RUHR

ECONOMIC PAPERS

Said Benjamin Bonakdar

Michael Roos

Dissimilarity Effects on House Prices: What Is the Value of Similar Neighbours?

RUB

#894

Imprint

Ruhr Economic Papers

Published by

RWI – Leibniz-Institut für Wirtschaftsforschung
Hohenzollernstr. 1-3, 45128 Essen, Germany

Ruhr-Universität Bochum (RUB), Department of Economics
Universitätsstr. 150, 44801 Bochum, Germany

Technische Universität Dortmund, Department of Economic and Social Sciences
Vogelpothsweg 87, 44227 Dortmund, Germany

Universität Duisburg-Essen, Department of Economics
Universitätsstr. 12, 45117 Essen, Germany

Editors

Editorial Office

Ruhr Economic Papers #894

Responsible Editor: Thomas Bauer

ISSN 1864-4872 (online) – ISBN 978-3-96973-034-8

Ruhr Economic Papers #894

Said Benjamin Bonakdar and Michael Roos

Dissimilarity Effects on House Prices: What Is the Value of Similar Neighbours?

Bibliografische Informationen der Deutschen Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at **http://dnb.dnb.de**

RWI is funded by the Federal Government and the federal state of North Rhine-Westphalia.

http://dx.doi.org/10.4419/96973034
ISSN 1864-4872 (online)
ISBN 978-3-96973-034-8

Said Benjamin Bonakdar and Michael Roos[1]

Dissimilarity Effects on House Prices: What Is the Value of Similar Neighbours?

Abstract

Residential choice does not only depend on properties of the dwelling, neighborhood amenities and affordability, but is also affected by the population composition within a neighbourhood. All these attributes are capitalised in the house price. Empirically, it is not easy to disentangle the effect of the neighbourhood on house prices from the effects of the dwelling attributes. We implement an agent-based model of an urban housing market that allows us to analyse the interaction between residential choice, population composition in a neighbourhood and house prices. Agents differ in terms of education, income and group affiliation (majority vs. minority). The results show that the "wrong" neighbourhood can lead to an average house price depreciation of up to 13,500 monetary units or 7.1 percent. Whereas rich agents can afford to move to preferred places, roughly 13.01% of poor minorities and 8.02% of poor majority agents are locked in their current neighbourhood. By introducing a policy that provides agents more access to credit, we find that all population groups denote higher satisfaction levels. Poor agents show the largest improvements. The general satisfaction level across all population groups increases. However, the extra credit accessibility also drives up house prices and leads to higher wealth inequality within the city. If agents have a preference for status rather than for similarity, the effect of the overall inequality is smaller, since agents become more satisfied living in areas with less similar agents.

JEL-Code: C63, R21, R23, R32

Keywords: Agent-based modelling; residential choice; housing demand; neighbourhood characteristics; house prices

January 2021

1 Both RUB. – All correspondence to: Said Benjamin Bonakdar, e-mail: benjamin.bonakdar@rub.de

1 Introduction

Households seem to have a preference for being among neighbours similar to them. Such a preference was already postulated by Schelling (1971, 1978) and more recently shown empirically (e.g. Clark 1992, Luttmer 2005). Of course, the composition of the population in the neighbourhood is not the only factor that determines residential choice. Where households buy a home also depends on the properties of the house itself, amenities and disamenities in the neighbourhood and last but not least on affordability (Sirmans et.al 2006, Baker et.al 2015). House prices are not independent of the other factors. In fact, in a competitive market equilibrium, house prices capitalise the attributes of the house and the neighbourhood (see Rosen 1974). A large literature on hedonic pricing in the housing market estimates how the value of homes depends on these attributes (see Sirmans et.al 2005). Empirically, it is not easy to disentangle the effect of the neighbourhood on house prices from the effects of the dwellings attributes. It is particularly difficult to control for endogeneity effects that arise because the composition of the population in the neighbourhood is endogenous and depends on amenities and prices. Ioannides (2011) provides an overview how the literature attempts to identify and estimate these social interaction effects.

In this paper, we present an agent-based model of an urban housing market that allows us to analyse the interaction between residential choice, the composition of the population in a neighbourhood and house prices. In particular, we ask the following research questions. 1) How large is the effect of a preference for similarity on houses prices? 2) What is the effect of population diversity and income inequality on house prices? 3) How do population sorting and satisfaction levels affect the house prices of different groups of households with their homes with different kinds of preferences? 4) What are the effects of policy measures aimed at making housing affordable to less well-off households?

Understanding how house prices depend on preferences for similar neighbours is important for hedonic estimations of house prices and their interpretations. The correct specification of empirical models that deal with the above-mentioned endogeneity problem depends on the assumptions about preferences and behaviour of the agents, which are difficult to observe. With our model, we can analyse how sensitively house prices respond to variations in unobservable preference parameters. We consider several dimensions of similarity, namely income, education and ethnicity, which are often treated either separately or implicitly in empirical studies (e.g. Green and Lee 2016, Leung & Tsang 2012). We also distinguish a *preference for similarity* from a *preference for status*. Preference for similarity means that households dislike living among different neighbours, no matter whether they are privileged or underprivileged relative to their neighbours. Preference for status, in contrast, means that households dislike being underprivileged in terms of income or education, but gain satisfaction from having higher income or better education that their neighbours. The resulting moving decisions and house price dynamics might be quite different in the two cases. Relatively rich or educated households have an incentive to leave deprived neighbourhoods if they have a preference for similarity, but with a preference for status they have an incentive to stay there. Finally, we analyse how the *evaluation sensitivity* of the satisfaction with dwelling conditions affects house prices. Households' evaluation of their own house and of houses available in the market depends on how satisfied they are with attributes of those homes. How strongly dissatisfaction translates into lower evaluations might be an important driver of house price dynamics.

The effect of diversity and inequality on house prices is of particular relevance for policy makers. In many countries, the ethnic and cultural diversity of the population increases due to international migration (see e.g. Bove & Elia 2017, p. 227). At the same time, globalisation and technological change have increased and might further increase income inequality (see e.g. Jaumotte et.al 2013). If households prefer similar neighbours, increased ethnic diversity and income inequality might exacerbate house price differentials leading to even stronger disparity in material living conditions. A related topic are policies to change the social mix of urban neighbourhoods (see Graham et al. 2009). According to Galster and Friedrichs (2015, p. 175), "`Social Mix´ is currently one of the `hottest´ (to say nothing of controversial) topics in urban policy-making and scholarly circles across the First World". Proponents of socially diverse neighbourhoods argue that disadvantaged households can benefit from living among richer and more educated neighbours. Furthermore, socially mixed neighbourhoods could facilitate the social integration of minority groups and might foster creativity and productivity (Florida 2002). However, planning attempts to enhance the social mix might backfire, if households prefer to live in rather homogeneous neighbourhoods and discount the value of their homes if they are forced to live among dissimilar neighbours.

While house price differential are surely important from a policy perspective, the recent literature of social well-being argues that well-being is a multidimensional concept (see Linton et.al 2016). Well-being does not only have a material dimension, but also an immaterial one, which is in the centre of the large literature on subjective well-being or happiness (see Diener et.al 2018). We hence also analyse whether the satisfaction with dwelling conditions differs systematically among population groups in our model. If poor households are locked in a neighbourhood because they cannot afford to move to a preferred location, their life satisfaction might be depressed not only due to their deprived socio-economic conditions, but also due to dissatisfaction with their neighbours.

In order to avoid such a lock-in, urban planners pursue policies aimed at the affordability of housing. Many OECD countries use a variety of policy instruments such as grants and financial assistance for home-buyers to make good-quality housing affordable to poor households (see Del Pero et al. 2016). How affordability policies affect house prices and satisfaction levels is not clear a priori. It might lead to a more efficient sorting that raises social welfare, because households have more choice. On the other hand, it might also happen that grants and financial assistance only drive up house prices without any major effect on where households reside. Our model allows us to investigate how these policy instruments affect both house prices and satisfaction levels.

Agent-based models do not impose equilibrium conditions on market processes and make it possible to analyse behaviour and price dynamics out of equilibrium. This is an advantage of agent-based models over analytical models, because existence, uniqueness and stability of a general equilibrium in the housing market can only be guaranteed under specific and quite restrictive assumptions (Li 2014). Furthermore, even if there is a long-run general equilibrium, we do not know how long it takes to attain it from an out-of-equilibrium state, e.g. after some external shock or policy intervention. In fact, it might be the case that housing markets are most of the time far away from any equilibrium, because the transaction costs of moving might be high and adjustments by moving might be slow.

In this model, the main social interaction effect is a pure preference for similarity or preference for status. We do not model spillover effects or indirect social effects, such as having better labour market chances if one resides in an educated or rich neighbourhood (see e.g. Wilson 2012). However, we can incorporate such effects by assuming that households prefer living among neighbours with a higher socio-economic status. Our model is meant to be a theoretical investigation of mechanisms that play a role in any housing market. Therefore, the model is not calibrated to fit any particular city or validated against empirical data. The application to housing markets in specific cities could be done as a next step after the mechanisms are well understood.

In Section 2, we describe the model in detail. Section 3 explains how the model is parameterised and implemented in computer software. Our main results are presented and discussed in Section 4. Finally, we conclude in Section 5.

2 Model

We first give a short overview of the model in order to highlight its logic. Afterwards, we describe all assumptions in detail and motivate them.

2.1 Model overview and process schedule

The only agents in the model are N households that buy and sell houses to live in. There is only owner-occupied housing. Households decide to sell their current house and to move to a new one if they are dissatisfied with their current housing conditions. Housing transactions are managed by a virtual real estate agent, which does not make any autonomous decisions, but only serves as a market maker. For simplicity, we assume that the supply and the quality of houses are fixed. The city has a constant stock of $H > N$ houses. Houses differ in quality, e.g. in terms of size, number of rooms, age etc. We do not model these characteristics explicitly, but summarise them in a quality indicator variable $Q_h \in [0,1[$ for each house h. There can be several houses of the same quality and a larger index value indicates higher quality. Space is modelled as a two-dimensional grid of 3,249 patches. We assume a classic Thünen-type monocentric city, in which amenities are concentrated in the centre. Amenities are exogenous and do not change over time. As with the characteristics of the houses, we do not model amenities like shopping and leisure facilities explicitly. Instead, each house has an amenities index $Q_a \in [0,1]$ that captures the quality of the neighbourhood with regard to the availability of amenities nearby. In line with the Thünen model, we assume that $Q_a = 1$ in the city centre and declines for every unit further away linearly by ~0.0256 vertically and horizontally and by ~0.0357 (=0.0256*√2) diagonally under consideration of Moore neighbourhoods. We assume discrete time steps equivalent to one month.

The sequence of events and actions is summarised in Table 1. A detailed description of the assumptions and the procedures is given in the following sections.

Table 1: Schedule of events and actions

Step	**Event or action**
1	All households receive a stochastic income.
2	All households determine how dissimilar they are from their current neighbours. All households determine their satisfaction with the current house and neighbourhood.
3	All households decide to stay in the current house or to move.
4	Potential movers determine their willingness-to-accept for the current house.
5	Potential movers determine the offer price for the current house.
6	Potential movers determine their willingness-to-pay for a new house.
7	The estate agents collects all offer prices of available houses. Available houses are auctioned off in 3 rounds to potential movers in a second-price auction. Actual prices are determined.
8	Households that bought a house sell their current house to the estate agent and move. Households that were not successful in the auctions stay in their current house.

2.2 Income, education and ethnicity of households

Households have random incomes. Initially incomes are exponentially distributed with a mean income of 40,000 and a minimum income of 10,000, which roughly reflects the income distribution in the U.S.

in 2015 (OECD, 2017). In every period, each household's income is updated by the following stochastic process:

$$y_{i,t} = \begin{cases} y_{i,t-1} & with\ prob\ 0.9 \\ \epsilon_{i,t} y_{i,t-1} & with\ prob\ 0.1 \end{cases} \quad (1)$$

where $\epsilon_{i,t}\ i.i.d \sim [0.8, 1.2]$.

Households differ in their level of education, by which we mean formal education acquired at school or at colleges and universities. We measure education by years of schooling. Every household is endowed with a level of schooling drawn from a normal distribution with mean 13.5 and a standard deviation of 1.5. Draws below 11 and above 21 are set to these thresholds. A household's education does not vary in the course of the simulation. Furthermore, we do not model any correlation between education and income. We want to analyse the effects of both variables separately in order to distinguish between the pure income effect and the effect from potential creative neighbourhoods, as introduced in Malik et.al (2015). Each household belongs to one of two ethnic groups, which are indicated by "majority" and "minority".

2.3 Satisfaction of households

Households' satisfaction with living conditions is a crucial variable in our model. On the one hand, we assume that dissatisfaction is a main driver of moving decisions, which is supported by empirical evidence. Coulter et al. (2011) show with British data that dwelling dissatisfaction and disliking the neighbourhood are positively related with moving desire, moving expectation and the likelihood of moving. On the other hand, satisfaction is a component of well-being, which can be measured and used for welfare analyses. Among many others, Kahneman and Krueger (2006) and Stiglitz et al. (2009) argue that the subjective dimension of well-being, as measured by questions about people's satisfaction with their lives and living conditions, is important and should inform public policy.

We assume that households i have a satisfaction level $S_{i,h,,n,t}$ that refers to the house h in the neighbourhood n that they own and occupy at time t. Marans (1976) suggests three dimensions of residential satisfaction: the dwelling and its attributes (i.e. the number and size of rooms, the age of the building, or the availability of a garden or a balcony), the area, in which the dwelling is located and the neighbourhood. The satisfaction with the spatial community refers to the attractiveness of the area due to the availability of local amenities such as school or shops and the satisfaction of the neighbourhood depends on how similar the households is to its neighbours in terms of socio-economic characteristics. We follow the study of Marans (1976) and define satisfaction as follows: (1) satisfaction with the house itself, $SH_{i,h,t}$, (2) satisfaction with the area, where the house is located, $SA_{i,n,t}$, (3) satisfaction with the current neighbours, $SN_{i,n,t}$. Total satisfaction is the product of the three components, because they reinforce each other:

$$S_{i,h,t} = SH_{i,h,t} \times SA_{i,n,t} \times SN_{i,n,t} \tag{2}$$

Satisfaction with the house itself depends on the quality of the house:

$$SH_{i,h,t} = (Q_h)^{\delta_1} \tag{3}$$

We assume that $0 < \delta_1 < 1$ in order to capture a strong responsiveness of satisfaction at low levels of quality. Since $Q_h \in [0,1]$ satisfaction will range from 0 to 1, too. Satisfaction with the attractiveness of the area is modelled analogously, again with $0 < \delta_2 < 1$:

$$SA_{i,n,t} = (Q_a)^{\delta_2} \tag{4}$$

A crucial assumption in this paper is that households in general prefer to live among neighbours who are similar to them. If we define $\Delta_{i,n,t} \in [0,1]$ as the dissimilarity of the household from its neighbours, $(1 - \Delta_{i,n,t})$ is a measure of the degree of similarity. A household experiences the more satisfaction, the higher the degree of similarity is:

$$SN_{i,n,t} = (1 - \Delta_{i,n,t})^{\delta_3} \quad with\ 0 < \delta_3 < 1 \tag{5}$$

We focus on three dimensions of dissimilarity: income, education and ethnicity. Luttmer (2005) presents evidence from the U.S. that people report lower happiness if their income is lower than the average income of their neighbours. He calls this effect a psychological externality, suggesting that people's utility functions depend on relative consumption in addition to absolute consumption. Clark and Coulter (2015) show with data from the UK that people who feel that they belong to their neighbourhood or are similar to their neighbours report a lower desire to move. Bourdieu (1984) argues that individuals do not only differ in the economic dimension due to their economic capital, but also in terms of their cultural capital, which is mainly determined by their education. Education is hence another important characteristic of social class or milieu. Following Schelling (1971) it is common in the literature to assume that people have a (slight) preference for neighbours of the same race or ethnicity. Clark (1992) presents evidence for the U.S. is indeed the case and that preferences for the own race or ethnicity are rather strong. Hipp (2009) shows that larger ethnic heterogeneity in the neighbourhood reduces satisfaction levels and Coulter et al. (2011) show that British households have a stronger desire to move if they are a member of an ethnic minority in their neighbourhood.

We hence model the dissimilarity between a household i and the households in its neighbourhood n as a weighted sum of the dissimilarity in these three dimensions:

$$\Delta_{i,n,t} = \gamma_1 \Delta^{Y}_{i.n.t} + \gamma_2 \Delta^{E}_{i.n.t} + \gamma_3 \mathrm{q}_{i.n.t} \, , \tag{6}$$

where $\gamma_k \geq 0$ and $\gamma_1 + \gamma_2 + \gamma_3 = 1$. Income dissimilarity $\Delta^{Y}_{i,n,t}$ and educational dissimilarity $\Delta^{E}_{i,n,t}$ depend on the difference of the household's own income or education and the average income $\bar{Y}_{n-i,t}$ or education $\bar{E}_{n-i,t}$ of the neighbours:

$$\Delta^{Y}_{i,n,t} = \begin{cases} \varrho \frac{Y_{i,t} - \bar{Y}_{n-i,t}}{Max(Y_{n,t})} & if\ Y_{i,t} \geq \bar{Y}_{n-i,t} \\ \frac{\bar{Y}_{n-i,t} - Y_{i,t}}{Max(Y_{n,t})} & if\ Y_{i,t} < \bar{Y}_{n-i,t} \end{cases} \tag{7}$$

$$\Delta^{E}_{i,n,t} = \begin{cases} \varrho \frac{E_{i,t} - \bar{E}_{n-i,t}}{Max(E_{n,t})} & if\ E_{i,t} \geq \bar{E}_{n-i,t} \\ \frac{\bar{E}_{n-i,t} - E_{i,t}}{Max(E_{n,t})} & if\ E_{i,t} < \bar{E}_{n-i,t} \end{cases} \tag{8}$$

The relevant neighbourhood consists of the eight direct neighbours in a Moore-neighbourhood of the household. We allow for a potential asymmetry of the dissimilarity effect, $0 < \varrho \leq 1$. Fehr and Schmidt (1999) developed a theory of inequity aversion according to which individuals in general dislike unequal economic outcomes, but prefer situations in which the inequality favours themselves to situations in which others are better off. In order to capture this asymmetry, ϱ can be smaller than one. If $\varrho = 1$, households do not distinguish whether the dissimilarity favours them or their neighbours. We could also incorporate a preference for status into the model by allowing for $\varrho < 0$. In this case, $(1 - \Delta_{i,n,t}) > 1$ is possible, implying that being richer or more educated than the neighbours would increase a household's satisfaction.

Ethnic dissimilarity $\mathrm{q}_{i.n.t}$ is defined as the share of neighbours whose ethnicity is different from the one of the household i.

2.4 Moving intention

As mentioned before, there is evidence in Coulter et al. (2011) that households which are dissatisfied with their home or their neighbours have an intention to move and a higher likelihood of moving than households with high satisfaction levels. We model the moving intention, $MI_{i,n,t}$, as a function of total satisfaction, $S_{i,h,t}$, and interpret it as the probability that the household decides to move:

$$MI_{i,n,t} = \begin{cases} 0 & if\ S_{i,h,t} \geq \overline{S} \\ \frac{\overline{S}}{\overline{S}-\underline{S}} - \frac{1}{\overline{S}-\underline{S}} S_{i,h,n,t} & if\ \underline{S} \leq S_{i,h,n,t} < \overline{S} \\ 1 & if\ S_{i,h,t} < \underline{S} \end{cases} \quad (9)$$

If the satisfaction level is above an upper threshold $\overline{S}$, the probability that the household will move is zero; there is no moving intention. Likewise, the household definitely wants to move, i.e. $MI_{i,n,t} = 1$, if the satisfaction falls below a lower threshold $\underline{S}$. Between the upper and the lower threshold, the household is uncertain whether to move or to stay. The likelihood of moving is a linear function of the satisfaction level such that the moving intension is 1 at the lower threshold and 0 at the upper one.
If the satisfaction level is in between the two thresholds, we draw a random number from a uniform distribution [0,1]. The household decides to move, if this random number is smaller than $\frac{\overline{S}}{\overline{S}-\underline{S}} - \frac{1}{\overline{S}-\underline{S}} S_{i,h,n,t}$. Note that the decision to move does not mean that the households actually will move. Whether a household with a moving intention moves or not, depends on the availability of affordable houses in the market.

2.5 Pricing and house sales

Households with an intention to move first determines the subjective value of the current house. Households' willingness to accept for their current home depends on the price for which they bought the house, P_{i,h,t_0}, and their current satisfaction with the home and its attributes

$$WTA_{i,h,t} = P_{i,h,t_0}(S_{i,h,n,t})^{\sigma}\ ,\ \ \sigma > 0 \quad (10)$$

We assume that the willingness to accept is anchored on the original purchasing price, because there is evidence that even in the housing market, sellers exhibit loss aversion (see Genesove and Mayer 2001, Einiö et al. 2008). In our model, an agent is more likely to sell the house again, if the satisfaction level is lower than it was when she bought it. We call σ the evaluation sensitivity of the satisfaction with dwelling conditions. Since the purchasing price is discounted with the satisfaction level, the seller would experience a nominal loss. In order to avoid losses, sellers offer the house with a mark-up over their true willingness to accept. Hence the offer price, for which they would like to sell the house, is

$$\tilde{P}_{i,h,t} = (1 + \mu) WTA_{i,h,t} \quad (11)$$

The willingness to pay for a new home determines the maximum price an agent would pay for a new house and it is given by

$$WTP_{i,h,t} = B_{i,t}(S_{i,h,n,t})^{\sigma},\ \sigma > 0 \quad (12)$$

where $B_{i,t}$ is agent i's available budget for a new home at time t. For the agent's ideal home, $S_{i,h,n,t} = 1$ holds so that the maximum amount of money she would be willing to pay is equal to the available budget. This WTP function implies a demand function for satisfaction of the form

$$S_{i,h,n,t}^{1-\sigma} = \sigma \frac{B_{i,t}}{p_{h,n,t}}$$

where $p_{h,n,t}$ is the price that a unit of satisfaction would cost. The budget is determined by the minimum proceeds the agent expects from selling the old house (the willingness to accept) and access to credit or savings ψ that we assume to depend on the agent's income:

$$B_{i,t} = WTA_{i,h,t} + \psi Y_{i,t}\,,\ \ \psi > 0 \tag{13}$$

When an agent wants to move, she offers the currently owned house to a (virtual) estate agent for the offer price $\tilde{P}_{i,h,t}$. The real estate agent collects all offers. In the next step, each agent that wants to move considers all available houses with an offer price up to her personal willingness to pay for this house and expresses interest for the house for which she has the highest WTP. The estate agent matches all potential buyers with the available houses as follows. Each house is sold to the bidder with the highest WTP. If only one bidder has a WTP that is above the offer price, the house is sold at the offer price. If there are several buyers with a WTP higher than the offer price, the price is the second-highest price paid by the bidder with the highest WTP. Otherwise, the house is not sold in this period. To summarize, the actual selling price $P_{i,h,t}$ agent i pays for a new house is

$$P_{i,h,t} = \begin{cases} \tilde{P}_{j,h,t} & if\ WTP_{i,h,t} > \tilde{P}_{j,h,t}\ \ and\ WTP_{k,h,t} \leq \tilde{P}_{j,h,t}\ \forall\ k \neq i \\ WTP_{k,h,t} & if\ WTP_{i,h,t} > WTP_{k,h,t} > \tilde{P}_{j,h,t}\ and\ WTP_{k,h,t} > WTP_{l,h,t} \quad\quad \forall\ l \neq i,k \\ WTP_{i,h,t} & if\ WTA_{j,h,t} <\ WTP_{i,h,t} \leq \tilde{P}_{j,h,t}\ and\ WTP_{i,h,t} > WTP_{k,h,t}\ \forall\ k \neq i \end{cases} \tag{14}$$

3 Implementation and simulation method

The model is not meant to be a realistic representation of a housing market in a particular city. Instead, it is a theoretical model that describes important mechanisms operative in typical housing markets. Also it can be used to analyse house price dynamics depending on housing and area qualities, as well as neighbourhood sorting[1]. With respect to the research questions, we conduct several analyses, for which we set the same 20 different seeds at the beginning of each simulation and let the model run for 200 periods, respectively. Also, we set another seed only for the housing quality indicator for each house to ensure that houses keep their characteristics among simulation runs.

[1] The simulation model is programmed in *NetLogo 6.0.2.*

The analyses are conducted as follows:

1) The parameters δ_1, δ_2 and δ_3 weigh the effects of housing quality, area quality and neighbourhood similarity on an individual's satisfaction. In order to disentangle the effect of similarity on house prices, we design two scenarios:
    a. A model simulation with $\delta_3 = 0$, which implies no neighbourhood effects. The parameters δ_1 and δ_2 get varied simultaneously with $\delta_1, \delta_2 \in [0.1, 0.2, 0.3, 0.4]$, where $\delta_1 = \delta_2 = 0.4$ is denoted as Treatment 1 and $\delta_1 = \delta_2 = 0.1$ is denoted as Treatment 4. Here, the model runs 80 times (4 parameter settings x 20 fixed seeds).
    b. A model simulation as in 1a., but with varying δ_3, where $\delta_3 \in [0.2, 0.4, 0.6, 0.8]$. Within the treatments the parameters sum up to 1 ($\sum \delta_i = 1$). The model runs again 80 times.

    Based on 1a. and 1b., we extract micro-data of the selling prices of each house and create the housing discount as difference of the baseline prices and the treatment prices of the same houses. Also, we represent the average house prices graphically and show the house price differences between the baseline case and the treatment in a table. In order to check upon significant changes, we conduct t-tests between the baseline cases and the treatments.

2) We use one of the treatments from analysis 1 and varied the share of minorities G_i within a city and the minimum income $\min(Y_i)$ of the initial distribution. We tested various population shares with $G_i \in [0.05, 0.1, \ldots, 0.5]$ and afterwards the minimum income with $\min(Y_i) \in [0, 5000, 10000, 20000]$ for each seed. We extract the selling prices of all houses and present the results graphically. For the population shares, the model runs 200 times, thus 20 times for each parameter setting and for the varying minimum income 80 times, here 20 times for each setting.

3) We use the treatment used in analysis 2 and fixed values for the population share and the minimum income. We split the population into six groups: low-income agents, average-income agents and high-income agents, each within the minority and the majority population. We extract micro-data to run an OLS regression to test the effect of the different satisfaction levels (housing satisfaction, area satisfaction and neighbourhood satisfaction) on the buying-prices among population groups. We also distinguish between a preference for similarity and a preference for status. The model runs 20 times, once for each seed.

4) In this analysis, we consider explicit policy measures, which allows for higher access to credit ψ, first for low-income agents and middle-income agents by setting $\psi = 3$ and $\psi = 2.5$

respectively. Alternatively, we give all agents better access to credit ($\psi = 3\ for\ all$). We extract micro-data for all settings and create the relative deviation from the baseline case, where all agents have $\psi = 2$. We then visualize the policies barplots. This analysis is done for preferences for similarity and preferences for status. The model runs 120 times, 20 times for each parameter setting.

4 Analysis

We show the results of the simulation runs to answer the respective research questions. Section 4.1 focuses on the effect size of neighbourhood similarity on house prices. In 4.2 we check upon income and population diversity and analyse the effects of various satisfaction levels of different population groups on buying prices in 4.3. Section 4.4 contains specific policy analyses by providing different population groups with more credit access.

4.1 The effect size of similarity on house prices

Figure 1 visualizes the importance of neighbourhood satisfaction, cartographically by showing exemplary similarity cluster at $t = 0$ and at $t = 200$. Green areas represent agents with a high degree of neighbourhood similarity, yellow areas show an intermediate degree of similarity and red areas represent agents, which are highly dissimilar to their neighbours. The simulation shows that neighbourhood sorting leads to a strong improvement of an agent's similarity and neighbourhood satisfaction. According to our research questions, we expect changes in house prices, too, when we consider neighbourhood satisfaction as further impact.

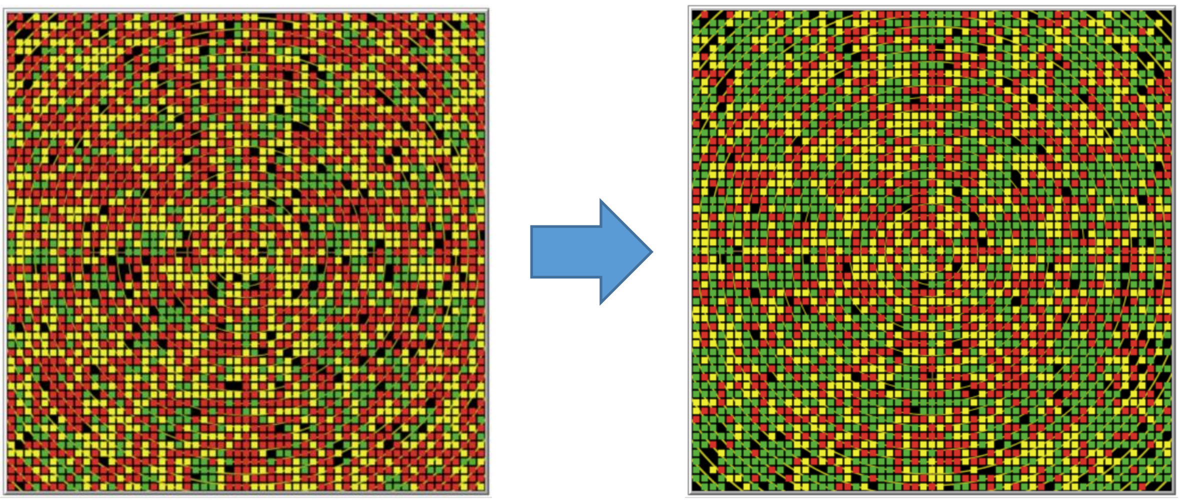

Figure 1: Similarity evolvement over time, left: t=0, right: t=200

The boxplots in Figure 2 represent the average selling prices over all houses as means over the different seeds within each time step. Decreasing the value of δ_1 and δ_2 from 0.4 to 0.1 in the baseline cases (Ba1-4: only housing quality and distance to city centre) generates an interverted u-shaped effect on house prices. The highest average house prices are found in Ba2 and Ba3 with $\delta_1 = \delta_2 = 0.3$ and $\delta_1 = \delta_2 = 0.2$ respectively. Adding the similarity factor lowers average house prices in Tr1 and Tr4, whereas there is practically no effect in Tr2 and a small effect in Tr3.

Figure 2 shows that the interquartile ranges (IQR) in the first and the last scenario differ significantly between the baseline case and the respective treatment. Except for scenario 2, the medians in all treatments are lower than in the baseline cases. In scenario 1 and 4, those differences account for a change of roughly (here) 12.000 monetary units, as soon as agents consider the similarity to their neighbourhood and do not evaluate them as perfect anymore. This means that the values of the neighbourhood satisfaction can now vary between 0 and 1 and are not equal to 1. In scenario 3, the absolute differences between the baseline case and the treatment is (here) roughly 5.000 monetary units under consideration of neighbourhood similarities. This implies that as soon as agents evaluate their neighbourhood composition together with their current housing characteristics, the satisfaction level becomes lower, which leads to higher depreciation of the current house price.

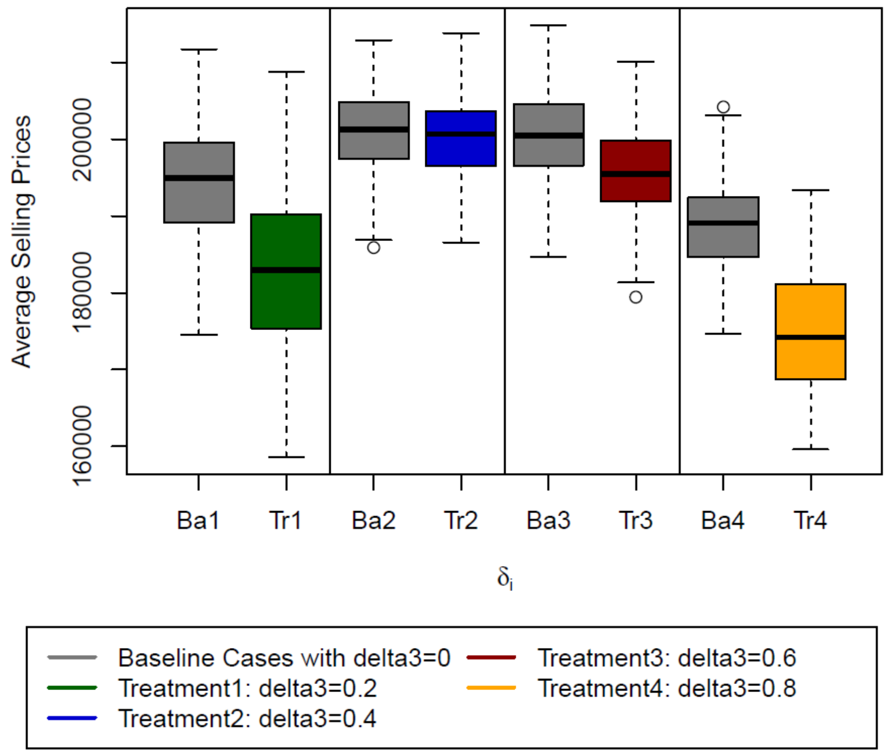

Figure 2: Baseline and Treatment Scenarios for different degrees of neighbourhood similarities

For that reason, Table 2 shows the exact values of the house price means and a t-test for each treatment. We find that the differences of the Baseline scenarios 1, 3 and 4 and the respective treatments are significant on the 1%-level. Only scenario 2 is insignificant with a p-value of 0.20.

Scenario 4 shows the greatest absolute differences, namely -13,439.5 monetary units, which is a decrease by 7.1% from the average price in Ba4. However, we choose the parametrization of scenario 3 for further analyses[2]. Here, we find a highly significant, yet the smallest absolute difference between the baseline case and the treatment. We use this parameterization in order to perform a conservative analysis. All further results would depend more strongly on neighbourhood dissimilarity if we used the parameter values of Tr1 or Tr4.

Table 2: House Price Means and t-test for Baseline and Treatment cases

	Ba1	Tr1	Ba2	Tr2	Ba3	Tr3	Ba4	Tr4
Mean Price	194,413.3	183,208.0	200,968.8	200,309.4	200,505.4	195,567.2	188,635.3	175,195.8
Mean Price difference	-11,205.3		-659.4		-4,938.2		-13,439.5	
Relative Price Change	-5.76%		-0.33%		-2.46%		-7.12%	
t-test	13.162		1.2686		8.6831		19.945	
p-value	<2.2e-16		0.2053		<2.2e-16		<2.2e-16	

4.2 The effects of income variety and population diversity on selling prices

At first, we describe how and if the population composition of an urban area has an effect on the average house prices. We conduct the analysis because the dissimilarity function could be affected, if higher shares of neighbours with different ethnicity can be found. Afterwards, we show how the variation of minimum income affects the average selling prices, since income is an important driver for the individual budget and thus, for the market process. Figure 3 shows the various average selling prices as means over the different seeds within each time step for each setting.

The boxplots show that the variation of the population shares has only minor effects on the average house prices, if the share varies between 5% and 35%. As soon as the share is higher (or equal) than 40%, we observe that the IQRs are positioned at lower absolute levels than in the other cases. However, we also observe that the absolute difference among population shares is rather small.

[2] The outputs of the other seed settings can be found in the Appendix.

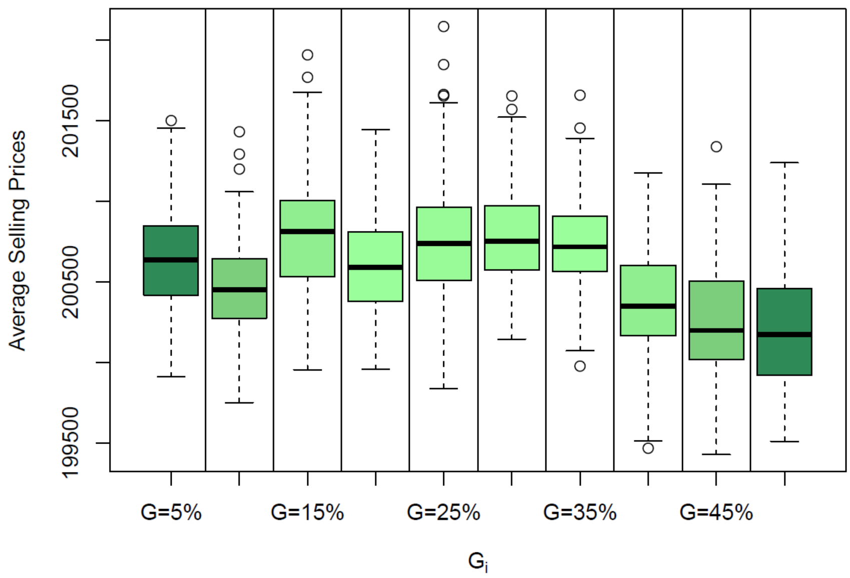

Figure 3: Boxplots, Average Selling Prices with varying population shares, Treatment 3

Figure 4 shows the average selling prices among different levels of minimum income. The boxplots show that the IQR in the case of *Ymin = 10000* is largest and thus, shows the greatest variation over the simulation time. By considering all four boxplots, we observe a decrease in the medians on average, if the minimum income increases. Setting a minimum income of 5000 units would lower the average selling price by about 1000 monetary units. At Y_{min}=20000, the average selling price is about 2000 monetary units lower.

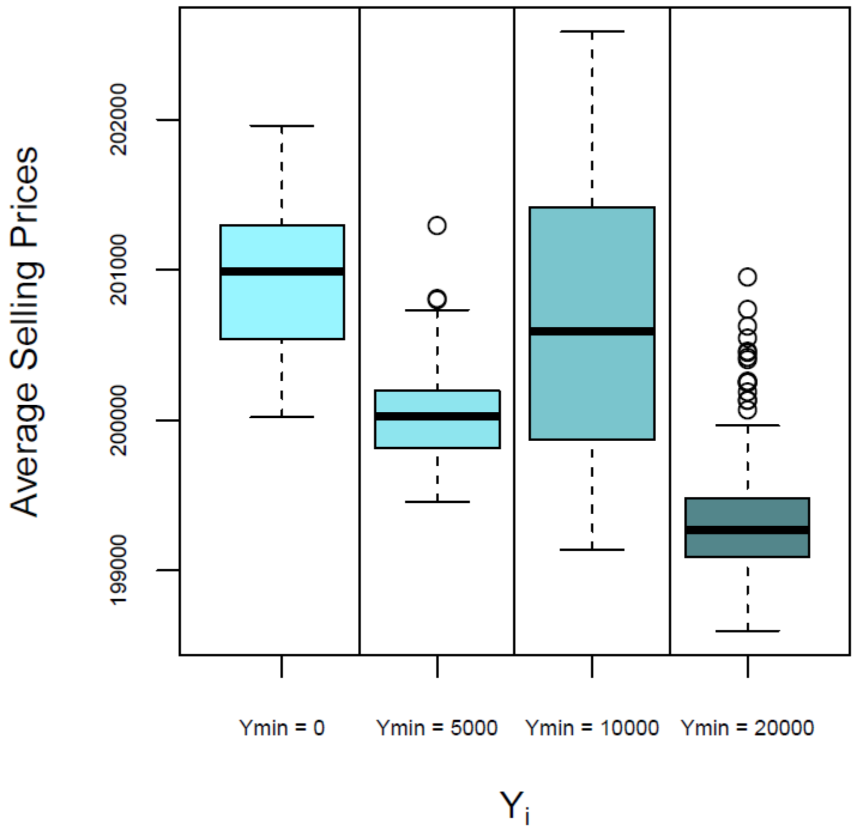

Figure 4: Boxplots, Average Selling Prices with varying minimum Income, Treatment 3

4.3 The effects of satisfaction levels on buying prices for various population groups with different kinds of preferences

In this section, we disentangle the effects of different satisfaction levels on the buying prices of six population groups *g*. Here, we want to analyse, how the various satisfaction levels affect the actual buying price of the current house. We distinguish two different cases: 1) agents have a *preference for similarity* or 2) agents have a *preference for status*. Even if individuals move during a specific period, the effects are not biased, since this evaluation is identical before moving and directly after moving for that particular neighbourhood due to the sequential execution of events by all agents.

Since the initial income distribution is an exponential distribution with $E\left[Y_{i,t_0}(X)\right] = 40{,}000$, we categorise the income groups by the following rules in order to get a small share of very rich individuals and a rather large share of poor agents:

- Poor agents: If $Y_i < \mu_Y - 0.25\sigma_Y$
- Average income agents: If $\mu_Y - 0.25\sigma_Y < Y_i < \mu_Y + 2\sigma_Y$
- Rich agents: If $Y_i > \mu_Y + 2\sigma_Y$

At first, we show an exemplary development of different satisfaction levels among all population groups for a fixed seed at four different moments of the simulation, namely at $t \in (1; 30; 100; 200)$. Figure 5 shows the average satisfaction of each population group at each simulation moment. The arrows indicate the change of the mean satisfaction per population group over time.

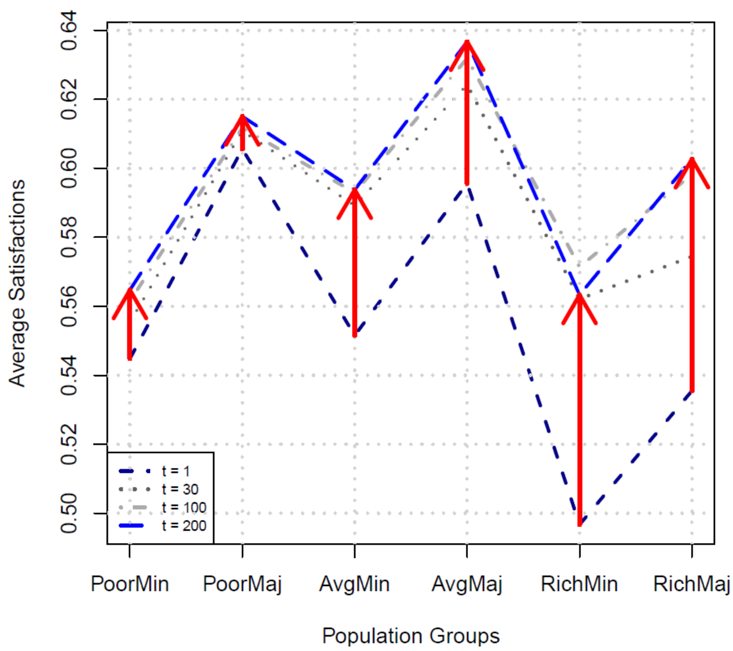

Figure 5: Average satisfaction among population groups at different simulation moments

We distinguish population groups not only by their income, but also by the criterion whether the belong to a minority (Min) or the majority (Maj) defined e.g. by ethnicity. We assume that the minority share is G = 30%. Not surprisingly, the average satisfaction of agents in the majority group is always higher than the satisfaction of the minority members. The reason for this is that it is easier for majority members to find similar neighbors than for members of the minority. The red arrows in Figure 5 show how the satisfaction levels change during the course of the simulation runs from time t = 1 to t = 200. We can observe several remarkable findings.

First, the rich agents, both in the minority and in the majority start with the lowest satisfaction levels, which are even lower than the satisfaction levels of the poor agents. This can be explained by the sizes of the groups. Since the exponential income distribution is very skewed, we defined the groups asymmetrically, such than there are many more poor agents than rich agents. Accordingly, it is much more difficult for rich – and especially so for the rich in the minority group – to find neighbors that are similar in terms of income than it is for the poor. The initial random spatial allocation of agents on the grid in t = 1 implies that most rich agents will have poorer neighbours leading to low neighbourhood satisfaction.

Second, at the end of the simulation at t = 200 the average satisfaction levels of the poor and the rich agents are almost identical, while the average income agents are more satisfied. This finding might be in contrast to the expectation that the rich agents will end up with the hightest satisfaction levels and the poor are the most dissatisfied agents.

Third, the arrows show that the rich can improve their satisfaction a lot, while the improvement in the group of the poor is much smaller. The average income agents' improvement is at an intermediate level. This result indicates that rich agents can move more freely within an urban area due to higher liquidity. Poor agents do not have that much flexibility in order to find the right peer group and are potentially locked in their current neighbourhood, if they are not located within a neighbourhood with the "right" peers. Especially this result demonstrates the interaction between population sorting according to similiarity and contraints by the affordability of houses for the different population groups.

Table 3 shows the relative average amount of locked-in agents across all simulation runs. "Locked-in" means that agents want to move (i.e. $MI = 1$ in eq. (9)), but cannot do so because they either do not find a more preferred house or cannot afford it. We find that roughly 13.01% of poor minority and 8.02% of poor majority agents are especially dissatisfied with their current living condition and want to move. The amount decreases with increasing disposable income so that only 3.27% and 2.44% of the rich population are locked in their current neighbourhood. Poor agents suffer under affordability problems and rich agents do not find suitable houses.

Table 3: Relative amount of locked-in agents

Population group	% of locked agents
Poor minority	13.01
Poor majority	8.02
Average income minority	4.08
Average income majority	2.30
Rich minority	3.27
Rich majority	2.44

In order to determine the effect of satisfaction on house prices, we run the following OLS regression:

$$BP_{i,g,k,n_k,t} = \beta_0 + \beta_1 SH_{i,g,k,n_k,t} + \beta_2 SA_{i,g,k,n_k,t} + \beta_3 SN_{i,g,k,n_k,t} + \epsilon_{i,g,k,n_k,t} \,, \tag{15}$$

with individual *i* in population group *g*, living in house *k,* in neighbourhood n_k at time *t*. Also $BP_{i,g,k,n_k,t}$ denotes the respective buying price, $SH_{i,g,k,n_k,t}$ the house satisfaction, $SA_{i,g,k,n_k,t}$ the area satisfaction and the $SN_{i,g,k,n_k,t}$ the neighbourhood satisfaction. Table 4 shows the "absolute"[3] regression results for all agents of the minority population, which accounts for 30% of the total population. Whereas, Table 4 shows the results for agents with *preference for similarity*, Table 5 shows the respective regression results for agents with *preference for status*.

Table 4 shows that the house satisfaction and the area satisfaction have a large positive effect on the buying prices among all minority groups. The higher the satisfaction with the house and the closer the agents can live near the city centre, the higher is the effect on the buying prices. Thus, the high valuation of these indicators leads to the willingness to pay more for the houses. These effects are highest for the average income agents and lowest for the rich agents in terms of area satisfaction and lowest for poor agents in terms of house satisfaction. The reason for this is that the valuation of the neighbourhood composition, thus the effect of neighbourhood satisfaction, differs strongly among population groups and counteracts. The effect varies between a strong negative value for the low-income agents and a high positive value for the rich agents. Poor agents are locked in their neighbourhood, since they do not have the budget to afford expensive houses. Thus, agents, who are locked in their neighbourhood continue to be dissatisfied because they cannot find a neighbourhood, in which their peers with similar socioeconomic status live in. The consequence is the depreciation of the own house price. The effect is smaller for average income agents, since a fraction of this group is

[3] The results of the regression analyses cannot be taken as "true" values, since the numbers are based on the initialization of the agent-based model. However, the effect sizes are important to consider.

able to move to more prosperous neighbourhoods and others are rather close to the lower income agents. The richer ones have a higher likelihood to find their own peer group.

Rich agents can simply move to the locations, where they find their peers. This implies that rich minority agents move more selectively to find the suitable neighbourhood, which covers the majority of one's individual characteristics. As soon as this neighbourhood has been found they remain there. Thus, rich minority agents are not only satisfied with the house characteristics and the area, but also with their peer group. This implies that the effect of the neighbourhood satisfaction has a large effect on the buying price of a house if the neighbourhood composition suits one's personal characteristics.

Similar results can be seen in Table 5, which shows the regression results for minority agents with a *preference for status*. Compared to Table 4, we find that the house satisfaction is estimated with a lower coefficient than in the case, where agents have a *preference for similarity*. Also, poor and average income agents show smaller values for area satisfaction, whereas rich agents evaluate the area higher. When agents have a preference for status, poor agents show a more positive valuation concerning the neighbourhood satisfaction whereas average income and rich agents value the neighbourhood more negatively.

Table 4: OLS Regression "absolute" results for all agents of the minority population, preference for similarity, S=Satisfaction

	Dependent variable:		
	BuyingPrice_poor	BuyingPrice_average	BuyingPrice_rich
	(1)	(2)	(3)
HouseS_poor	274,817.500***		
	(158.378)		
AreaS_poor	269,682.300***		
	(242.500)		
NeighborhoodS_poor	−148,297.000***		
	(373.550)		
HouseS_average		370,426.900***	
		(371.055)	
AreaS_average		348,584.600***	
		(503.667)	
NeighborhoodS_average		−81,928.260***	
		(592.398)	
HouseS_rich			311,419.700***
			(2,255.532)
AreaS_rich			243,629.500***
			(2,699.947)
NeighborhoodS_rich			299,510.200***
			(3,100.715)
Constant	−137,952.400***	−347,018.700***	−431,625.400***
	(419.792)	(844.799)	(4,577.007)
Observations	2,099,323	1,445,439	177,758
R^2	0.694	0.527	0.129
Adjusted R^2	0.694	0.527	0.129
Residual Std. Error	31,896.690	49,188.900	83,666.510
	(df = 2099319)	(df = 1445435)	(df = 177754)
F Statistic	1,585,602.000***	537,457.100***	8,797.274***
	(df = 3; 2099319)	(df = 3; 1445435)	(df = 3; 177754)
Note:			*p<0.1; **p<0.05; ***p<0.01

Table 5: OLS Regression "absolute" results for all agents of the minority population, preference for status, S=Satisfaction

	Dependent variable:		
	BuyingPrice_poor	BuyingPrice_average	BuyingPrice_rich
	(1)	(2)	(3)
HouseS_poor	261,885.600***		
	(140.942)		
AreaS_poor	246,868.800***		
	(215.094)		
NeighborhoodS_poor	−106,362.600***		
	(354.733)		
HouseS_average		338,633.900***	
		(268.107)	
AreaS_average		330,364.400***	
		(357.821)	
NeighborhoodS_average		−107,198.400***	
		(598.675)	
HouseS_rich			295,269.100***
			(1,224.953)
AreaS_rich			277,149.800***
			(1,449.526)
NeighborhoodS_rich			77,832.360***
			(2,292.681)
Constant	−137,760.900***	−272,630.900***	−337,774.700***
	(377.253)	(747.377)	(2,963.124)
Observations	2,104,394	1,443,150	174,976
R^2	0.705	0.643	0.325
Adjusted R^2	0.705	0.643	0.325
Residual Std. Error	28,653.200	35,648.360	44,005.000
	(df = 2104390)	(df = 1443146)	(df = 174972)
F Statistic	1,679,564.000***	865,161.500***	28,056.000***
	(df = 3; 2104390)	(df = 3; 1443146)	(df = 3; 174972)
Note:			*p<0.1; **p<0.05; ***p<0.01

Table 6 shows the regression results for the majority population, which accounts for 70% of the total population. Again, Table 6 shows the results for agents with *preference for similarity* and Table 7 the results for agents with *preference for status*. The results are similar to the results of the minority population. The effect sizes, especially for the neighbourhood satisfaction, are smaller though than for the minority case. However, the poor agents denote slightly higher Housing and Area Satisfactions. The reason is that individuals who belong to the majority population have higher chances to find neighbours with similar ethnicity. Thus, the positive evaluation of potential neighbourhoods is easier than for individuals from the minority population. This implies that agents from the minority population assign higher monetary values to houses than individuals from the majority population. The necessity to move more often than the majority population leads to a higher valuation, until the right neighbourhood composition fits their own characteristics.

By comparing Table 6 and 7, we find similar results like in Table 4 and 5. Like in the minority case, the majority agents show smaller coefficients with respect to house satisfaction. Poor and average income agents show smaller values for area satisfaction, whereas rich agents show higher values. Neighbourhood satisfaction is different from the previous comparison. Here, it is higher for poor and average income agents and lower for rich agents.

Table 6: OLS Regression "absolute" results for all agents of the majority population, preference for similarity, S=Satisfaction

	Dependent variable:		
	BuyingPrice_poor	BuyingPrice_average	BuyingPrice_rich
	(1)	(2)	(3)
HouseS_poor	282,250.200***		
	(82.494)		
AreaS_poor	277,616.900***		
	(127.933)		
NeighborhoodS_poor	−95,594.470***		
	(229.388)		
HouseS_average		338,557.300***	
		(188.929)	
AreaS_average		324,866.900***	
		(264.458)	
NeighborhoodS_average		−91,150.220***	
		(329.311)	
HouseS_rich			278,044.900***
			(1,333.860)
AreaS_rich			225,305.400***
			(1,662.260)
NeighborhoodS_rich			156,528.700***
			(2,223.901)
Constant	−181,365.400***	−277,247.600***	−294,017.300***
	(248.863)	(432.453)	(2,786.058)
Observations	4,888,583	3,382,372	416,265
R^2	0.776	0.579	0.120
Adjusted R^2	0.776	0.579	0.120
Residual Std. Error	25,546.920	39,619.530	79,315.450
	(df = 4888579)	(df = 3382368)	(df = 416261)
F Statistic	5,660,342.000***	1,548,703.000***	18,939.270***
	(df = 3; 4888579)	(df = 3; 3382368)	(df = 3; 416261)
Note:			*p<0.1; **p<0.05; ***p<0.01

Table 7: OLS Regression "absolute" results for all agents of the majority population, preference for status, S=Satisfaction

	Dependent variable:		
	BuyingPrice_poor	BuyingPrice_average	BuyingPrice_rich
	(1)	(2)	(3)
HouseS_poor	264,253.600***		
	(67.786)		
AreaS_poor	257,258.500***		
	(105.102)		
NeighborhoodS_poor	−65,113.810***		
	(192.048)		
HouseS_average		324,026.100***	
		(136.410)	
AreaS_average		311,143.100***	
		(188.148)	
NeighborhoodS_average		−31,282.360***	
		(367.241)	
HouseS_rich			257,811.100***
			(561.524)
AreaS_rich			271,599.600***
			(686.367)
NeighborhoodS_rich			116,118.800***
			(1,349.818)
Constant	−172,793.000***	−301,504.300***	−339,070.100***
	(206.458)	(430.348)	(1,614.755)
Observations	4,883,444	3,391,506	412,270
R^2	0.816	0.700	0.444
Adjusted R^2	0.816	0.700	0.444
Residual Std. Error	21,104.860	28,980.010	33,783.810
	(df = 4883440)	(df = 3391502)	(df = 412266)
F Statistic	7,210,067.000***	2,635,162.000***	109,759.800***
	(df = 3; 4883440)	(df = 3; 3391502)	(df = 3; 412266)
Note:			*p<0.1; **p<0.05; ***p<0.01

Table 8 and 9 show the price predictions from the regression analyses with the respective averages of the independent variables. Table 8 shows the results, if agents have a preference for similarity and Table 9 shows the results, if agents have a preference for status.

Table 8: Price predictions from OLS regression with respective averages of independent variables - preference for similarity

Preference for Similarity	**Predicted House Price**	**Mean House Satisfaction**	**Mean Area Satisfaction**	**Mean Neigh. Satisfaction**	**Mean Satisfaction**
Poor minority	258,250.40	0.8341	0.8338	0.8032	0.5586
Poor majority	282,907.23	0.8338	0.8356	0.8836	0.6156
Avg Income minority	290,064.54	0.8516	0.8412	0.8139	0.5831
Avg Income majority	295,025.38	0.8520	0.8412	0.8786	0.6297
Rich minority	422,934.00	0.8854	0.8525	0.7349	0.5547
Rich majority	365,861.70	0.8866	0.8539	0.7865	0.5954

In Table 8, we see that poor minority agents have the cheapest houses and rich minority agents own the most expensive ones. House prices as well as average house and area satisfaction increase with increasing disposable income. However, mean neighbourhood satisfaction shows a different pattern. Poor and average income agents show higher neighbourhood satisfaction than rich agents. Although rich agents have enough financial liquidity they cannot find the right neighbourhood due to a lack of suitable houses. On average, the total satisfaction level is roughly between 0.55 and 0.63 for all population groups.

Table 9: Price predictions from OLS regression with respective averages of independent variables - preference for status

Preference for Status	**Predicted House Price**	**Mean House Satisfaction**	**Mean Area Satisfaction**	**Mean Neigh. Satisfaction**	**Mean Satisfaction**
Poor minority	264,630.90	0.8335	0.8348	0.8079	0.5621
Poor majority	283,605.29	0.8344	0.8357	0.8901	0.6207
Avg Income minority	289,169.00	0.8572	0.8403	0.8732	0.6290
Avg Income majority	302,382.54	0.8515	0.8387	0.9459	0.6755
Rich minority	312,476.56	0.8857	0.8619	0.8984	0.6858
Rich majority	306,459.40	0.8770	0.8480	0.9714	0.7224

If agents have a preference for status, the picture looks different. First, the predicted house prices of the poor agents and the majority agents with average income are higher and the prices of the other groups are lower compared to the case, when agents have a preference for similarity. This indicates that some agents are willing to live with poorer neighbours because they derive satisfaction from their higher social status in such a neighborhood. This effect increases house demand and prices among the poor and the middle-income-majority agents, while it dampens competition among the rich. In total, preference for status sigificantly compresses the distribution of house prices and hence reduces wealth inequality. Furthermore, we find that the mean satisfaction across all population groups is higher and increases with higher income. Rich majorities show the greatest difference of 12.7 percentage points from 0.595 to 0.722. The overall neighbourhood satisfaction is higher, because agents do not feel dissatisfied when living among neighbours who do not have the same attributes.

4.4 The effects of varying credit access for different population groups

Our last research question refers to the effects of affordability policies on satisfaction levels and house prices. Again, we distinguish between 2 scenarios: 1) agents have a *preference for similarity* and 2) agents have a *preference for status*. We change the parameter ψ in Eq. (13) so that agents have higher disposable budgets, which we interpret as better access to credit. We run the model for three different settings, where the willingness-to-accept (WTA) is the base of the disposable budget. Additionally, agents can access credit depending on their individual income.

1) Baseline: All agents have twice the amount of their individual income for the additional budget, thus: $\psi = 2$
2) Policy 1: Poor agents get more access to credit than rich agents, in order to make houses more affordable and reduce social exclusion. We call this scenario "*staggered credit*", thus: Poor agents: $\psi = 3$, average income agents: $\psi = 2.5$, rich agents: $\psi = 2$
3) Policy 2: All agents have higher access to credit: $\psi = 3$, we call this scenario "*extra credit for all*"

We create the relative deviation for cases 2) to 3) from the baseline case described in 1). Figures 6 – 9 show the deviations of house satisfaction, area satisfaction and neighbourhood satisfaction as well as the deviations in overall satisfaction for the different policies across all population groups with agents' preference for similarity. Figure 10 shows the overall price deviations from the baseline case. Figures 11 – 15 show the respective results for agents with a preference for status. The stacked barplots represent the average deviations of the two different policies.

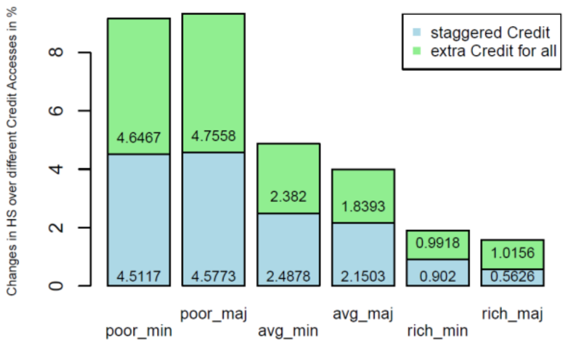

Figure 6: Relative deviations (house satisfaction) of better access to credit among all population groups, preference for similarity

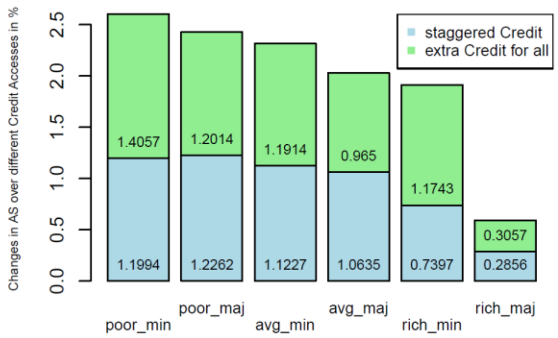

Figure 7: Relative deviations (area satisfaction) of better access to credit among all population groups, preference for similarity

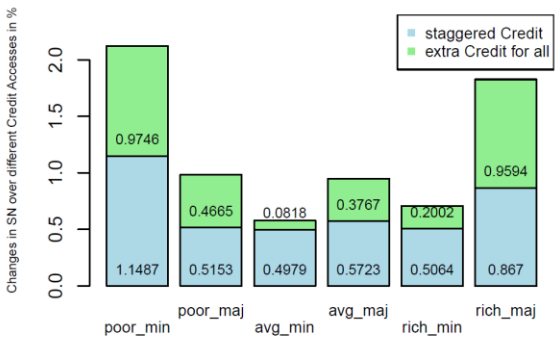

Figure 8: Relative deviations (neighborhood satisfaction) of better access to credit among all population groups, preference for similarity

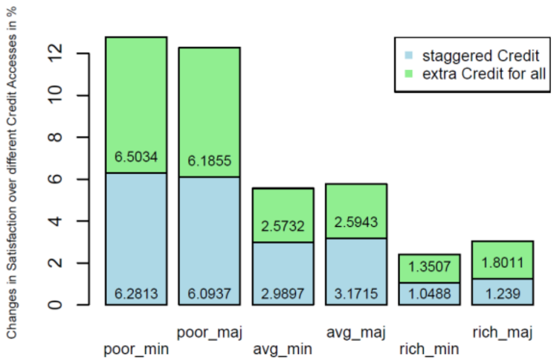

Figure 9: Relative deviations (overall satisfaction) of better access to credit among all population groups, preference for similarity

Figure 6 shows that especially poor agents benefit from extra credit with respect to house satisfaction. Giving them more access to credit improves their house satisfaction, compared to the baseline case, by up to 4.75%. Average income agents improve their house satisfaction between 1.8% and 2.5%. Even though rich agents do not get any further credit in the staggered credit policy, they can increase their house satisfaction by 0.56% or 0.9%, respectively. If they also get more credit (policy 2), the improvements denote roughly 1%.

Figure 7 indicates that higher amounts of credit make houses closer to the centre more affordable. Especially poor agents benefit from this policy by increasing their area satisfaction by up to 1.4% compared to the baseline case. Minorities show greater improvements than majorities. Across all population groups, the improvement rates become smaller the more disposable income the agents have. Rich majority agents show small variations (between 0.28% and 0.3%) indicating that they are not liquidity constrained in the baseline case.

Neighbourhood satisfaction shows a different pattern than house or area satisfaction. Figure 8 shows that higher access to credit improves the neighbourhood satisfaction, especially for poor minorities and rich majorities. The former show improvements, compared to the baseline case, by up to 1.15% and the latter by up to 0.96%. This indicates that poor minorities, as well as rich majorities can cluster themselves among their peer group more likely, if credit access increases. Average income agents either barely improve their neighbourhood satisfaction shown by 0.08% in the scenario, where all agents get extra credit or improve their neighbourhood satisfaction by up to 0.57%. The fact that rich agents benefit in this dimension although there are only small effects with regard to the other dimensions of satisfaction points to a price effect. If better access to credit drives up prices in general, rich agents can outcompete agents with lower budgets.

Finally, Figure 9 shows the relative deviations of the overall satisfaction levels compared to the baseline case. All population groups become more satisfied with their living conditions when getting extra credit. However, with higher income, the increases of the overall satisfaction become smaller. Poor agents improve their overall satisfaction between 6.09% and 6.50%, whereas average income agents show higher satisfaction level between 2.57% and 3.17%. Rich agents do not increase their satisfaction that strongly. The improvements lie between 1.04% and 1.80%.

In order to visualize the effect of higher access to credit on house prices, Figure 10 shows the average price increases caused by the two policies for all population groups. In the treatment policy 1 (staggered credit), prices increase on average between 24.8% and 70.8%. As soon as all population groups get the same amount of higher credit (policy 2: extra credit for all), the smallest average price increase is roughly 25% and experienced by the poor majority group. The maximum change reaches 78.9% and affects the majority group with average incomes. This is an indication that the general income and wealth inequality within the economy rises by introducing such a credit policy, counteracting the increases in satisfaction levels.

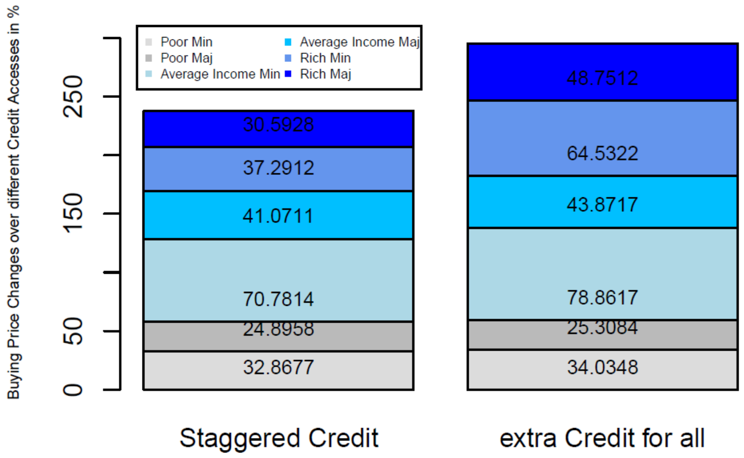

Figure 10: Relative deviations (prices) of better access to credit, preference for similarity

Similar dynamics can be found if agents have a preference for status. Figure 11 – 14 show the deviations of higher credit access compared to the baseline case, where $\psi = 2$. The relative deviations of house, area and neighbourhood satisfaction as well as overall satisfaction are shown. Figure 15 shows the overall price deviations from the baseline case. As before, the stacked barplots represent the average deviations of the two different policies.

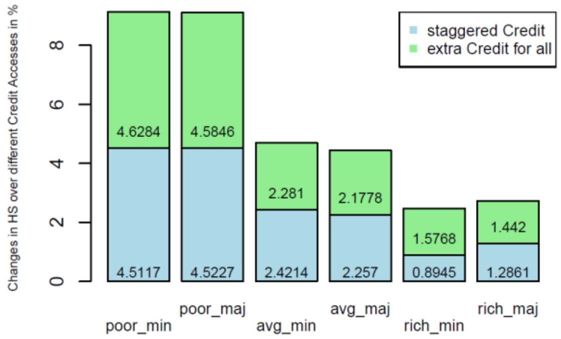

Figure 11: Relative deviations (house satisfaction) of better access to credit among all population groups, preference for status

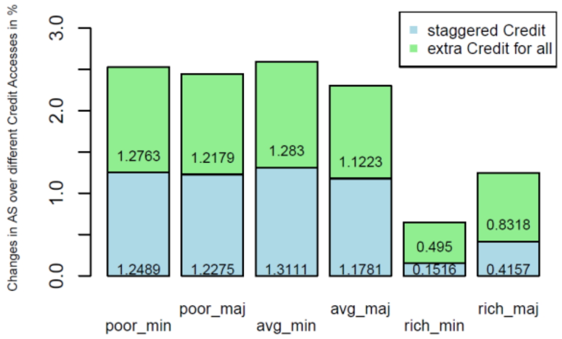

Figure 12: Relative deviations (area satisfaction) of better access to credit among all population groups, preference for status

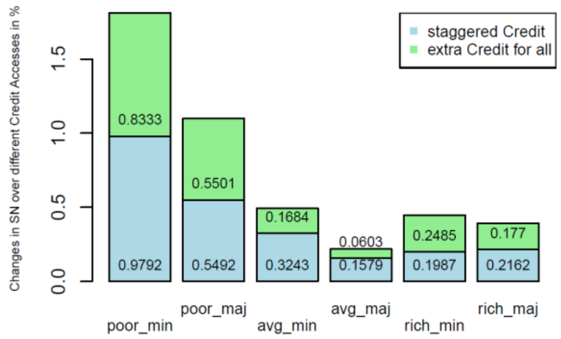

Figure 13 Relative deviations (neighborhood satisfaction) of better access to credit among all population groups, preference for status

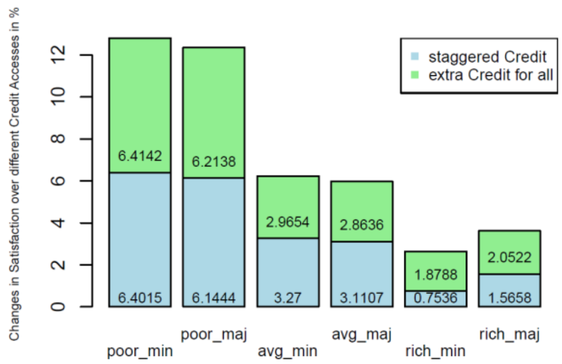

Figure 14: Relative deviations (prices) of better access to credit among all population groups, preference for status

The deviations caused by extra credit with respect to house satisfaction are very similar to the results found for the preferences for similarity case (Figure 11). Figure 12 shows the relative deviations of area satisfaction from extra credit to the baseline case. The most important difference to the effects shown in Figure 7 is that agent in the rich minority benefit very little both from Policy 1 and from Policy 2. Opposite to the case with preference for similarity, the rich majority group benefits more than the rich minority. This may indicate that rich minority agents do not move as much and find their "right" neighbours more quickly.

Preference for status also matters with regard to the neighbourhood satisfaction for the rich majority, but also for the average-income majority (Figure 13). In both groups, better access to credit increases the neighbourhood satisfaction considerably less, if there is a preference for status instead of a preference for similarity. Again, this implies that average-income and rich agents from the majority group sort themselves quickly into the most suited neighbourhood. Since the preference for status allows agents to be better off than their neighbours, agents get satisfied very quickly and do not need extra credit.

The effects on the overall satisfaction of the groups are qualitatively very similar for both types of preferences (Figure 14). However, average-income agents from the minority population show higher increases between 0.28 percentage points and 0.3922 percentage points. Although all agents are more satisfied, the overall inequality rises and the extra credit drives up house prices, but on a lower scale, as Figure 15 illustrates.

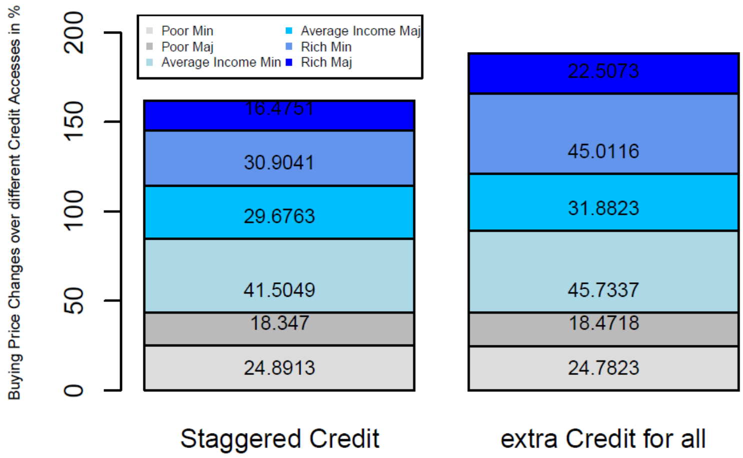

Figure 15: Relative deviations (prices) of better access to credit, preference for status

4.5 The role of the evaluation sensitivity

A crucial assumption of our model is that house prices are mainly determined by the satisfaction with dwelling conditons. Our results might be driven by the evaluation sensitivity of the satisfaction with dwelling conditions, which governs how agents translate their subjective satisfaction into monetary evaluations. We did a sensitivity analysis to get an impression of the importance of this parameter.

Figure 16 shows how sensitive the average house prices react upon changes of the satisfaction evaluation, which has a direct influence on the willingness to pay and the willingness to accept. The boxplot within the red lines represents the average house prices when $\sigma = 1$. We find that the average house prices decrease if σ increases, which was to be expected. The differences are rather small as doubling σ would decrease average house prices by roughy 2000 monetary units or about 1%. If the evaluation sensitivity is smaller than 1, agents respond less than linearly to changes in their dwelling satisfaction. Dissatisfaction hence leads to lower discounting and hence higher average prices. Figure 16 also shows the size of this effect on average house prices.

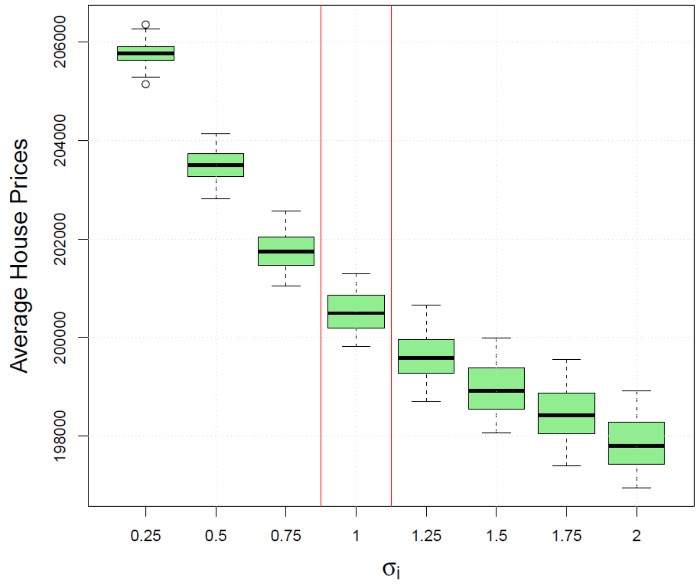

Figure 16: Evaluation sensitivity - average house price with values lower and higher than σ = 1

4.6 Discussion

There is a consensus in the literature that discrepancies in socioeconomic characteristics among neighbours lead to a decline in residential satisfaction (e.g. Mason & Faulkenberry, 1978; Vera-Toscano & Ateca-Amestoy, 2008). In our model, this result is reflected in a depreciation of the willingness to accept a price for the own house. The relation between less residential satisfaction and lower willingness to accept is in line with the results of Jansen (2014, p.20), who explores empirically the impact of personal characteristics, dwelling aspects and match/mismatch variables on residential satisfaction. She finds a positive correlation between house prices and residential satisfaction. Our finding gets also confirmed by Nordvik & Osland (2017, p. 169), who estimate a random effects and a fixed effects model with data for Oslo to test how the population composition within a neighbourhood affects house prices. The authors find that neighbourhoods with a higher share of African and Asian country background, and therefore a higher discrepancy in ethnicity, show reduced house prices.

The variation of minimum income for poorer agents has a small impact on the average house prices. Even though poor agents may have the opportunity to buy a better house once or twice, some are still locked in the outer areas of the city[4], due to affordability problems (see e.g. Zwiers et.al, 2017, p.364). Since house prices increase with smaller distance to the city center and therefore better access to amenities, average income and rich agents “crowd out” the poorer ones by the sorting process (ibid, p.366). The minimum income does not provide enough financial liquidity to compete in the market and thus, to let poor agents afford better-located houses.

[4] If a Thünen-type monocentric city design is assumed.

We find the same result for poor agents after the variation of credit accessibility. Brueckner et.al (1999) confirm this spatial sorting by analysing the relative location of different income groups within an urban area. The authors find that if the center has strong advantages in exogenous amenities, rich people are likely to live at those central locations. More recently, Lee & Lin (2018) also confirmed this result, by combining a dynamic model of household neighbourhood choice with empirical data. The authors find that high income agents are anchored in neighbourhoods, where natural amenities are present (ibid, p.691).

5 Conclusion

This paper introduces a theoretical agent-based model for house price dynamics depending on housing quality, access to amenities and, especially, neighbourhood composition. The purpose of this model is to gain insights on how house prices and dwelling satisfaction are affected by (dis-)similar neighbours. Therefore, the model contains several features: agents' endowment with socioeconomic characteristics like yearly income and education, a multidimensional dissimilarity index, the quantification of agents' willingness-to-move to a different house and an auction process for buying and selling houses in an urban area.

The analysis shows that neighbourhood composition and thus, the preference for similarity can decrease house prices by up to 13,500 monetary units or 7.1%. Thus, the individual perception of the "wrong" neighbours has a considerable impact on individual house prices.

Our second research question referred to the effects of population diversity and income inequality. Even though the share of people from another ethnicity has an effect on average house prices within a neighbourhood, population diversity within the entire city has no substantial impact on the average house price level. Due to neighbourhood sorting, areas which contain neighbourhoods with higher shares of the minority population, become spatially bigger and more homogenous. We find that reduced income inequality has a small effect on average house prices in the whole city. If we endow poor agents with various amounts of minimum income, they still get "crowded out" by average-income and high-income agents, which have more financial liquidity. Therefore, poor agents have less ability to compete in the market.

In order to analyse our third research question on how population sorting and satisfaction levels affect the house prices of different groups of households, we defined six different population groups. These groups are defined by their income (poor, average, rich) and their affiliation to a minority or the majority group. We find that population sorting is a strong driver of house prices, if agents have a preference for similarity. In particular, competition among the rich for houses with suitable neighbours leads to very high prices of attractive houses. If agents have a preference for status, there is less population sorting and less competition among the well-off agents. The willingness to live among poorer agents increases the prices of their houses and leads to an overall compressed house price distribution and hence to less wealth inequality. If agents prefer status over similarity, the average dwelling satisfaction of all agent groups is higher, indicating more efficient population sorting.

Finally, we analysed how policy measures aimed at making housing affordable to less well-off households affect house prices and satisfaction levels. Proving better access to credit drives up house prices of all groups, even if only poor and average-income agents are directly affected. The effect is particularly strong on houses bought by average-income agents. However, better access to credit also increases the satisfaction of poor and average-income agents, especially if they are the only ones to benefit from the policy. The poor and average-income agents can escape from the lock-in to some extent and afford houses of better quality and with better access to amenities. For the improvement of neighbourhood satisfaction, the differences between the groups are less pronounced unless all agents get better access to credit. In this case, both the poor minority agents and the rich majority agents improve their neighbourhood satisfaction significantly more than the other groups. If agents have a preference for status, the effects of better credit access are somewhat different. First, the overall price increase is less pronounced. Second, the effects of better access to credit on satisfaction in the different dimensions in general are more favourable to the poor and the average-income agents and do not favour the rich so much. This is also true of all agents get more credit.

These findings suggest that the value of similar neighbours plays an important role for urban planning. A potentially surprising lesson is that the satisfaction from living among peers can compensate poor and minority agents to some extent for having to reside in houses and areas of poor quality. Policies of social mixing might not improve the dwelling satisfaction of agents, if they have a preference for similarity. Affordability policies such as granting better access to credit are a double-edged sword, because they have a positive effect on dwelling satisfaction, but also increase wealth inequality by driving up house prices.

References

Baker, E., Mason, K., & Bentley, R. (2015). Measuring housing affordability: A longitudinal approach. *Urban policy and research*, 33(3), 275-290.

Bourdieu, P. (1984). *Distinction: A social critique of the judgement of taste.* Harvard university press.

Bove, V., & Elia, L. (2017). Migration, diversity, and economic growth. *World Development*, 89, 227-239.

Brueckner, J. K., Thisse, J. F., & Zenou, Y. (1999). Why is central Paris rich and downtown Detroit poor?: An amenity-based theory. *European economic review*, 43(1), 91-107.

Clark, W.A.V. (1992). Residential preferences and residential choices in a multiethnic context. *Demography,* 29(3), 451–466.

Clark, W. A., & Coulter, R. (2015). Who wants to move? The role of neighbourhood change. *Environment and Planning A,* 47(12), 2683-2709.

Coulter, R.; van Ham, M.; Feijten, P. (2011): A Longitudinal Analysis of Moving Desires, Expectations and Actual Moving Behaviour. *Environment and Planning A,* 43(11), 2742–2760.

Del Pero, A. S., Adema, W., Ferraro, V., & Frey, V. (2016). Policies to promote access to good-quality affordable housing in OECD countries, *OECD Social, Employment and Migration Working Papers,* No. 176, OECD Publishing, Paris.

Diener, E., Oishi, S., & Tay, L. (2018). Advances in subjective well-being research. *Nature Human Behaviour,* 2(4), 253-260.

Einiö, M.; Kaustia, M.; Puttonen, V. (2008): Price setting and the reluctance to realize losses in apartment markets. *Journal of Economic Psychology,* 29 (1), 19–34.

Fehr, E. and Schmidt, K. M. (1999). A theory of fairness, competition, and cooperation. *The quarterly journal of economics*, 114(3), 817-868.

Florida, R. (2002). *Cities and the Creative Class*. Psychology Press.

Galster, G. C., & Friedrichs, J. (2015). The dialectic of neighborhood social mix: Editors' introduction to the special issue. *Housing Studies*, 30(2), 175-191.

Genesove, D., Mayer, C. (2001): Loss Aversion and Seller Behavior. Evidence from the Housing Market. *The Quarterly Journal of Economics,* 116(4), 1233–1260.

Graham, E., Manley, D., Hiscock, R., Boyle, P., & Doherty, J. (2009). Mixing housing tenures: Is it good for social well-being? *Urban studies,* 46(1), 139-165.

Green, R. K., & Lee, H. (2016). Age, demographics, and the demand for housing, revisited. *Regional Science and Urban Economics* 61, 86-98.

Hipp, J. R. (2009). Specifying the determinants of neighborhood satisfaction: A robust assessment in 24 metropolitan areas. *Social Forces,* 88(1), 395-424.

Ioannides, Y. M. (2011). Neighborhood effects and housing. In: *Handbook of Social Economics* (1), 1281-1340. Elsevier.

Jansen, S. J. T. (2014). The impact of the have–want discrepancy on residential satisfaction. *Journal of environmental psychology,* 40, 26-38.

Jaumotte, F., Lall, S., & Papageorgiou, C. (2013). Rising income inequality: technology, or trade and financial globalization? *IMF Economic Review*, 61(2), 271-309.

Kahneman, D., & Krueger, A. B. (2006). Developments in the measurement of subjective well-being. *Journal of Economic Perspectives,* 20(1), 3-24.

Lee, S., & Lin, J. (2018). Natural amenities, neighbourhood dynamics, and persistence in the spatial distribution of income. *The Review of Economic Studies,* 85(1), 663-694.

Leung, T. C., & Tsang, K. P. (2012). Love thy neighbor: Income distribution and housing preferences. *Journal of Housing Economics,* 21(4), 322-335.

Li, Q. (2014). Ethnic diversity and neighborhood house prices. *Regional Science and Urban Economics*, 48, 21-38.

Linton, M. J., Dieppe, P., & Medina-Lara, A. (2016). Review of 99 self-report measures for assessing well-being in adults: exploring dimensions of well-being and developments over time. *BMJ open*, 6(7), 1-16.

Luttmer, E.F.P. (2005). Neighbors as negatives: Relative earnings and well-being. *The Quarterly Journal of Economics,* 120(3), 963–1002.

Malik, A., Crooks, A., Root, H., and Swartz, M. (2015). Exploring creativity and urban development with agent-based modeling*. Journal of Artificial Societies and Social Simulation,* 18(2), 1-12.

Marans, R. W. (1976). Perceived quality of residential environments: some methodological issues. In: Craik, H. & E.H. Zube (eds.), *Perceiving Environmental Quality,* 123-147. Springer.

Mason, R., & Faulkenberry, G.D. (1978). Aspirations, achievements and life satisfaction. *Social Indicators Research,* 5, 133-150.

Nordvik, V., & Osland, L. (2017). Putting a price on your neighbour. *Journal of Housing and the Built Environment,* 32(1), 157-175.

OECD (2017). Income distribution.

Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. *The Journal of Political Economy,* 82(1), 34–55.

Schelling, T.C. (1971). Dynamic models of segregation. *Journal of Mathematical Sociology,* 1(2), 143–186.

Schelling, T.C. (1978). *Micromotives and Macrobehavior*. New York, Norton.

Sirmans, G. S., MacDonald, L., Macpherson, D. A., & Zietz, E. N. (2006). The value of housing characteristics: a meta analysis. *The Journal of Real Estate Finance and Economics,* 33(3), 215-240.

Sirmans, S., Macpherson, D., & Zietz, E. (2005). The composition of hedonic pricing models. *Journal of Real Estate Literature*, 13(1), 1-44.

Stiglitz, J.E., Sen, A., & Fitoussi, J.-P. (2009). Report by the commission on the measurement of economic performance and social progress.

Vera-Toscano, E., & Ateca-Amestoy, V. (2008). The relevance of social interactions on housing satisfaction. *Social Indicators Research* 86, 257-274.

Wilson, W. J. (2012). *The truly disadvantaged: The inner city, the underclass, and public policy*. University of Chicago Press.

Zwiers, M., Kleinhans, R., & Van Ham, M. (2017). The path-dependency of low-income neighbourhood trajectories: An approach for analysing neighbourhood change. *Applied Spatial Analysis and Policy*, 10(3), 363-380.

Appendix

Parameters

Table 7: Parameters of the model

Parameter	Value	Meaning
δ_1	[0.1; 0.2; 0.3; 0.4]	Sensitivity of satisfaction to house quality
δ_2	[0.1; 0.2; 0.3; 0.4]	Sensitivity of satisfaction to amenities
δ_3	[0.2; 0.4; 0.6; 0.8]	Sensitivity of satisfaction to similarity
γ_1	1/3	Weight on income dissimilarity in dissimilarity function
γ_2	1/3	Weight on education dissimilarity in dissimilarity function
γ_3	1/3	Weight on ethnic dissimilarity in dissimilarity function
ϱ	[-0.2; 1]	Self-serving bias in income and education dissimilarity
$\underline{S}$	0.25	Lower threshold of satisfaction in moving intention
$\overline{S}$	0.6	Upper threshold of satisfaction in moving intention
σ	1	Sensitivity of WTA/WTP to satisfaction
µ	0.05	Price mark-up over WTA
ψ	[2; 2.5; 3]	Liquidity parameter/ access to credit
P_0	300,000	Maximum House Price value for the initialization

Initial values

Table 8: Initial value

Variable	Function	Meaning
y_{i,t_0}	Exponentially distributed with $E[y_{i,t_0}(X)] = 40{,}000$	Initial income across agents
P_{h,t_0}	$P_{h,t_0} = P_0 * QH_{h,t_0}^{\delta_1} * QA_{h,t_0}^{\delta_2}$	Initial house prices depending on P_0, $QH_{h,t_0}^{\delta_1}$, $QA_{h,t_0}^{\delta_2}$
QH_{h,t_0}	Uniform distribution with $QH_{h,t_0} \in [0;1[$	Initial Housing Quality as random draw
QA_{h,t_0}	$QA_{h,t_0} = \frac{\max\{D\} - D_h}{\max\{D\}}$	Initial Area Quality as function of the difference of the maximum distance to the center $\max\{D\}$ and house h's distance to the center D_h
S_{i,h,t_0}	0	Initial satisfaction is equal to 0

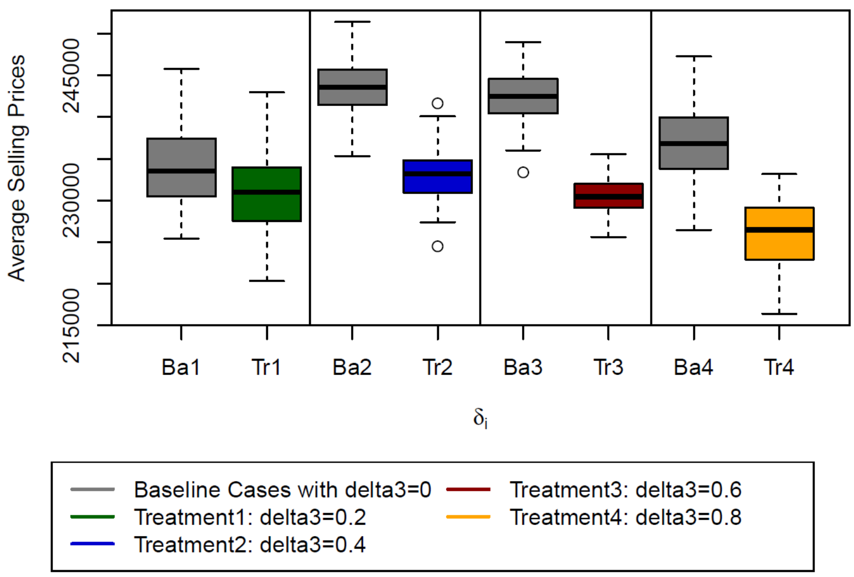

Figure 17: Baseline and Treatment Scenarios for different degrees of neighbourhood similarities, QH = 1

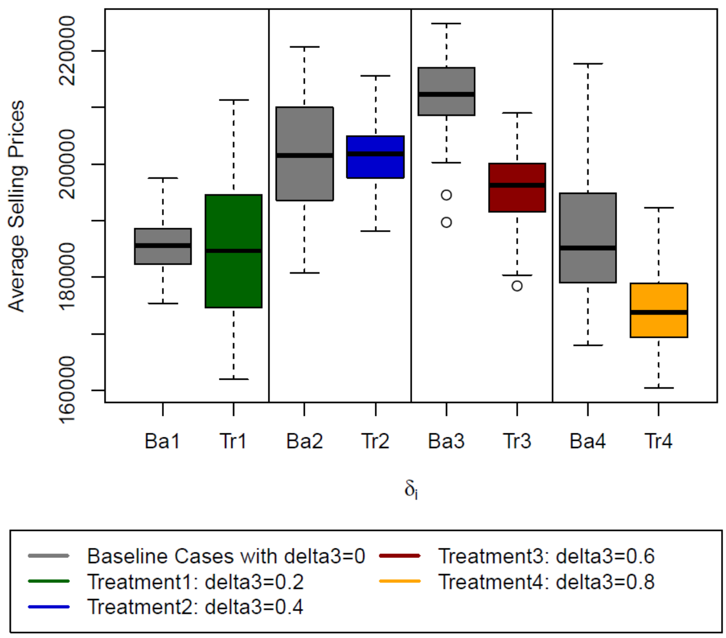

Figure 18:Baseline and Treatment Scenarios for different degrees of neighbourhood similarities, random QH