income households have been moving into downtowns, where housing prices have gone up and neighborhoods have changed drastically as a result (Couture et al., 2021; Couture & Handbury, 2020). As high-income households become wealthier, the demand for upscale amenities in downtown neighborhoods increases. Wealthy households are more likely to live downtown than middle-income households, partly because these areas offer access to local amenities such as restaurants. As incomes rise, the overall demand for neighborhoods with these luxury amenities increases (Couture et al., 2021). As a result, more high-income households choose to live downtown, which triggers the redevelopment of previously low-income neighborhoods. The rising demand drives up house prices and encourages the development of higher-quality inner-city neighborhoods.

Also in Dutch cities, there is found a causal effect of the level of amenities on consumer income, suggesting that wealthier households sort to locations with higher amenities. Based on a newly developed model, locations are differentiated by two attributes, namely distance to employment centers and accessibility to certain amenities. This shows that heterogeneous households are sorted in income across urban space (Gaigne et al., 2017). When the center has a strong amenity advantage over the suburbs, and this valuation of these amenities also increases with income, the rich are likely to live in the center. When the center's amenity advantage is weak or negative, the rich are likely to live in the suburbs (Brueckner & Zenou, 1999). So, when the city center offers attractive amenities, you can expect that this attracts high-income households in downtown areas.

2.1.3. House price growth

A result of gentrification is a price increase in the downtown areas. When households are looking for an owner-occupied house, they set the attractiveness of a neighborhood against its costs. These costs depend on local house prices and commuting costs. Higher income households are willing to pay the higher cost of living in attractive neighborhoods (Rouwendal et al., 2018). As top incomes rise, demand for high-end inner-city neighborhoods, including amenities, increases (Gaigne et al., 2017). This leads to an increase in prices throughout the inner city, including in lower-quality neighborhoods where the poor live.

These lower-quality neighborhoods are also affected because the supply in the initial rich neighborhoods cannot match demand. There is simply a shortage of housing in the original rich areas.

This causes a spread of the rich areas over nearby neighborhoods. These neighborhoods realize especially strong price increases, due the inflow of the richer residents into these border neighborhoods, causing the original poorer residents to move away (Guerrieri et al., 2013). An increase in the supply of high-quality neighborhoods and a decrease in the supply of low-quality neighborhoods reinforce this price mechanism (Rouwendal et al., 2018). Through these mechanisms, an influx of wealthier households into the inner city harms the lower-income households who live there. However, the original owner-occupiers in the neighborhood financially benefit due an increase in house price.

What sets the Netherlands apart from other countries is the large amount of social housing and rent protection. Especially due to social housing and regulated rent, there are also low-income households that are able to move into or stay put in the upgraded neighborhoods. However, transformations in shops and meeting places, and the nature of the local social structure and government interventions, create a sense of loss of place even without physical displacement (Shaw & Hagemans, 2015). This aligns with the reasoning of Couture et al. (2021), who agued that gentrification of downtowns areas negatively impacts lower-income residents, as they are either displaced to the suburbs or pay higher rents for amenities that they do not value as much.

Besides that, some social housing has entered the regulation-free housing market in recent years. These houses thus went from the protected social rent to the free market prices. The sale of rental properties in Amsterdam in the local housing market, increases the supply for owner-occupied properties. An increase in the supply of owner-occupied houses by 15% of the total stock over a 20-year period was absorbed by the market, with no depressive effect on price. This indicates a modest gentrifying effect of the sale of private rental housing in the city center (Rouwendal et al., 2018). It is not that previous tenants bought up the properties. In fact, there is only limited overlap between the groups of renters and owner-occupiers. An important reason for the separation between the two groups is that the maximum size of a mortgage loan depends on income, making owner-occupation in an expensive place like Amsterdam possible only for higher-income households. The results suggest that the gentrifying effect was greater than the effect of increased supply in the city center (Rouwendal et al., 2018).

2.1.4. Policy

Policy can play a major role in the degree of gentrification and urban structure, for example by investing in amenities or deregulating social housing. When implementing policies, particular attention should be paid to where the policy is applied and what the impact of the policy will be. Place-based policies are implemented to target deprived neighborhoods for economic improvement, business development or affordable housing. A place-based policy that targets specific neighborhoods for economic and social reinvestment is one of the most popular approaches. Place-based programs are usually used to achieve specific objectives, such as workforce development or affordable housing. Besides the larger goal,

namely, to improve the overall well-being of residents in disadvantaged neighborhoods (Brazil & Portier, 2020).

However, literature suggests that place-based programs particularly benefit areas that are already engaged in gentrification (Brazil & Portier, 2020). These neighborhoods qualify based on their current low-income status and because they are more likely to improve. Place-based investments will speed up the gentrification process, failing to improve the overall well-being of initial residents.

As mentioned before, The Netherlands is known for the large amount of social housing and rent protection. The highly regulated Dutch context has in general led to relatively soft outcomes of gentrification. Even in gentrifying neighborhoods, lower-income residents stay longer in the neighborhood and can therefore enjoy the benefits of the improved neighborhood (Hochstenbach et al., 2015). However, some social housing has entered the free housing market in recent years (Rouwendal et al., 2018). This kind of policy is called deregulation. Deregulations spurs gentrification, but this way of pursuing policy will do little to improve the welfare of initial residents (Rodríguez-Pose & Storper, 2020).

The impact of a policy even varies by city. The way policy affects the social geography of an urban region depends heavily on its historically evolved characteristics, in particular its housing market structure and labor market (Musterd et al., 2020). Spatial patterns and recent trends differ significantly between the four urban regions in the Netherlands, Amsterdam, Utrecht, The Hague, and Rotterdam. These cities are related to different urban profiles determined by their positions in global networks, the diversity of the economy and how national and local policies have been implemented. Utrecht and Amsterdam, are the most economically successful, encouraging gentrification in the core and a migration to the periphery of lower status groups. Whereas The Hague and Rotterdam do not experience widespread gentrification and retain poor inner cities and relatively prosperous suburbs.

2.2. The municipality of Rotterdam

2.2.1. Policy

Rotterdam is a port city situated in the province of South Holland. As of January 1st, 2021, the population of Rotterdam was estimated to be approximately 651,000. Over the course of the last decade, the city has experienced an increase in its population by 41,000 residents (OBI Gemeente Rotterdam, 2021). *Table 1* shows the neighborhoods that belong to the municipality of Rotterdam.

Table 1: Neighborhoods of the municipality of Rotterdam

Neighborhoods of Rotterdam
Charlois
Delfshaven
Feijenoord
Hillegersberg-Schiebroek
Hoek van Holland
Hoogvliet
IJsselmonde
Kralingen-Crooswijk
Noord
Overschie
Pernis
Prins Alexander
Rotterdam Centrum
Rozenburg

Over the course of recent decades, the municipality has implemented a range of measures, commonly referred to as place-based policies, with the objective of enhancing the livability of the city. Since 2014, the municipality of Rotterdam has been pursuing a policy to make several neighborhoods in and around the Rotterdam city center more attractive for families with children. The policy program 'Kansrijke wijken' places its emphasis on families comprising highly educated parents who reside in relatively costly rental or owner-occupied dwellings (Doff & van der Sluis, 2017). This policy program aligns with other initiatives geared towards attracting and retaining households commonly referred to as the strong shoulders within the context of Rotterdam. The overarching goal is to not only stimulate the city's economic growth but also enhance its social resilience.

An assumption of the policy is that the target families have a preference for settling in older neighborhoods in and around the inner city. This assumption is consistent with the findings presented in existing literature (Brueckner & Zenou, 1999; Gaigne et al., 2017; Koster & Rouwendal, 2017). The settlement of promising families in these older neighborhoods is already underway, and the program seeks to accelerate this further, which is also found in the literature (Brazil & Portier, 2020). The program focuses on increasing the livability in the neighborhoods, providing suitable housing for families, ensuring good education in the neighborhood, and strengthening initiatives of private parties and residents. It focuses on nine districts around the center: Oude Noorden, Nieuwe Westen, Middelland, Liskwartier, Nieuw-Crooswijk, Kralingen-West, Lloydkwartier, Katendrecht and Kop van Zuid-Entrepot (OBI Gemeente Rotterdam, 2018). Which districts belong to which neighborhood can be found in Appendix A.

In its pursuit of enhancing the livability of the city, Rotterdam seeks to direct its attention not only towards the strong shoulders but also the weak shoulders. To this end, various programs have been implemented to address the needs of these more vulnerable groups. The best-known programs are the WBMGP, the KW program and NPRZ. The Dutch government introduced the Act on Extraordinary Measures for Urban Problems ('Wet Bijzondere Maatregelen Grootstedelijke Problematiek'), henceforth WBMGP in 2005. The Act allowed local governments to prevent specific households to move into public housing. The main aim of the WBMGP is to improve livability of distressed streets as well as neighborhoods by increasing social mixing and thereby avoiding too high concentrations of disadvantaged households (Koster & van Ommeren, 2022). Simply put, the WBMGP excludes non-working (no income from work, pension or student loans) newly arrived people from five specific districts in Rotterdam (Hochstenbach et al., 2015). The five designated districts are Bloemenhof, Carnisse, Hillesluis, Oud-Charlois and Tarwewijk. By limiting the influx of households without income from work, the WBMGP should contribute to upgrading livability by reducing segregation and allowing existing policies to be used more effectively.

To qualify for a housing permit, applicants must either have an uninterrupted period of residence of six years or more in the Rotterdam City Region or have income from work above the social assistance standard. The applicant will not qualify if both criteria are not met. Simply put, the WBMGP aims to keep unemployed newcomers out of these neighborhoods (Hochstenbach et al., 2015). Later, the law was extended so that local governments could also refuse persons with a criminal record (Koster & van Ommeren, 2022).

The WBMGP leads to a change in relocation flows and, by extension, the population composition of designated neighborhoods. However, these changes have not translated into improvements in the livability and safety of these neighborhoods (Hochstenbach et al., 2015). The Act indeed leads to a reduction in non-employed households in public housing, that is, the redlining effect, but did not induce a change in the share of non-employed in private housing or a noticeable change in other demographic variables. The preferred specification shows that the share of non-employed households in targeted neighborhood is reduced by about 2 percentage points (Koster & van Ommeren, 2022).

Due to prominent advertising of targeted deprived neighborhoods, a stigma may have been created. Research provides a causal evidence of a sizeable negative price effect in the housing market incurred by place-based policies that publicly announce which neighborhoods are deprived (Koster & van Ommeren, 2022). Annual housing market losses due to the policy are estimated to be about €200 for households residing in treated neighborhoods, as reflected by house price drops of about 4%. The presence of this negative price effect has been established for three different place-based policies, namely the WBMGP, the KW program and the NPRZ (Koster & van Ommeren, 2022).

NPRZ (‘Nationaal Programma Rotterdam Zuid’), aimed to improve neighborhoods in Rotterdam South since 2012. The aims are to improve school performance of children, labor market opportunities of young workers as well as the livability of the neighborhood. An alternative program is the KW program (‘Krachtwijken’). The main aim of this program was to improve quality of public housing units by demolition and renovation in various neighborhoods in the Netherlands. About €1 billion was spend in 40 neighborhoods over the course of five years, starting in 2007, which amounted to about €2,800 per household per year. Neighborhoods were treated when the deprivation score exceeded a certain threshold.

The fact that the presence of this negative price effect has been established for these three place-based policies suggests that neighborhood stigma is important, which implies that individuals living in deprived neighborhoods experience disutility from living in a place with a low status (Koster & van Ommeren, 2022). The various plans to upgrade livability in the city can be reflected in the level of education, the type of housing and the income level.

2.2.2. Level of education

Until recently, Rotterdam was the only one of the four major cities to have a slightly lower share of highly educated people than the rest of the Netherlands, although the difference was small (as can be seen in *Figure 1*). Over the past four years that difference has caught up, and according to figures for 2021, Rotterdam's share is now 0.2 percentage points higher (OBI Gemeente Rotterdam, 2022).

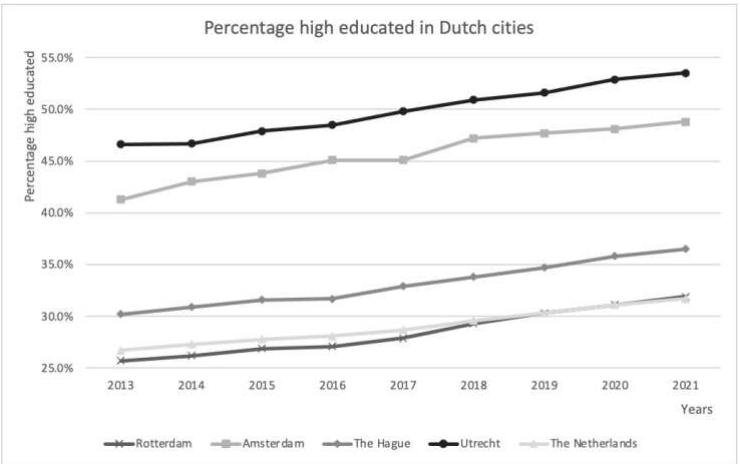

Figure 1: Percentage high educated in Dutch cities. Source: KWB customized.

Compared to the other major cities, and especially Amsterdam and Utrecht, Rotterdam has a relatively high proportion of low and medium educated and a low proportion of highly educated. The educational level of residents of Rotterdam is steadily increasing (OBI Gemeente Rotterdam, 2021). As the share of highly educated people in all cities has increased similarly, Rotterdam is still lagging behind the other cities.

2.2.3. Income

As well as the level of education, the percentage of high incomes has been gradually increasing for several years and the share of low incomes has been correspondingly decreasing (OBI Gemeente Rotterdam, 2021). This can be found in *Figure 2.* The difference with other large cities remains almost the same.

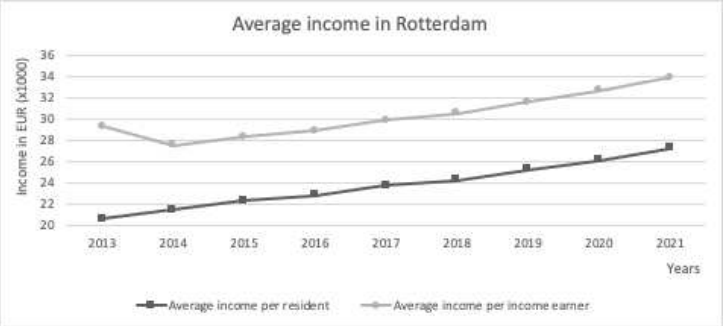

Figure 2: Average income in Rotterdam. Source: KWB customized.

In all four big cities, the low-income group is overrepresented. In Rotterdam (53%) even slightly more so than in the other three big cities. The share of high-income households is smaller in most large cities than nationally (Rotterdam: 14%). Utrecht is an exception to this. In all four major cities, the low-income group is very slowly getting slightly smaller, and the high-income group is very slowly getting slightly larger (OBI Gemeente Rotterdam, 2021). The differences between Rotterdam and the other big cities hardly changed over the years.

2.2.4. Type of housing

The housing stock in Rotterdam (and the three other big cities) is very different from the Dutch average. The proportion of rental housing is much higher, there are many more pre-war houses and there is an overrepresentation of multi-family houses (OBI Gemeente Rotterdam, 2021). From this perspective, it is logical to compare the situation in Rotterdam to other big cities and not with the Dutch average.

Since the end of the economic crisis, the market value has risen sharply. In 2020, the average WOZ value of a house in Rotterdam was €222,000. That is 52% more than in 2015. The average sales price of an existing owner-occupied house in Rotterdam has increased by 62% since 2015, from €190,000 to €307,000 in 2020. The increase is significantly higher than in The Hague (54%), but less than in Utrecht (65%) and Amsterdam (68%). Three quarters of the residents of Rotterdam are satisfied with their homes and seven in ten are satisfied with their neighborhood (OBI Gemeente Rotterdam, 2021).

Rotterdam's housing stock has a total of almost 318,000 accommodation units on January 1st, 2021, of which 304,500 are independent housing units and around 13,500 are non-independent housing units (student units, care units). The independent housing stock consists of two-thirds rental housing and one-third owner-occupied housing (OBI Gemeente Rotterdam, 2021; StatLine, 2023). Amsterdam and Rotterdam have the highest stock of rental housing. Rotterdam and Amsterdam also have many housing

associations; 44% and 40% respectively are rented by housing associations (OBI Gemeente Rotterdam, 2021).

Rotterdam, along with Utrecht, has relatively few old houses: 30% are pre-1945 (in Amsterdam and The Hague around 40%). In Rotterdam, much of the pre-war housing was destroyed by the bombing of 14 May 1940. Almost a quarter of Rotterdam's houses date from the early post-war period (1945-1970) and another quarter are from 1971-1990. Over a fifth of the houses were built after 1990. Of the four major cities, Amsterdam and Utrecht have built the most new homes in the past decade (OBI Gemeente Rotterdam, 2021).

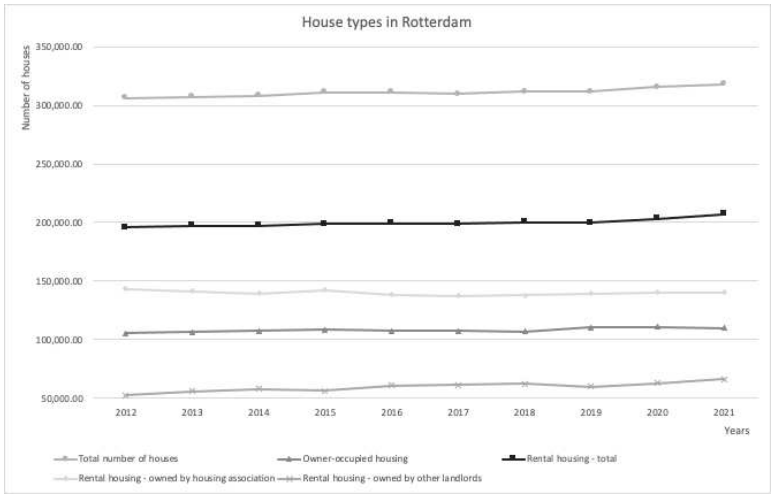

Figure 3: House types in Rotterdam. Source: Statline Voorraad woningen customized.

3. Methodology

In this chapter, an outline of the procedures used to conduct the study is provided. The purpose of the chapter is to demonstrate that the study is precise and was performed in full compliance with all applicable research standards. Two analyses were conducted for this thesis. First, a hedonic pricing model was conducted, based on a dataset from the NVM. Second, a residential sorting model was conducted, based on the datasets KWB and WoOn. The method will be explained per model.

3.1. Study area

In this thesis, the focus is on the different neighborhoods in the municipality of Rotterdam. These 14 neighborhoods can be found in ***Figure 4.*** The neighborhoods Spaanse Polder, Nieuw Mathenesse, Waalhaven-Eemhaven, Vondelingenplaat, Botlek-Europoort-Maasvlakte, Rotterdam-Noord-West, Rivium and Bedrijventerrein Schieveen were removed from the datasets. These are all industrial areas, where very few households live. Therefore, this data is not applicable for this study. There is an overview of the neighborhoods and districts in Appendix A.

Figure 4: The municipality of Rotterdam and the neighborhoods. Source: https://www.woneninrotterdam.nl/info/wijken-in-rotterdam/

3.2. Hedonic pricing model

3.2.1. Data and descriptives

To estimate the hedonic price function there is made use of the NVM data. This dataset provides information about housing transactions collected by the Dutch Association of Real Estate Agents (NVM). One of the main advantages of the NVM data is the rich set of housing characteristics. The dataset covers a ten-year period, namely 2012-2021. During this period the NVM registered 40,870 transactions within the municipality of Rotterdam. The summary statistics offer insights into the basic descriptive elements of the data. The descriptive statistics are shown in ***Table 2.***

Table 2: Descriptive statistics variables for hedonic pricing model. Source: NVM

Housing characteristics	Mean	Std. Dev.	Min	Max
Price (log)	12.325	.623	9.616	15.703
Size (log)	4.583	.382	3.258	7.066
Rooms (log)	1.321	.36	0	3.135
Year	2016.651	2.66	2012	2021
Neighborhood	7.128	3.952	1	14
Type of property	6.699	3.843	1	16
Construction year >1905	.044	.205	0	1
Construction year 1906-1930	.121	.326	0	1
Construction year 1931-1944	.163	.37	0	1
Construction year 1945-1959	.12	.325	0	1
Construction year 1960-1970	.109	.311	0	1
Construction year 1971-1980	.071	.257	0	1
Construction year 1981-1990	.115	.319	0	1
Construction year 1991-2000	.092	.289	0	1
Construction year 2001-2010	.14	.346	0	1
Construction year 2011-2020	.024	.154	0	1
Construction year 2021-2030	.001	.024	0	1
Garden	.734	.442	0	1
Maintenance state is good	.793	.405	0	1
Maintenance score inside	.724	.149	0	1
Maintenance score outside	.74	.111	0	1
Newly built property	.006	.074	0	1

Notes: (i) number of observations is 40,870.

Many of the variables consist of dummies, where, for example, 0 means the house has no garden and 1 means it does have a garden. In addition, 16 housing types are distinguished. The observation period is 10 years and was measured between 2012-2021. The year indicates the year in which the transaction of the house took place, so not the year the house came on the market. Standard house features are also added to the model, such as size, rooms, and price. These variables are measured in logs.

3.2.2. Analysis

The first analysis performed is a hedonic pricing model. Location choices of households and the amount of money they pay for a property provide useful information on the preferences of households for locations. In the field of economics, it is assumed that the behavior of people can be modelled as the outcome of the maximization of a utility function. This concept can also be applied in the housing market. Households will consider a wide range of characteristics of the available houses and their location. Eventually they will choose the property that maximize the utility, given the available budget. Making use of hedonic housing price analysis is a way to measure those preferences and quantify the so-called marginal willingness to pay (MWTP) of households for location and housing characteristics. The hedonic pricing analysis requires information on many location choices, the prices of properties, as well as location and housing characteristics. The powerful characteristic of hedonic price techniques is that house prices provide information on the MWTP of people for public goods and location characteristics, for which it is otherwise hard to measure the benefits (Koster & Rouwendal, 2022). This hedonic price technique gives an indication of the MWTP for specific neighborhoods over time. This can be the first indicator of a process of gentrification.

In the model there is made use of the logarithm of price, size and rooms. Besides that, there are dummies included for year, neighborhood, type of property, construction year, garden, maintenance and newly built property. Formally, the model is represented as follows:

Equation 1:

$$(log)price_i = \beta_0 + \beta_1 * logsize_i + \beta_2 * logrooms_i + \beta_3 * year_i + \beta_4 * proptype_i + \beta_5 * neighborhood_i + \beta_6 * constrlt1905_i + \beta_7 * constrlt19061930_i + \beta_8 * constrlt19311944_i + \beta_9 * constrlt19451959_i + \beta_{10} * constrlt19601970_i + \beta_{11} * constr19711980_i + \beta_{12} * constr19811990_i + \beta_{13} * constr19912000_i + \beta_{14} * constr20012010_i + \beta_{15} * constr20112020_i + \beta_{16} * constr20212030_i + \beta_{17} * garden_i + \beta_{18} * maintgood_i + \beta_{19} * maintinside_i + \beta_{20} * maintoutside_i + \beta_{20} * newbuilt_i + \varepsilon_i$$

The model is extended with explanatory variables to give, from an econometric point of view, a better representation of reality.

3.3. Residential sorting model

3.3.1. Data and descriptives

The residential sorting model utilizes two distinct datasets: the KWB dataset, which offers insights into location-specific characteristics, and the WoON dataset, which provides comprehensive information regarding household characteristics.

3.3.1.1. KWB

One of the datasets that is used to investigate the residential sorting model is obtained from the Central Statistics Office (CBS). The dataset is called key figures neighborhoods and districts (Kerncijfers wijken en buurten), from now on KWB. KWB contains core figures on neighborhoods for instance on population, housing type and income by neighborhood for every year. This thesis utilizes the KWB 2015 dataset.

3.3.1.2. WoON

The second dataset used for the residential sorting model is the so-called Housing research Netherlands (Woononderzoek Nederland). This is abbreviated to WoON. The dataset comes from 'Ministerie van Binnenlandse Zaken en Koninkrijksrelaties'. The dataset is a basic residential survey, where data are collected by a survey that is conducted every three years. In this survey respondents are asked for topics such as income, education, as well as neighborhood satisfaction. This thesis utilizes the WoON 2015 dataset.

The descriptive statistics offer insights into the basic descriptive elements of the data. For the residential sorting model there is thus made use of the KWB for the location characteristics and WoOn for the household characteristics. The average house price per neighborhood in 2015, the variable price in *Table 3*, was extracted from the NVM dataset. This is the same dataset used for the hedonic pricing model. The descriptive statistics are shown in *Table 3*. Only owner-occupiers are considered in this thesis.

Table 3: Descriptive statistics variables for residential sorting model. Source: WoON, KWB & NVM

	Mean	Std. Dev.	Min	Max
Household characteristics				
Age (years)	48.062	14.065	18	93
College degree (1,0)	0.455	.498	0	1
Income (log) (2015 EUR)	10.925	.622	8.206	13.225
Location characteristics				
Price (log) (2015 EUR)	12.135	.3	11.542	12.651
Density (log)	8.377	.802	6.583	9.587
Households with kids (%)	30.57	6.086	14.942	35.88
Migrants (%)	41.914	18.034	13.056	70.49
High income households (%)	14.8	5.563	6.1	27.4

Notes: (i) number of observations is 7.658. (ii) Number of observation of alternatives (neighborhoods) is 14.

First some comments on the household characteristics. The WoON survey was completed by people between the ages of 18 and 93. The variable income is a logarithmic variable. College degree is a dummy variable. The dummy indicates if the participant is highly educated. If the survey participant has completed college (HBO) or university education (WO), this equals 1. All levels below this equal 0. College and university were chosen for indicators for highly educated because this is also used by the CBS.

In addition, some comments on location characteristics. As mentioned, the variable price equals the average house price per neighborhood in 2015. This is measured in logs. The variable density, this means the population density in a neighborhood, is measured as the logarithm of the number of residents per km^2. The variables household with kids, migrants and high income households are shown in percentages. This means that the variable household with kids indicates the percentage of households with children by neighborhood. Households with children include unmarried couples with children, married couples with children and single-parent households. The percentage ranges from 14% to 35%. The variable migrants indicate the percentage of persons in a neighborhood with a migration background. The percentage of migrants ranges from 13% to 70%. The variable high income households indicates the share of households belonging to the national 20% of households with the highest household disposable income.

3.3.2. Analysis

The primary objective of this analysis is to examine the gentrifying factors that exert an influence on the decision-making process of households when selecting their residential locations in Rotterdam. To do so, the equilibrium sorting model in accordance with the approach of Bayer, et.al. (2007) is estimated. Within this model, it is assumed that households derive utility from residing in specific location alternatives, and this utility is contingent upon both the locational attributes of each alternative and the unique characteristics of their own household.

The residential sorting model utilized in this study is a discrete choice model that explains the residential location decision of heterogeneous households over a set of alternative locations. The underlying assumption is that households opt for a location that maximizes their utility. In addition, it allows that heterogeneous households have different preferences and therefore value different locational attributes differently. The outcomes of the model yield choice probabilities for each alternative location, offering valuable insights into the valuation patterns of heterogeneous households, expressed as the MWTP for specific location attributes (Ommeren van & Rouwendal, 2023).

The estimation of the residential sorting model in this research adheres to the methodology outlined by Van Ommeren & Rouwendal (2023), who provide an explanation of the approach originally proposed by Bayer et al. (2007). Specifically, there is analyzed how a household (i) with characteristics (Z_l^i) sorts into alternative locations (j). It begins by assuming a household's (indirect) utility (U_j^i) in location j is a function of the location's systematic utility (V_j) and the household's idiosyncratic preference for the location (ϵ_j^i), which is unobserved:

Equation 2:

$$U_j^i = V_j^i + \epsilon_j^i$$

Now assume the systematic component of utility, V_j^i, consists of two components. First, it is assumed that there is a fixed level of utility (δ_j) attached to each location. This is referred to as an alternative specific constant, also called ASC. Second, it is assumed that V_j is affected by the location attributes ($X_{k,j}$) which include, for example, house prices and density. To allow for household heterogeneity, interactions are included, between location attributes ($X_{k,j}$) and household characteristics (Z_l^i). Thus, the systematic component of utility (V_j) is defined as follows:

Equation 3:

$$V_j^i = \delta_j + \sum_{k=1}^{K}\sum_{l=1}^{L}\beta_{k,l}\left(Z_l^i - \bar{Z}_l\right)X_{k,j}$$

In this equation the inclusion of the interaction effects between household characteristics (Z_l^i) and location attributes ($X_{k,j}$) allows for the latter to have heterogeneous effects across households. Note that Z_l^i is mean centered by subtracting $\bar{Z}_l$, that is, the mean of household characteristic l. Only non-dummy household characteristics are expressed like this. The fixed level of utility (δ_j) is a function of location attributes ($X_{k,j}$):

Equation 4:

$$\delta_j = \sum_{k=1}^{K}\beta_{k,o}\,X_{k,j} + \xi_j$$

Where ξ_j denotes a location specific unobserved characteristic. The full residential sorting model then becomes:

Equation 5:

$$U_j^i = \sum_{k=1}^{K}\beta_{k,o}\,X_{k,j} + \sum_{k=1}^{K}\sum_{l=1}^{L}\beta_{k,l}\left(Z_l^i - \bar{Z}_l\right)X_{k,j} + \xi_j + \epsilon_j^i$$

Where U_j^i denotes the indirect utility of household i in location j, $X_{k,j}$ denotes the value of k-th attribute for location j, Z_l^i denotes the value of l-th characteristic for household i. $\beta_{k,o}$ is the direct effect coefficient. The setting of this model enables to obtain a set of $k * l$ coefficients of $\beta_{k,l}$, which reflects the interaction effect between household characteristics and location attributes and gives the preference of household with characteristic l to location characteristics k.

Furthermore, it cannot be said with certainty that all unobserved location characteristics that influence the household residential location choice are included. Hence, therefore an alternative-specific term ξ_j is added to account for possible unobserved location characteristics and assume that households take these unobserved characteristics into account in deciding where to reside. Besides that, there is a household specific error term ϵ_j^i included. Finally, suppose location attributes ($X_{k,j}$), includes the logarithm of house prices, ln(P_j). Correlation between ln(P_j) and the location specific error term, ξ_j in ***Equation 4*** means endogeneity is likely to be a problem. Ignoring this endogeneity issue would lead to a biased estimation of the price coefficient. To address this problem, we estimate the sorting model in two steps.

Estimation step 1:

The first step involves estimating *Equation 3* using a logit model. In the logit model, the probability of a household choosing for a location ($Prob_j^i$) is given by:

Equation 6:

$$\left(Prob_j^i\right) = \frac{e^{V_j^i}}{\sum_{j=1}^{J} e^{V_j^i}} = \frac{e^{(\delta_j + \sum_{k=1}^{K}\sum_{l=1}^{L}\beta_{k,l}\left(Z_l^i - \bar{Z}_l\right)X_{k,j})}}{\sum_{j=1}^{J} e^{(\delta_j + \sum_{k=1}^{K}\sum_{l=1}^{L}\beta_{k,l}(Z_l^i - \bar{Z}_l)X_{k,j})}}$$

Estimating *Equation 6* yields estimates of (1) the ASCs, δ_j, which define the constant level of utility for each location and (2) the interaction coefficients ($\beta_{k,l}$), which vary by attribute k and characteristic l.

Estimation step 2:

The second step involves estimating *Equation 4*. We use the vector of ASCs, (δ), estimated in *Equation 6* as the dependent variable, with explanatory variables formed by the location attributes ($X_{k,j}$). As noted above, it is expected that house prices, ln(P_j), are correlated with the error term ξ_j. For this reason, the second step often uses instrumental variables to account for endogeneity. In this thesis is made use of an instrument that is created by Van Duijn & Rouwendal (2018). In the model, the heterogeneity in the choice probabilities is related to the heterogeneity of the characteristics of the actors. This distribution of the actor characteristics is exogenous information and thus can serve as the basis of an instrument. Van Duijn & Rouwendal (2018) make use of the suggestion of Bayer et al. (2007) to strip the unobserved characteristics from the model and compute the prices that will equilibrate demand and supply in that situation. Instead of estimating the price, the price is set equal to -10, which is the outcome in the second-stage estimation in the paper of Van Duijn & Rouwendal (2018), and estimate the other coefficients based on this assumption. To measure the correctness of the model, the model is also estimated for -15 and -5. So, these values count as the robustness checks.

Estimating marginal willingness-to-pay (MWTP):

After having estimated the sorting model, the marginal willingness to pay (MWTP) for location attributes for each type of household in the data can be estimated. Note *Equation 5* explicitly links utility to the logarithm of house prices, ln(P_j), implying a relationship similar to a hedonic price function, that is, $U(P, X, Z, \xi, \epsilon) \Rightarrow P(U, X, Z, \xi, \epsilon)$. Differentiating $P(U, X, Z, \xi, \epsilon)$ with respect to location attributes X defines the change in price required to keep utility constant and is thus the MWTP for X. To proceed, let the first attribute ($k = 1$) be the logarithm of house prices, that is, $X_{1,J} = P_j$ and $\beta_{1,l} = \beta_{p,l}$, where subscript p denotes house price. Second, we can re-arrange *Equation 5* for ln(Pj) to yield ln(P_j):

Equation 7:

$$\ln(P_j) = -\frac{\sum_{k=2}^{K} \beta_{k,o} X_{k,j} + \sum_{k=2}^{K} \sum_{l=1}^{L} \beta_{k,l}(Z_l^i - \bar{Z}_l) X_{k,j} + \xi_j - U_j^i + \epsilon_j^i}{(\beta_{p,0} + \sum_{l=1}^{L} \beta_{p,l}(Z_l^i - \bar{Z}_l))}$$

MWTP for $X_{k,j}$ is derived by partially differentiating ***Equation 7*** with respect to $X_{k,j}$:

Equation 8:

$$\frac{\partial P_j}{\partial X_{k,j}} = -\frac{\beta_{k,0} + \sum_{l=1}^{L} \beta_{k,l}(Z_l^i - \bar{Z}_l)}{\beta_{p,0} + \sum_{l=1}^{L} \beta_{p,l}(Z_l^i - \bar{Z}_l)} P_j$$

For households with average characteristics, ***Equation 8*** reduces to:

Equation 9:

$$\frac{\partial P_j}{\partial X_{k,j}} = -\frac{\beta_{k,0}}{\beta_{p,0}} P_j$$

4. Results

This chapter is dedicated to the presentation of the outcomes obtained from the different analyses conducted in this thesis. The results will be presented separately for each analysis. Firstly, the findings of the hedonic pricing method will be presented. Secondly, the results derived from the residential sorting model will be presented.

4.1. Hedonic pricing model

Based on *Equation 1*, the following results emerged. The results for the hedonic price function can be found in *Table 4*.

Table 4: Logarithmic hedonic pricing model

Housing characteristics		Coefficient		Std. Error
Neighborhood	Rotterdam Centrum	0.593	***	(0.006)
	Kralingen-Crooswijk	0.525	***	(0.005)
	Hillegersberg-Schiebroek	0.502	***	(0.006)
	Noord	0.433	***	(0.005)
	Feijenoord	0.244	***	(0.007)
	Delfshaven	0.226	***	(0.006)
	Prins Alexander	0.219	***	(0.005)
	Overschie	0.203	***	(0.008)
	Hoek van holland	0.200	***	(0.020)
	IJsselmonde	0.095	***	(0.005)
	Hoogvliet	0.035	***	(0.006)
	Rozenburg	0.024	*	(0.014)
	Pernis	-0.038	***	(0.012)
	Charlois			
Year	2013	-0.049	***	(0.006)
	2014	-0.010	*	(0.006)
	2015	0.034	***	(0.005)
	2016	0.144	***	(0.005)
	2017	0.303	***	(0.005)
	2018	0.462	***	(0.005)
	2019	0.557	***	(0.005)
	2020	0.644	***	(0.005)
	2021	0.808	***	(0.005)
Type of property	Landhuis	0.609	***	(0.090)
	Villa	0.438	***	(0.016)
	Bungalow	0.389	***	(0.030)
	Woonboerderij	0.306	***	(0.104)
	Penthouse	0.185	***	(0.017)
	Herenhuis	0.166	***	(0.012)
	Grachtenpand	0.106		(0.089)
	Eengezinswoning	0.053	***	(0.010)
	Tussenverdieping	0.022		(0.017)
	Benedenwoning	-0.009		(0.010)
	Portiekflat	-0.045	***	(0.010)
	Galerijflat	-0.077	***	(0.010)
	Bovenwoning	-0.092	***	(0.010)
	Portiekwoning	-0.099	***	(0.011)
	Maisonnette	-0.144	***	(0.011)
Construction year	>1905	0.123	***	(0.024)
	1906-1930	0.099	***	(0.023)
	1931-1944	0.067	***	(0.023)
	1945-1959	0.079	***	(0.023)

1960-1970	0.032		(0.023)
1971-1980	0.028		(0.023)
1981-1990	0.031		(0.023)
1991-2000	0.163	***	(0.023)
2001-2010	0.229	***	(0.023)
2011-2020	0.292	***	(0.022)
2021-2030	0.412	***	(0.041)
Size (log)	0.946	***	(0.007)
Rooms (log)	-0.053	***	(0.007)
Garden	0.018	***	(0.003)
Maintenance state is good	0.043	***	(0.004)
Maintenance score inside	0.384	***	(0.016)
Maintenance score outside	0.103	***	(0.018)
Newly built property	-0.023		(0.022)
Constant	6.975	***	(0.040)

Notes: (i) Number of observations is 40,870. (ii) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. (iii) Neighbourhood reference category is Charlois. (iv) R-squared is 0.880.

The regression table presents that almost all coefficient variables are statistically significant different from zero. Notably, the year and neighborhood variables provide interesting insights. The variable year demonstrates an increasingly positive relationship between year and price compared to the reference category 2012. All year coefficients are statistically different from zero at the 1% level, except for 2014 which is statistically significant different form zero at the 10% level. The observed positive relationship aligns with expectations, given the overall upward trend in house prices experienced in recent years. The average price per year in Rotterdam is shown in ***Figure 5***.

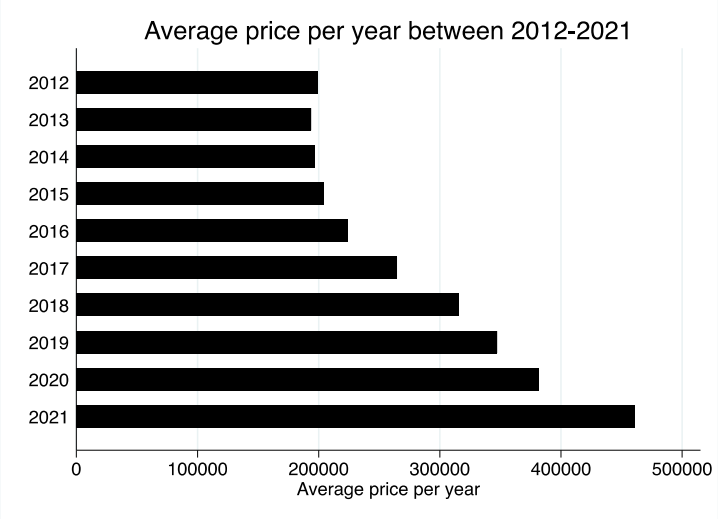

Figure 5: Average house price per year. Source: NVM customized.

The coefficients for the different neighborhoods are also statistically significant different from zero at the 1% level, except for Rozenburg which is statistically significant different from zero at the 10% level. This may be because the limited number of observations available for this specific neighborhood. The reference category

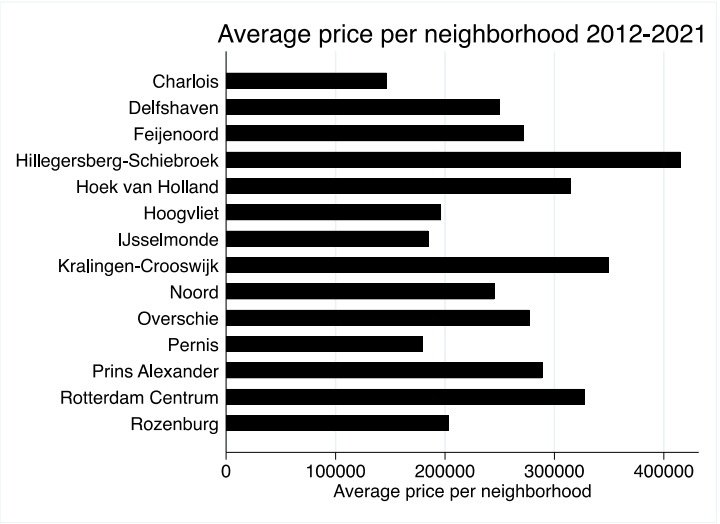

Figure 6: Average price per neighborhood between 2012-2021. Source: NVM customized.

for the variable neighborhoods is the neighborhood Charlois. For instance, the house prices in Noord are higher compared to Charlois, whereas in Pernis, they are comparatively lower in relation to Charlois. The average price per neighborhood between 2012 and 2021 is shown in *Figure 6*. *Figure 6* illustrates variations in average house prices across different neighborhoods. Hillegersberg-Schiebroek exhibits the highest average house price, while Charlois demonstrates the lowest average house price. This shows which neighborhoods are already more or less expensive over time. *Figure 5* shows that on average, house prices have risen substantially over the past 10 years. However, the average prices per neighborhood have not changed at the same rate between 2012 and 2021. *Figure 7* shows the development of hedonic house prices per neighborhood between 2012 and 2021.

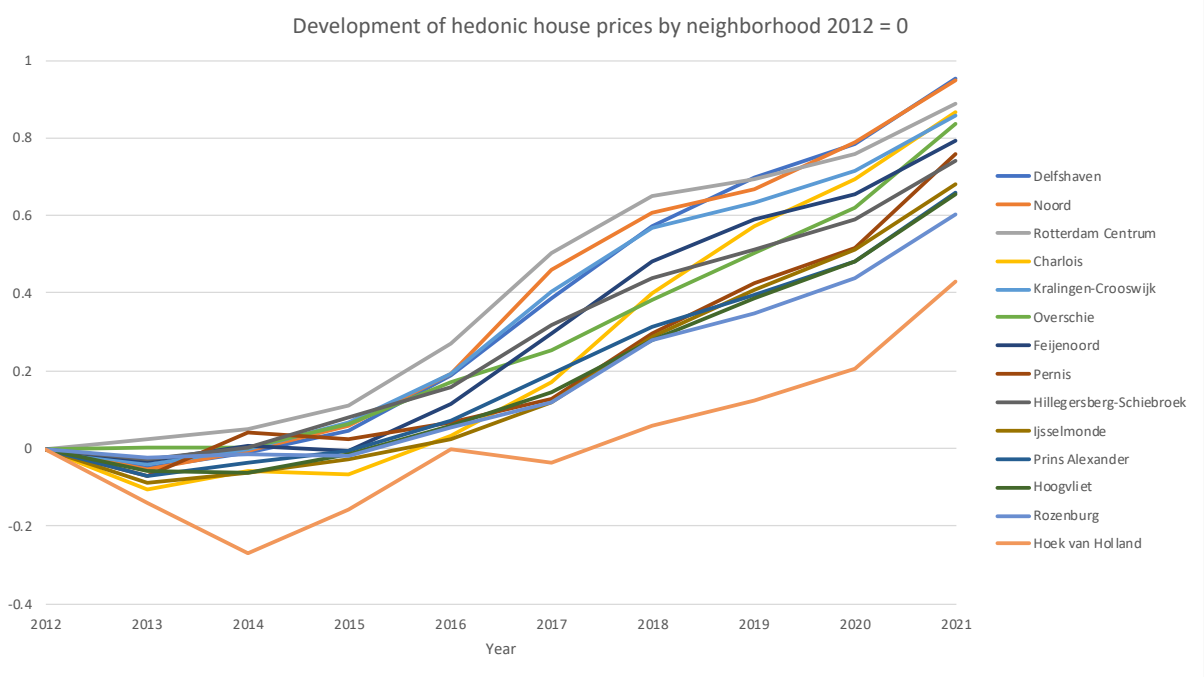

Figure 7: Development of hedonic house prices by neighborhood. Source: NVM customized.

Figure 7 shows the development of house prices taking into account property characteristics such as garden, size, rooms, construction year. The same variables are included as shown in *Table 2*. First, a regression is performed for each neighborhood separately. The coefficients by year between 2012-2021 are then examined. The figure therefore shows the interaction effect between each neighborhood and year. 2012 is the base year so this year equals 0. All year coefficients of all 14 neighborhoods were then combined.

Figure 7 shows that house prices in some neighborhoods have risen much faster than in other neighborhoods. The figure highlights substantial price rises in Delfshaven, Noord and Rotterdam Centrum compared to the baseline year of 2012. These findings suggest that these neighborhoods have experienced significant growth in demand and desirability. In essence, these observations indicate a growing popularity of these neighborhoods. This is in line with the existing literature that states that as

top incomes rise, demand for high-end inner-city neighborhoods, including amenities, increases (Gaigne et al., 2017). This leads to an increase in prices throughout the inner city.

4.2. Residential sorting model

4.2.1.KWB

This section gives some insight in the neighborhood statistics based on the KWB data. *Figure 8* shows the average income per resident per neighborhood in Rotterdam. In all neighborhoods there is an increase in average income visible. However, the figure indicates that the average income in Rotterdam. Centrum and Hillegersberg-Schiebroek is significantly higher compared to other neighborhoods. To illustrate how much the average income changed since 2013 the average income in year 2013 is set to 0. *Figure 9* shows that the average income since 2013 increased the most in Rotterdam Centrum, followed by Noord and Kralingen-Crooswijk. The average income per resident per neighborhood increased respectively €11,000, €9,000 and €7,900 per year.

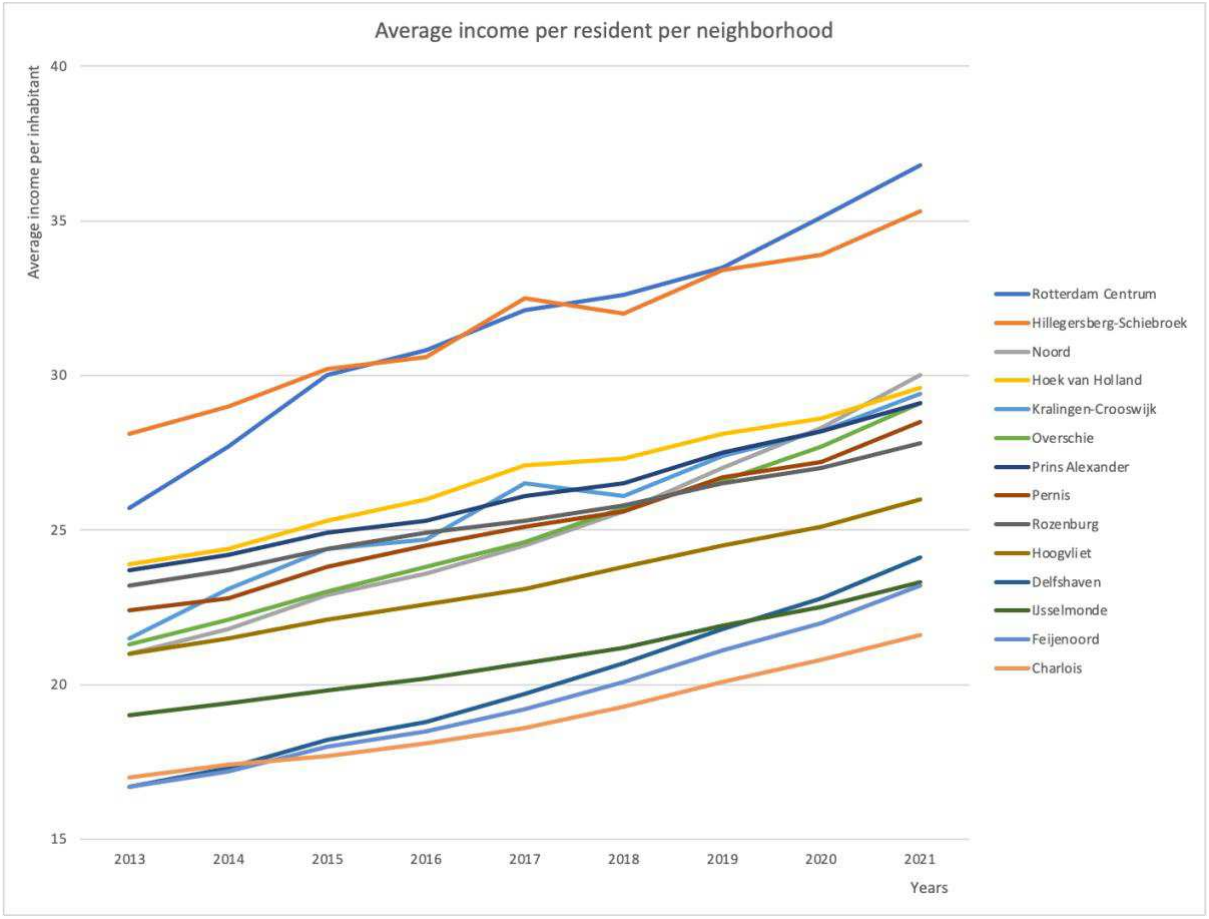

Figure 8 : Average income per resident per neighborhood in Rotterdam. Source: KWB customized.

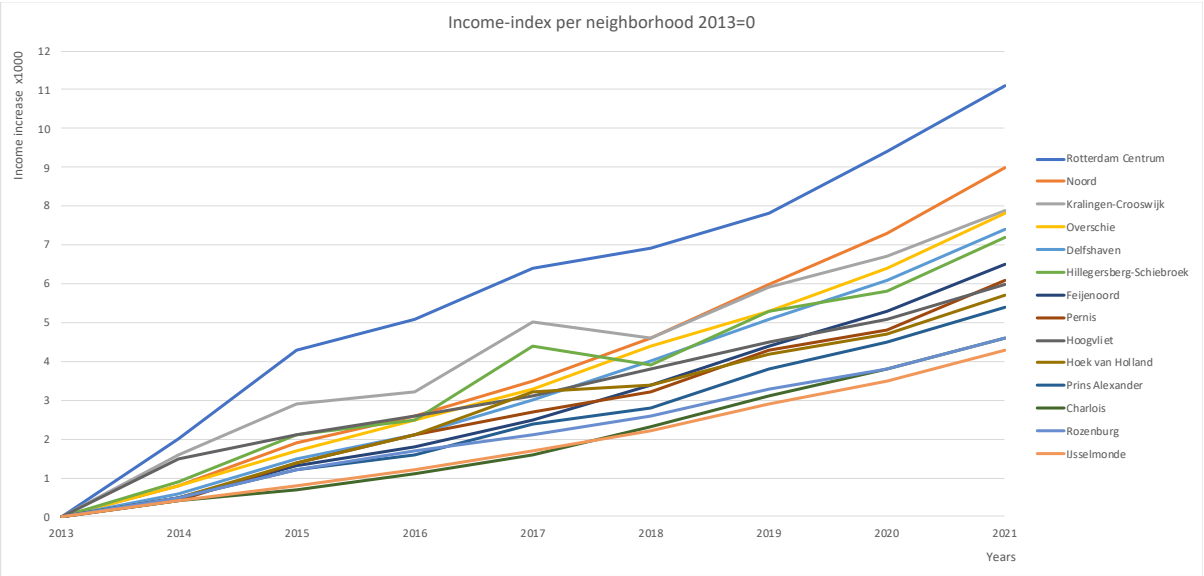

Figure 9 : Income-index per neighborhood in Rotterdam. Source: KWB customized.

4.2.2. First-stage estimation

In the first-step procedure of the sorting model we estimate the mean utilities and the attributes-based on *Equation 5* with location choice of household as dependent variable. In the year 2015, Rotterdam consisted of a total of 14 neighborhoods. The average utilities were estimated as ASCs. It is crucial to highlight that the number of ASCs in this study is limited to only 14, which can be considered relatively small. The coefficients represent the interaction effects between household and location characteristics in the owner-occupier market. These interaction effects, which give an indication of how different type of household's value neighborhood characteristics, are reported in *Table 5*. For example, households with a college degree are less sensitive for price than the average household. There are three interaction effects which are statistically significant different from zero.

Table 5: First-stage estimation results

Location characteristics	**Household characteristics**	Coefficient		Std. Error
Price (log)	Age (years)	-0.0235		0.0236
	University degree (1,0)	0.987		0.717
	Income (log)	0.217		0.552
Density (log)	Age (years)	-0.00443		0.00886
	University degree (1,0)	0.367		0.271
	Income (log)	0.473	**	0.214
Households with kids (%)	Age (years)	-0.00106		0.000705
	University degree (1,0)	-0.0605	***	0.0213
	Income (log)	0.0338	**	0.0164
Migrants (%)	Age (years)	-0.000163		0.000687
	University degree (1,0)	0.0121		0.0208
	Income (log)	-0.0222		0.0163
High income households (%)	Age (years)	0.00327		0.00217
	University degree (1,0)	0.0528		0.0656
	Income (log)	0.0213		0.0511
Alternative-specific constants		Included		

Notes: (i) 14 alternative specific constants included. (ii) Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.1$

4.2.3. Second-stage estimation

In the second-step procedure, the estimated ASCs obtained from the first stage are set as the dependent variable and regressed upon the location characteristics based on *Equation 6*. The dependent variable of ASCs is the vector of mean indirect utilities which could be viewed as the part of the utility that is equal for all households. The results are visible in *Table 6*. The first model estimation (ASC (1)) shows the estimation without using an instrument and thereby ignores the endogeneity problem. Therefore, as mentioned in the method, there is assumed that price equals -10 in the second model estimation (ASC (2)). Since this is a strong assumption, price = -15 in the third model estimation (ASC (3)) and price = -5 in the fourth model estimation (ASC (4)) are used as robustness checks.

Table 6: Second-stage estimation results

	ASC (1)	Std. Error	ASC (2)		Std. Error	ASC (3)		Std. Error	ASC (4)		Std. Error
Price	-1.034	1.281	-10			-15			-5		
Density	-0.106	0.483	-1.769	*	0.951	-2.696	*	1.418	-0.841		0.529
Households with kids	0.032	0.041	-0.074		0.086	-0.133		0.129	-0.015		0.048
Migrants	0.057	0.032	0.235	***	0.062	0.335	***	0.093	0.136	***	0.035
High income households	0.084	0.078	0.751	***	0.146	1.123	***	0.217	0.379	***	0.081
Constant	7.321	17.629	115.942	***	8.212	176.518	***	12.245	55.365	***	4.572

Notes: (i) number of observations is 14. (ii) Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The results from the second model estimations in *Table 6* shows that the average household likes to live next to high income households. The coefficient has a positive sign and is statistically significant from zero at the 1% level. Similar results are observed for the share of migrants. The coefficient of migrants is positive and statistically significant from zero at the 1% level as well. Therefore, you can say that household value living next to migrants. This is somewhat unexpected.

The coefficient for density is negative and statistically significant at the 10% level. The coefficient shows that density has a negative external effect on the attractiveness of locations. For the share of households with kids there is found a negative sign, but this is not statistically significant.

4.2.4.MWTP

The sorting model allows to calculate the marginal willingness-to-pay (MWTP) of each type of household that is included in the analysis. These figures give a clear overview of the impact of different neighborhood characteristics on the location choice of heterogeneous households with respect to the price of a standard house. With the coefficients from the first- and second-stage estimation, the implied marginal-willingness-to-pay (MWTP) values of various household groups for each location characteristic are calculated. When interpreting the effects, it should be kept in mind that the city of Rotterdam is only divided into 14 neighborhoods. There will also be differences within these

neighborhoods. However, the resulting values of the MWTP only allows comparison between neighborhoods, but not within neighborhoods (Van Duijn & Rouwendal, 2013). Column 1 of ***Table 7*** reports the average MWTP for households in Rotterdam. Colums 2 through 4 report the deviations from the average for age, college degree and income.

Table 7: MWTP price = -10

	Average	Age (+10)	College degree	Income (+0.3)
Density	-34,446.64	-862.63	7,146.36	2,763.13
Households with kids	-1440.96	-206.40	-1,178.08	197.45
Migrants	4,576.01	-31.74	235.62	-129,69
High income households	14,623.76	636.76	1,028.14	124.43

Note: (i) the results are presented in €.

Table 8: MWTP price = -15

	Average	Age (+10)	College degree	Income (+0.3)
Density	-34,998.36	-575.08	4,764.24	1,842.09
Households with kids	-1,726.55	-247.61	-785.39	131.63
Migrants	4,348.83	-21.16	157.08	-86.46
High income households	14,578.32	424,50	685.43	82.95

Note: (i) the results are presented in €.

Table 9: MWTP price = -5

	Average	Age (+10)	College degree	Income (+0.3)
Density	-32,752.54	-1,725.25	14,269.36	5,526.26
Households with kids	-584.17	-52.97	-2,366.16	394.90
Migrants	5,296.49	-63.48	471.23	-259.37
High income households	14,760.06	1,273.49	2,056.28	248.86

Note: (i) the results are presented in €.

Below, price = -10 is used as the base scenario, therefore these results are discussed in more detail. It is worth noting that the results for -10 and -15 exhibit considerable similarity, with closely aligned coefficients and consistent signs. While the results for -5 display slightly more disparity, the coefficients remain consistent in their direction.

The average MWTP for an additional percentage point of migrants in their neighborhood is €4,576.01. Deviations from the mean of each group are shown in columns 2 through 4 of ***Table 7***. Their interpretation can be clarified as follows. If a household has an income that is 30% higher than the average income, while the age of the head of the household is equal to the average and has no college degree, their MWTP for an additional percentage point of migrants in their neighborhood is €129.69 lower than the average household. However, if a household has an income that is 30% higher than the average income and has a college degree while the age of the head of the household is equal to the average, their MWTP for an additional percentage point of migrants in their neighborhood is €105.93 (=235.62-129.69) more than the average household.

In general, there are in Rotterdam many residents with a migrant background. *Figure 10* in Appendix B shows the distribution of migrants per neighborhood. The results show that the average household is willing to pay for a percentage more migrants. This probably has to do with the distribution of migrants across neighborhoods, for example, there are many migrants in the neighborhoods of Rotterdam Centrum, Noord, Kralingen-Crooswijk, Feijenoord, Delfshaven and Charlois. These are all neighborhoods close to the center of Rotterdam. Perhaps this indicates that households are willing to pay for a neighborhood in the center (Gaigne et al., 2017) instead for a neighborhood with more migrants, because these neighborhoods offer more amenities (Brueckner & Zenou, 1999). The share of migrants maybe also has to do with the large amount of social rental housing in these neighborhoods. The household characteristics age and income have a lower MWTP than the average household perhaps this indicates that higher income and older households move to the outskirts of the city, whereas households with a college degree are willing to pay more than the average household.

The interpretation of the MWTP figures of the other neighborhood characteristics is similar. The presence of more high income households is positively valued by all household groups. The average MWTP in for an additional percentage point of higher income households in their neighborhood is €14,623.76. Households with a college degree are willing to pay €1,028.14 more to have an additional percentage point of higher income household in their neighborhood compared to the average household. Also, households with the other household characteristics, when the age of the head of the household is 10 years above the average age and when the income of the household is 30% above the average income, are willing to pay more for an additional percentage point of higher income households in their neighborhood. Respectively, €636.76 and €124.43 more than the average household.

The results show that households appear to appreciate living close to high income households. This result confirms that of Bayer et al. (2007) who found self-segregation based on income and ethnicity while all households prefer to live close to high income households. Households with a college degree or an income 30% above the average are willing to pay more to live next high income households. This suggests it is more likely that low income households are pushed out of gentrifying neighborhoods, rather than leaving them because they dislike their changing demographic composition (Van Duijn & Rouwendal, 2018). The result also confirm that high income households are more willing to pay the higher cost of living in attractive neighborhoods (Rouwendal et al., 2018).

The average MWTP for density is negative, namely €34,446.64. However, households with a college degree and an income that is 30% higher than the average income are willing to pay respectively €7,146.36 and €2,763.13 more than the average household. This result shows that an average household certainly does not want to live in the densely populated neighborhoods. The densely populated neighborhoods are Delfshaven, Feijenoord and Noord. *Figure 11* in Appendix B shows the density per

neighborhood. It is striking that households with a college degree and households with 30% more income than average want to pay a considerable amount more. This may be because households with more income generally appreciate amenities more (Koster & Rouwendal, 2017).

The MWTP for an additional percentage of households with children in the neighborhood is negative, the average MWTP is -€1,440.96. The households with an age 10 years above the average and a college degree are even willing to pay less than the average household. The MWTP for households with an income that is 30% higher than the average is willing to pay €197.45 more than the average household. This probably also has to do with the fact that households prefer to live in the city center, where there are relatively fewer children than on the outskirts of the city. The neighborhoods further from the center, such as Hillegersberg-Schiebroek, do have larger and more expensive homes. This is in line with the literature that higher-income households will choose to expand their housing by moving into the neighborhoods adjacent to the original richer neighborhoods (Guerrieri et al., 2013). This explains the more positive effect for households with a higher income.

5. Conclusion

5.1. Summary

This thesis examines the sorting behavior of diverse households and explores their MWTP. Through these analyses, it becomes possible to identify patterns indicative of gentrification. In this thesis, gentrification refers to the inflow of young and often well-educated households to inner-city neighborhoods that used to be inhabited by older and low-income households (Rouwendal et al., 2018).

There are various reasons why, where, and how gentrification can occur. The first one is because households like to live next to households that are like them. They therefore segregate based upon their income (Bayer et al, 2007). High-income households like to live next to high-income neighbors. Where households settle also has to do with the quality of the neighborhood and the number of amenities. When the center has a strong amenity advantage over the suburbs, and this valuation of these amenities also increases with income, the rich are likely to live in the center (Gaigne et al., 2017). When the center's amenity advantage is weak or negative, the rich are likely to live in the suburbs (Brueckner & Zenou, 1999). So, when the city center offers attractive amenities, you can expect that this attracts high-income households in downtown areas. The increasing demand for housing in the city center is causing a rise in house prices. Especially because higher-income households are willing to pay the higher cost of living in attractive neighborhoods (Rouwendal et al., 2018). As top incomes rise, demand for high-quality inner-city neighborhoods, including amenities, increases (Gaigne et al., 2017). This leads to price increases throughout the inner city, including in lower-quality neighborhoods where the poor live. As demand exceeds supply, new residents move to adjacent neighborhoods, where poorer households used to live. Place-based policies, such as investing in amenities or deregulating social housing, can also exert their impact on the process of gentrification. Some literature suggests that place-based programs particularly benefit areas that are already engaged in gentrification (Brazil & Portier, 2020). These neighborhoods qualify based on their current low-income status and because they are more likely to improve. Place-based investments will speed up the gentrification process, failing to improve the overall well-being of initial residents. Rotterdam is trying to attract strong shoulders, high-educated, young families, to the city center. This group particularly wants to live in the older neighborhoods around downtown (Brueckner & Zenou, 1999; Gaigne et al., 2017; Koster & Rouwendal, 2017).

All in all, from the literatue is concluded that gentrification is most common next to initially affluent neighborhoods, in and around the downtown area and in old town neighborhoods. When examining this phenomenon specifically for Rotterdam, most gentrification is expected to occur in Overschie, Noord, Delfshaven, Rotterdam Centrum and Kralingen-Crooswijk.

As already stated in the literature gentrification is often an intended or unintended consequence of policies. The municipality of Rotterdam has also implemented several measures to upgrade the city's

livability. Since 2014, the municipality of Rotterdam has been pursuing a policy to make several neighborhoods in and around Rotterdam city center more attractive for high educated families with children. An assumption is that the target families prefer settling in older neighborhoods in and around the inner center. The settlement of promising families in these neighborhoods in already underway, and the program seeks to accelerate this further, which happens often with this kind of policies (Brazil & Portier, 2020). In its efforts to enhance the overall quality of life in the city, Rotterdam aims to prioritize improvements not only in areas with existing strengths but also in areas facing challenges or weaknesses. There are several programs used for this purpose. The best-known programs are the WBMGP, the KW program and NPRZ. A striking result is that due to prominent advertising of targeted deprived neighborhoods, a stigma may have been created. Research provides a causal evidence of a sizeable negative price effect in the housing market incurred by place-based policies that publicly announce which neighborhoods are deprived (Koster & van Ommeren, 2022).

The significant disparity in house price increases across different neighborhoods suggests a recent surge in popularity for certain areas. The figure illustrates that Delfshaven, Noord, and Rotterdam Centrum have experienced the most substantial increases in house prices since 2012. This is in line with the literature that states that as top incomes rise, demand for high-end inner-city neighborhoods, including amenities, increases (Gaigne et al., 2017). This leads to an increase in prices throughout the inner city.

Throughout Rotterdam, incomes have risen in recent years. However, as with the neighborhoods, it is extra interesting in which neighborhoods income has risen the most. Especially in Rotterdam Centrum, where income has always been high, a large increase in income can be seen. Followed by the neighborhoods Noord and Kralingen-Crooswijk.

In the analysis is found that households like to live next to high income households. This applies strongly to all households, but in particular households with a college degree are willing to pay for this. This observation aligns with the popularity of the neighborhoods Noord and Kralingen-Crooswijk, as they are situated between Hillegersberg-Schiebroek and Rotterdam Centrum. Both Hillegersberg-Schiebroek and Rotterdam Centrum are characterized by a comparatively higher average income in comparison to the other neighborhoods. Households are also willing to pay for a percentage more immigrants in the neighborhood. This seems somewhat unusual at first glance, but the neighborhoods with the most migrants are close to downtown.

The willingness to pay for population density is negative. The most densely populated neighborhoods are Delfshaven, Feijenoord and Noord. The ‘Kracht wijken’ policy to get more strong shoulders to the inner city only started in 2014, this may explain why households are not yet willing to pay for population density. However, it is already shown that households with a college degree and households with 30%

more income are willing to pay more than the average household. Indeed, the hedonic pricing model does show that house prices in the neighborhoods Delfshaven and Noord rose sharply from 2015. Besides that, households are also not willing to pay for neighborhoods with more children. On the contrary, this may be an indication that households want to live near the center, where relatively fewer households with children live.

Thus, the results are not entirely uniform. This can predominantly be attributed to the fact that the sorting model is computed for the year 2015, whereas the hedonic price model encompasses the time period from 2012 to 2021. In any case, what comes back clearly is that households like to live next to originally wealthy neighborhoods and in the city center. In addition, it is visible that some neighborhoods have become much more popular, based on house price, and that in some neighborhoods the average income has increased much more than in the other neighborhoods. These are all indications of gentrification. These indications are found particularly in the neighborhoods of Rotterdam Centrum, Delfshaven, Kralingen-Crooswijk and Noord. Ensuring the preservation of space and opportunities for vulnerable and initial residents is of extra importance in these neighborhoods.

5.2. Discussion and further research

As often pointed out, gentrification is a difficult phenomenon to measure. But important, to strike a balance between renewing and maintaining a social mix. Therefore, it is good to do further research. Given the time and data sources available, this thesis has several limitations. These limitations may be good starting points for further research. First, this thesis only has 14 ASC, the neighborhoods of Rotterdam. Therefore, the results are also at the neighborhood level, while even within neighborhoods large differences can occur. Next research could emphasize even more the differences in neighborhoods, so at the districts level. In addition, policies are usually implemented per district. To measure the specific effect of policies, it also would be good to use the district level. Secondly, there are a limited number of variables tested. However, the phenomenon of gentrification cannot be captured in a few variables. It would therefore be good to test more characteristics in further research. Thirdly, no self-calculated instrument is used in this thesis to correct for endogeneity. In further research, it would be good to calculate this yourself instead of making assumptions. Lastly, as mentioned before several measures have been implemented that can have an impact to the process of gentrification. Further research can look at panel data to see what effects of these policies are over a longer period of time per neighborhood. Comprehensive research with more data can better capture the sorting pattern.

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Appendix

A: Overview neighborhoods and districts of the municipality of Rotterdam (GM0599)

Neighborhood code	Neighborhood	Districts
WK059901	Rotterdam Centrum	Stadsdriehoek, Oude Westen, Cool, CS kwartier, Nieuwe Werk, Dijkzigt
WK059903	Delfshaven	Delfshaven, Bospolder, Tussendijk, Spangen, Nieuwe Westen, Middelland, Oud Mathenesse, Witte Dorp, Schiemond
WK059904	Overschie	Kleinpolder, Noord Kethel, Schieveen, Zestienhoven, Overschie, Landzicht
WK059905	Noord	Agniesebuurt, Provenierswijk, Bergpolder, Blijdorp, Liskwartier, Oude Noorden, Blijdorpsepolder
WK059906	Hillegersberg-Schiebroek	Schiebroek, Hillegersberg Zuid, Hillegersberg Noord, Terbregge, Molenlaankwartier
WK059908	Kralingen-Crooswijk	Rubroek, Nieuw Crooswijk, Oud Crooswijk, Kralingen West, Kralingen Oost, Kralingse Bos, De Esch, Struisenburg
WK059910	Feijenoord	Kop van Zuid, Kop van Zuid – Entrepot, Vreewijk, Bloemhof, Hillesluis, Katendrecht, Afrikaanderwijk, Feijenoord, Noordereiland,
WK059912	IJsselmonde	Oud Ijsselmonde, Lombardijen, Groot IJsselmonde, Beverwaard
WK059913	Pernis	Pernis
WK059914	Prins Alexander	's-Gravenland, Kralingseveer, Prinsenland, Het Lage Land, Ommoord, Zevenkamp, Oosterflank, Nesselande
WK059915	Charlois	Charlois Zuidrand, Tarwewijk, Carnisse, Zuidwijk, Oud Charlois, Wielewaal, Zuidplein, Pendrecht, Zuiderpark, Heijplaat,
WK059916	Hoogvliet	Hoogvliet Noord, Hoogvliet Zuid
WK059917	Hoek van Holland	Strand en Duin, Dorp, Rijnpoort
WK059927	Rozenburg	Rozenburg, Noordzeeweg, Buitengebied Ootmarsum-West, Maasdam Buitengebied

B: Extra figures KWB

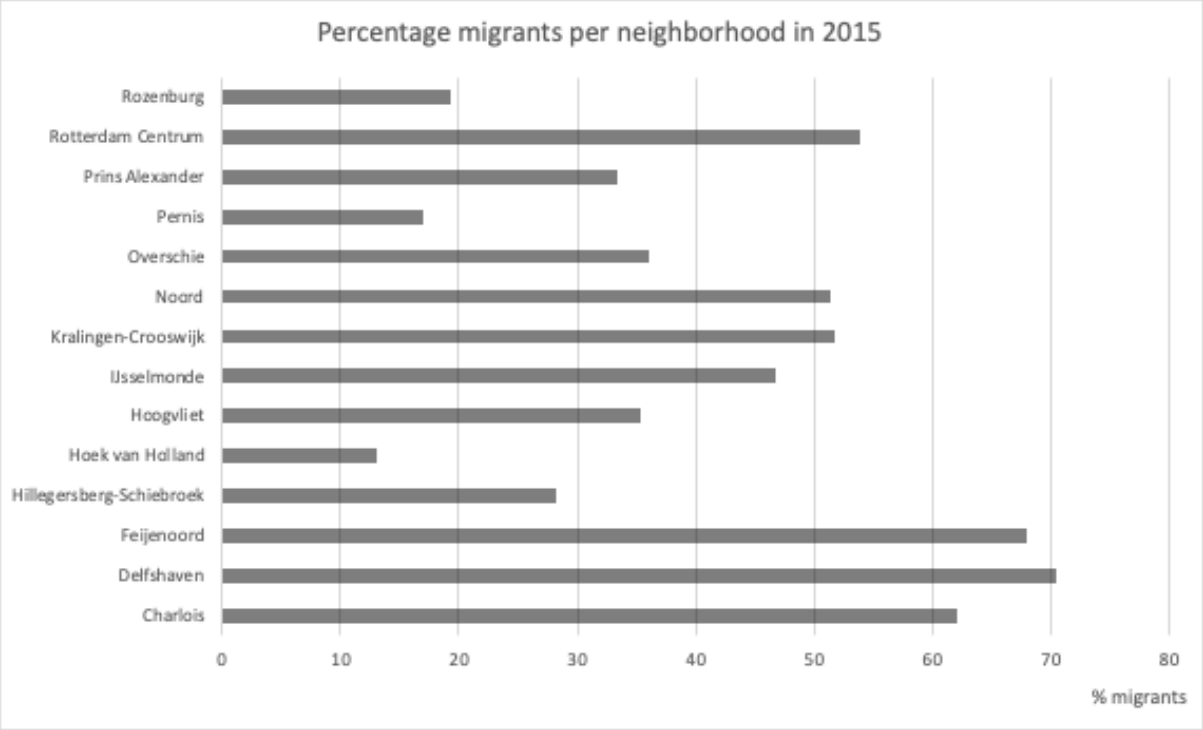

Figure 10: Percentage migrants per neighborhood. Source: KWB customized.

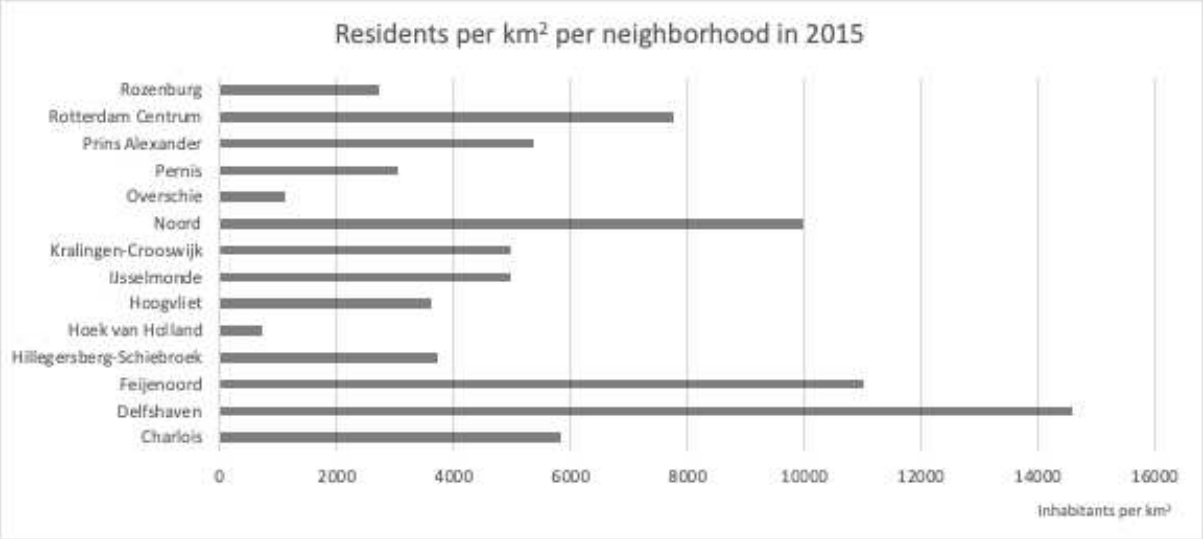

Figure 11: Residents per km^2 per neighborhood. Source: KWB customized.