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Said Benjamin Bonakdar[1]

Endogenous Segregation Dynamics and Housing Market Interactions: An ABM Approach

Abstract

In contrast to previous research, I hypothesize that residential segregation patterns do not only result from an individual's perception of different ethnicities, but is rather affected by housing market interactions and socioeconomic endowment, like income and education. I implement a theoretical agent-based model, which contains three main features: agents' socioeconomic endowment, the quantification of one's Willingness-to-Stay within a neighborhood and housing market interactions if an agent decides to move. The results indicate that housing market interactions, the valuation of socioeconomic factors, but also the increasing share of minority groups diminish the absolute level of racial segregation. The analysis shows that house price clusters dominate urban areas, since individuals have an incentive to stay in more expensive neighborhoods in which they made a bargain. An increase in house price segregation can be observed if individuals strongly undervalue their own house and if individuals have higher access to credit. I can show that these market interactions lead to lock-in effects for low-income individuals, since they lack the necessary budget and suffer under negative equity. Thus, residential segregation shows a strong dependency on housing market interactions and is more complex than presumed by Schelling's Spatial Model or the White Flight Hypothesis.

JEL Classification: C63, R21, R23

Keywords: Agent-based modelling; residential choice; housing demand; neighborhood characteristics; segregation

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1 Introduction

Segregation patterns emerge, even if individuals only have mild preferences for neighbors with similar ethnicity (Schelling, 1971, 1978). These racially driven aims, e.g. suggested by the *racial white flight hypothesis* (Kye, 2018, pp.1f.), lead to individual aversion towards integrated neighborhoods on the micro level and trigger the occurrence of residential segregated urban areas on the macro level.

In this paper, I introduce a theoretical agent-based model, in which individuals evaluate their willingness to remain in their current neighborhood. I hypothesize that residential segregation is not only the result of ethnic preferences, but also occurs due to individual socioeconomic endowment and, in this regard, the direct comparison to one's neighbors. There is evidence that specifically individual income and observed income inequality cause residential segregation based on social exclusion of disadvantaged groups (Feitosa et al. (2011); Sethi and Somanathan (2004)). Thus, income segregation has become a common pattern in Western societies due to increasing inequalities (Watson, 2009).

The model fills another gap in the segregation literature by suggesting an economic framework, in which individuals interact whenever they see the need of moving to another neighborhood: a housing market with house ownership [1]. The market mechanism is demand-driven and contains the creation of individual budgets and preference rankings for affordable vacant spots. This neighborhood sorting is typically done to rank neighborhoods according to their characteristics (Epple and Platt, 1998).

The incentive of moving to another location seems not only motivated by the prejudice and potential aversion towards other ethnicities, but rather by individual preferences for neighborhood characteristics and higher housing quality, if an individual experiences socioeconomic gains. Here, individuals often leave neighborhoods, which are populated by ethnic minorities (Iceland and Wilkes, 2006). For this economic approach, the following research questions stand in focus:

1. Do housing market processes reinforce racial residential segregation?
2. What are the factors for happy individuals to stay in their current neighborhood?
3. Can there be a lock-in effect for certain agents, due to affordability problems?

[1] This assumption is based on the high share of house ownership within the United States, the United Kingdom and others.

The recent literature has covered various social and economic issues with respect to segregation patterns [2]. Clark & Fossett (2008) analyze empirically the occurence of three different ethnicities and show that groups with varying cultural, religious and socioeconomic background denote different individual tolerance levels. These tolerance levels do not only vary among ethnic groups, but also across different households within one specific ethnicity (Ellis et al., 2012), which increases the relevance of socioeconomic endowments as well as the identification of one's individual peers. On a macro level, Hatna & Benenson (2014) analyze varying tolerance thresholds and find that different values lead not only to dichotomic segregation patterns, but also to mixed neighborhoods.

Considered from another angle, Benard & Willer (2007) analyze the segregation outcomes empirically under consideration of status, wealth and affordability of houses. The authors find that due to the high correlation between status and wealth, the segregation patterns become larger, since low-status/low-wealth agents get priced out from areas with higher average prices. Dorn (2008) extents this finding claiming that house owners suffer under economic loss, due to the moving process initiated by individual ethnic preferences. If this occurs, agents become more intolerant.

The interaction with the direct peers in the local neighborhood, as well as on the housing market lead to a higher degree of heterogeneity. My model can be interpreted as an extension of Schelling's original Spatial Proximity Model. It is specifically important to work out which factors influence the agents' decision of actually moving to another location and the subsequent effect on urban areas from a macro perspective.

The remainder of the paper is structured as follows. In Section 2, I introduce the model procedures and the underlying assumptions. Section 3 will present specific segregation measures, which then will be used to analyze the dynamics of the model. Here, the results of the model will be shown and interpreted. Section 4 closes with a conclusion and comments for future research.

[2] Based on Schelling's Proximity Model, where agents accept a certain fraction of "others" in their neighborhood

2 The Endogenous Segregation Model with Housing Market Interactions

The modelling approach in this paper is inspired by Schelling's Spatial Proximity Model (Schelling, 1971). The model is visualized as two dimensional geographical grid of the size of 23x23 fields, which accounts for 529 potential interacting spots [3]. On each spot is a house, which can be bought by an individual. The population is divided into two ethnicities, where both hold a share of 50%. In total, the individuals account for 95% of the environment, which leads to approximately 500 individuals on the grid. There is a housing agent with no physical appearance, who is in charge of financial transactions on the housing market. The simulation time is set to 200 periods, which may account for roughly 16 years in terms of real time (1 period $\widehat{=}$ 1 month).

On a system level, Figure 1 summarizes the model. The system image shows three different markets and a section for social interactions, in which individuals compare themselves to their current neighbors. The labor market, as well as the credit market are modelled exogenously and provide the individuals with income and credit accessibility. On the housing market, there is the interaction with the ficticious housing agent, who is in charge of all transactions. Individuals, who will move, function as supply and demand, one after another and can influence the selling price of their current accomodation by their own house value perception and their degree of pessimism ρ.

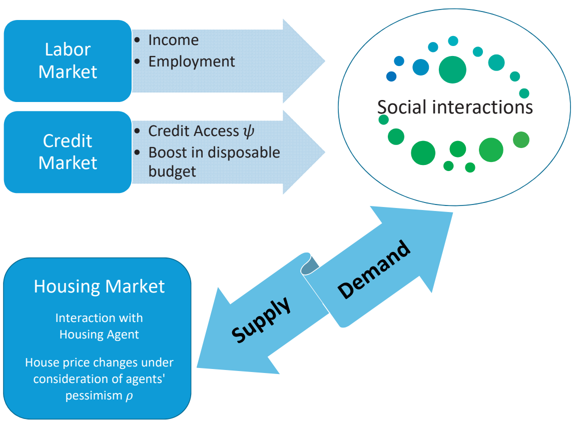


Figure 1: System Image of the Endogenous Segregation Model with Housing Market Interactions

[3]The whole simulation model is programmed in *NetLogo 6.0.2*

The upcoming subchapters will contain a detailed description of the model. Chapter 2.1 gives an overview of the simulation process and provides the reader with a flow chart for an overall picture. In 2.2, the actual model will be introduced, Chapter 2.3 gives insights about the housing market procedures and finally, Chapter 2.4 shows the parametrization of the model.

2.1 Process Overview

In every period, there are several procedures, which take place. Figure 2 shows the process within an overview.

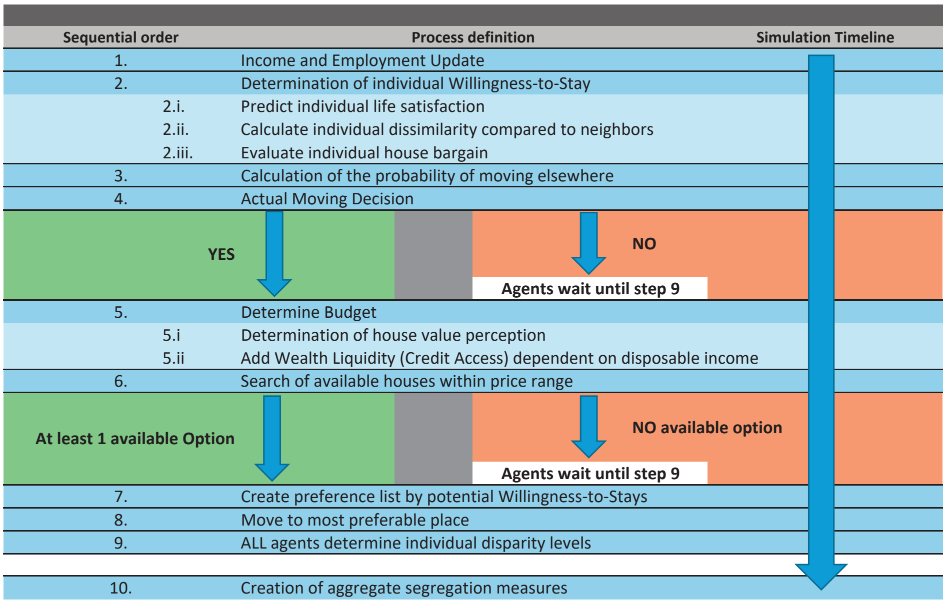


Figure 2: Process Overview of the Endogenous Segregation Model with Housing Market Interactions

All individuals have to perform procedure 1.-4., in which they determine their individual Willingness-to-Stay. This component is a key feature of the model, since it contains information about the individual life-satisfaction, current differences in comparison to direct neighbors and if recently moved, the attained house bargain. Thus, it is an information provider on group affiliation to the current neighbors with respect to income, education and house prices. Furthermore, individuals use the Willingness-to-Stay as moving determinant and as a proxy for preferences within the searching process in order to find the most suitable neighborhood.

Depending on the outcome of the "Moving Decision" in procedure 4., the process only continues for individuals, who decided to move elsewhere. The other individuals are satisfied with their neighborhood and do not interact on the housing market. In steps 5 and 6, the potential movers determine the disposable budget and check the urban area for unoccupied spaces, which fit into their personal price range. If no accomodation was found, the process pauses for those agents. The others follow the procedures 7. and 8., in which individuals create a preference list of potential spots and move to the most favored one. The ranking is made by determining the potential "Willingness-to-Stay" in each of the other neighborhoods. In step 9 and 10, individuals determine their current disparity level with respect to income, education, house prices and ethnicity. The aggregate segregation is the mean over the individual disparity levels.

2.2 Neighborhood interactions and Willingness-to-Stay

In Schelling's original approach, agents tolerate a certain share of direct neighbors with different ethnicity. The value was set to a fraction of $F = \frac{2}{3}$. Whenever the relative amount of neighbors with another ethnicity surpassed this fraction, the individual became unhappy and moved to another location.

In my approach, individuals determine their "Willingness-to-Stay" according to their socioeconomic status and the comparison to the direct neighbors within a Moore neighborhood [4]. In order to formalize the Willingness-to-Stay, I introduce Equation (1), which shows the analytical relation.

$$WS_{i,n,t} = \delta_1 \tau_{i,n,t} + \delta_2 (1 - \Delta_{i,n,t}) + \delta_3 HP_{i,n,t}^{index} \quad , \tag{1}$$

where $WS_{i,n,t}$ denotes individual i's Willingness-to-Stay, located in the center of a Moore neighborhood n at time t. It gets positively affected by higher individual life-satisfaction $\tau_{i,n,t}$, higher similarity to the respective neighbors $(1 - \Delta_{i,n,t})$ and a potentially attained house bargain $HP_{i,n,t}^{index}$, which is also denoted as house price index. δ_j with $j \in \{1, 2, 3\}$ are weighting parameters. Note that $\{(WS_{i,nt}, \tau_{i,n,t}, HP_{i,n,t}^{index}, \delta_j) \in \mathbb{R}^+ | \ 0 \leq (WS_{i,t}, \tau_{i,n,t}, HP_{i,n,t}^{index}, \delta_j) \leq 1\}$.

After determining the value for $WS_{i,n,t}$, household i decides if she moves to another neighborhood or

[4] A Moore neighborhood describes a locational situation, in which the respective agent is centered in a 3x3 field matrix. The surrounding 8 spots can be interpreted as direct neighbors.

stays situated within the current neighborhood n.

$$MD_{i,n,t} = \begin{cases} 0 & \textit{if } WS_{i,n,t} \geq 0.6 \quad \vee \quad X \geq Pr(move_{i,n,t} \mid 0.25 \leq WS_{i,n,t} < 0.6) \\ 1 & \textit{if } WS_{i,n,t} < 0.25 \ \vee \quad X < Pr(move_{i,n,t} \mid 0.25 \leq WS_{i,n,t} < 0.6) \end{cases} , \tag{2}$$

where $MD_{i,n,t}$ denotes the moving decision of individual i currently living in neighborhood n in period t. If her Willingness-to-Stay is larger than 60%, then agent i keeps living in neighborhood n and ends the process. In case household i determined her Willingness-to-Stay being lower than 25%, then the moving decision is made, since she is rather unhappy with her current neighbors. In each case in equation (2), two other conditions can be found. Individual i also makes her moving decision according to a random draw X within a stochastic process, whenever the value of $WS_{i,n,t}$ may lie within the interval $[0.25; 0.6]$. Note that $Pr(move)_{i,n,t} = 1 - WS_{i,n,t}$.

In the following subsections, equation (1) gets divided into its essential parts by discussing the psychological and analytical motivations for the respective influences. Thus, Chapter 2.2.1 discusses the details about the individually perceived life-satisfaction. Chapter 2.2.2, then, sets focus on individual's similarity measured by a multidimensional index and Chapter 2.2.3 examines the reasoning for house bargains and the accompanied house price index.

2.2.1 Determination of Agents' Life-Satisfaction

According to Veenhoven (1991, p.3), the term "life satisfaction" has been defined as follows: *"Life satisfaction is conceived as 'the degree to which an individual judges the overall quality of his life-as-a-whole favourably' "*. Based on this definition, I introduce a life-satisfaction function, which depends on income, education and individual dissatisfaction. The latter is influenced by individual experiences, such as unemployment, economic loss if agent i moved to a different neighborhood and/or the non-ability of moving, due to affordability problems [5]. Agent i's quality of life is strongly affected by the comparison to the direct neighbors. This approach goes back to Festinger (1954), who formally introduced and empirically tested the social comparison theory. Festinger (1954) claims that individuals constantly compare each other to their peers in order to assess

[5] see equation (5)

their attitudes and abilities. Equation (3) shows the analytical formalization of the life-satisfaction function.

$$\tau_{i,n,t} = \alpha_1(1-\nu_{i,t}) + \alpha_2 Y^{index}_{i,n,t} + \alpha_3 E^{index}_{i,n,t} \quad , \tag{3}$$

where $\tau_{i,n,t}$ denotes agent i's life satisfaction at time t. $\nu_{i,t}$ expresses the agent's dissatisfaction in every period. Furthermore, $Y^{index}_{i,n,t}$ and $E^{index}_{i,n,t}$ describe relations about individual i's standing compared to the direct neighbors within a Moore neighborhood in period t. α_m with $m \in \{1,2,3\}$ are weighting parameters. Note that $\{(\tau_{i,n,t}, \nu_{i,t}, Y^{index}_{i,n,t}, E^{index}_{i,n,t}, \alpha_m) \in \mathbb{R}^+ \mid 0 \leq (\tau_{i,n,t}, \nu_{i,t}, Y^{index}_{i,n,t}, E^{index}_{i,n,t}, \alpha_m) \leq 1\}$.

The indices $Y^{index}_{i,n,t}$ and $E^{index}_{i,n,t}$ capture empirical evidence in the literature according to the effect of peers' income and education on one's individual life satisfaction. Here, Rickardsson & Mellander (2017) examine if individual life satisfaction correlates with personal absolute income and/or with relative income under consideration of the neighbors' income. The authors find positive significant effects on life satisfaction for both absolute and relative earnings. Thus, individuals are not only more satisfied if they have a high income, but become even happier if their earnings are higher than the ones from their peers. Nikolaev (2016) analyses how individuals' years of education and the average years of education of the peer group influence an individual's happiness. Using data from the 'Household Income and Labour Dynamics in Australia' survey, he finds that peer group education is negatively correlated with individual happiness. Hence, an increase in the average education of the peers leads to less happiness, if the own educational level remains constant.

Accordingly, I introduce equation (4), which indexes the variables income $Y_{i,t}$ and education $E_{i,t}$, respectively. The transformation process for $Y_{i,t}$ and $E_{i,t}$ is identical, for which reason the auxiliary variable Z is introduced. The effect on life satisfaction becomes equal to 1 if agent i has the maximum income/education. If the household has the minimum endowment, then the index becomes equal to 0.

$$Z^{index}_{i,n,t} = \frac{Z_{i,t} - Min\{Z_{n,t}\}}{Max\{Z_{n,t}\} - Min\{Z_{n,t}\}} \quad , \tag{4}$$

where $Min\{Z_{n,t}\}$ and $Max\{Z_{n,t}\}$ denote the minimum and maximum value of variable Z in neighborhood n at time t.

In this modelling setup, the income level, unlike the educational level, is not fixed across all simulation periods. This implies that not only the individual income of households varies, but also their employment status. There are three possible updates, namely a potential drop-out of the labor market, a potential entry into the labor market or a job position change. I assume that high-income agents have a lower probability to become unemployed than low-income agents. Furthermore, I assume that unemployed individuals, who enter the labor market, cannot earn as much as incumbent workers. The reemployment salary is lower than at the beginning of the simulation process. The labor market interactions are proxied by changes in individual income. The income update follows a stochastic process, since it does not stand in focus of this paper. The probabilities are chosen in order to maintain an unemployment rate of approximately 4.5%.

After the income update, agents determine their individual dissatisfaction. This variable is affected by three different influence factors, namely the time being unemployed, if not operating on the labor market, the fact that the agent was unable to move in the last period and if agents suffered under economic loss after moving. Equation (5) shows the analytical form of the dissatisfaction function.

$$\nu_{i,t} = \beta_1 \frac{T_{e_{i,t}=0}}{Max\{T_{e_{all,t}=0}\}} + \beta_2 NM_{i,t-1} + \beta_3 EL_{i,t-1} \quad , \tag{5}$$

where $\frac{T_{e_{i,t}=0}}{Max\{T_{e_{all,t}=0}\}}$ denotes agent i's time of being unemployed in relation to the maximum time an individual has been unemployed in the entire society. $T_{e_{i,t}=0}$ gets reset if agent i reenters the labor market. $NM_{i,t-1}$ represents a dummy, which becomes equal to 1, if agent i decided to move, but could not afford any other place in period $t-1$. $EL_{i,t-1}$ is a dummy variable equal to 1, if agent i suffered under economic loss in $t-1$. β_o with $o \in \{1, 2, 3\}$ are weighting parameters. Note that $\{\beta_o \in \mathbb{R}^+ \mid 0 \leq \beta_o \leq 1\}$.

2.2.2 Determination of Agents' Dissimilarity

In the literature, the Dissimilarity Index is used to express the overall degree of an uneven distribution of different populations within one society (Sakoda, 1981, p.245). It is important to stress the term "evenness", since the deviation of an evenly distributed society results in segregation patterns (Massey and Denton, 1988, p.284). Accordingly, the Index of Dissimilarity is commonly used as a tool to measure segregation. It captures how the population composition of each neighborhood differs to the population composition of the whole economy (Barros and Feitosa, 2018, p.5).

It follows that the Dissimilarity Index is used to measure how smaller entities stand in relation to the entire system in terms of evenness. In this paper, I make use of this definition and introduce a smaller-scale reflection of the Dissimilarity Index, in which the index is not used as a macro evaluation of unevenness, but rather as tool to measure unevenness within a neighborhood. The index considers differences among several dimensions of agents' endowments. Thus, individual i determines how much she differs from her direct neighbors. Equation (6) provides information on agent i's sense of belonging.

$$\Delta_{i,n,t} = \left| \gamma_1 \frac{Y_{i,t} - \bar{Y}_{n-i,t}}{Max\{Y_{n,t}\}} + \gamma_2 \frac{E_{i,t} - \bar{E}_{n-i,t}}{Max\{E_{n,t}\}} + \gamma_3 q_{i,n,t} \right| \quad , \tag{6}$$

where $\bar{Y}_{n-i,t}$ denotes the average income of the direct neighbors without consideration of agent i himself. $Max\{Y_{n,t}\}$ represents the income of the richest agent within neighborhood n. Agent i determines how much he deviates from the average income in his current location and sets the absolute difference in relation to the maximum income within the area. The effect of the income relation on dissimilarity is stronger, the higher the difference between agent i's income and the mean income becomes. The same relation holds for the deviation of individual education levels, where $\bar{E}_{n-i,t}$ stands for the average education in neighborhood n without agent i. $Max\{E_{n,t}\}$ denotes the maximum level of education in the current neighborhood.

Finally, $q_{i,n,t}$ represents a quota, which gets formed in each period t depending on the number of agents j in neighborhood n. It captures the share of neighbors with a different ethnicity ($SC_i \neq SC_j$) than agent i.

$$q_{i,n,t} = \frac{\sum_{\substack{j=1 \\ SC_i \neq SC_j}}^{Max\{j\} \in n} j_{n,t}}{\sum_{j=1}^{Max\{j\} \in n} j_{n,t}} \quad , \tag{7}$$

Note that γ_p with $p \in \{1, 2, 3\}$ are weighting parameters for the multidimensional dissimilarity index. Furthermore, $\{(\Delta_{i,n,t}, q_{i,n,t}, \gamma_p) \in \mathbb{R}^+ \mid 0 \leq (\Delta_{i,n,t}, q_{i,n,t}, \gamma_p) \leq 1\}$ and $(\bar{Y}_{n-i,t}, \bar{E}_{n-i,t}, Max\{Y_{n,t}\}, Max\{E_{n,t})\} \in \mathbb{R}^+$.

2.2.3 House Price Development and Neighborhood House Bargain

As final determinant, individuals need to evaluate if the purchasing price of the current accomodation was appropriate compared to prices of the neighboring houses. For this purpose, I introduce the house price index, shown in equation (8). $HP^{index}_{i,n,t}$ becomes equal to 1 if agent i owns the house with the lowest buying price $P_{i,k,t-t_0}$ in the respective neighborhood. On the other hand, $HP^{index}_{i,n,t}$ is 0, if the agent bought the most expensive accomodation. This implies that agents, who manage to buy a house within their price range become more satisfied, if the neighborhood is considered to be more expensive.

$$HP^{index}_{i,n,t} = \frac{P_{i,k,t-t_0} - Max\{P_{n,t}\}}{Min\{P_{n,t}\} - Max\{P_{n,t}\}} \tag{8}$$

The index $t - t_0$ denotes the ownership time of agent i for the accomodation on location k. Note that $\{HP^{index}_{i,n,t} \in \mathbb{R}^+ | \; 0 \leq HP^{index}_{i,n,t} \leq 1\}$.

In general, the house prices themselves adjust towards the exogenous fundamental house values, if the prices deviate negatively. Secondly, house prices get reset to $P_{k,t} = 70\% P_{k,t-3}$, if houses remain unoccupied for three periods. However, house prices cannot fall below a certain threshold value, namely a minimum of $Min\{P_{k,t}\} = 7.500$ monetary units.

2.3 Housing Market Interactions

In Schelling's Spatial Proximity Model, moving agents can occupy any free available spot on the grid. In my model, I make the moving process dependent on housing market interactions, so house prices by the supply side and individual disposable budget and credit accessibility by the demand side. The focus lies on house ownership, due to the high share of house ownership in e.g. the United States and the United Kingdom. Also, individuals may suffer under potential economic loss after moving (Dorn, 2008), which may result in higher dissatisfaction. For the transactions on the housing market, individuals have to interact with a fictitious housing agent. This means that agents sell their houses to the housing agent and can only buy a new accomodation by interacting with that agent again. The individuals represent both sides of the market: demand and supply.

During the search process, individuals determine their budget and rank the available spots according to their preferences. The valuation for the own house occurs by the individuals themselves, since they may underestimate the own house due to bad individual life perception. As a consequence, they adjust the mark-up for the selling process.

2.3.1 Affordability and Budget Creation

Each individual determines her Willingness-to-Pay ($WP_{i,k,n,t}$) for her current accomodation, dependent on the neighborhood constellation and the dissimilarity from her direct peers. Thus, agent i determines her subjective value of the accomodation with the information set, she attains during her stay in neighborhood n at time t. I assume that individuals cannot evaluate their house objectively, due to a biased perception towards the neighborhood and the house itself. Accordingly, the individual's Willingness-to-Pay is a function of agent's Willingness-to-Stay. Equation (9) formalizes this process.

$$WP_{i,k,n,t} = P_{i,k,t-t_0} * (WS_{i,n,t})^{\rho} \quad , \tag{9}$$

where $WP_{i,k,n,t}$ denotes the Willingness-to-Pay for the current accomodation. $P_{i,k,t-t_0}$ shows the former buying price, agent i paid in period t_0 for the current house and $(WS_{i,n,t})^{\rho}$ is the degree of discounting[6] for the subjective evaluation of one's accomodation.

The parameter ρ can be interpreted as the degree of pessimism an individual has. If an individual is more pessimistic, she perceives the value of her current house worse than the actual buying price [7]. The perception is the quantification of how much the individual would be willing to pay herself for the same accomodation. Note that $(WP_{i,k,n,t}, \rho) \in \mathbb{R}^+$.

In a next step, agent i determines an individual mark-up factor $\mu_{i,t}$ for the selling process, which gets added to the Willingness-to-Pay $WP_{i,k,n,t}$ to create a larger budget for the buying process. The basic idea here is that agent i wants to improve herself, even though the subjective perception of improvement is not an actual enhancement. This mark-up gets determined by the difference of the original fundamental house value and the last buying price. The analytic relation is shown below.

$$\mu_{i,t} = \theta \frac{FHV_k - P_{i,k,t-t_0}}{FHV_k} + 0.5 \qquad \text{,with } FHV_k \neq 0 \tag{10}$$

Equation(10) states that the mark-up becomes close to a value of $\mu_{i,t} = 0.5$, the closer the buying price $P_{i,k,t-t_0}$ is to the Fundamental House Value FHV_k. If $P_{i,k,t-t_0}$ becomes larger than FHV_k, then $\mu_{i,t}$ is smaller than 0.5. Contrarily, the mark-up factor $\mu_{i,t}$ becomes larger the smaller the $P_{i,k,t-t_0}$ gets. Thus,

[6] Note that $0 \leq WS_{i,n,t} \leq 1$

[7] This accounts for the majority of all agents, who generate $WS_{i,n,t} < 1$

the mark-up functions as counterfactor to the price changes on the micro level. Note that θ is a weighting factor with $\theta \in \mathbb{R}^+$. Depending on the outcome, agent i adds the mark-up factor to his Willingness-to-Pay to get his Willingness-to-Accept ($WA_{i,k,n,t}$). The individual communicates this value to the housing agent. Equation (11) shows this relation.

$$WA_{i,k,n,t} = (1 + \mu_{i,t}) * WP_{i,k,n,t} \quad . \tag{11}$$

The individual predicts his disposable budget by adding the Willingness-to-Accept and possible credit loans depending on the personal income. Equation (12) shows the budget creation.

$$B_{i,t} = \psi Y_{i,t} + WA_{i,k,n,t} \quad , \tag{12}$$

where $B_{i,t}$ denotes the individual disposable budget of agent i in period t. ψ represents the credit access, which adds potential monetary units to the Willingness-to-Accept $WA_{i,k,n,t}$, dependent on individual income. Now, the individual seeks available unoccupied spots. The prices have to fit into the individual price range $WP_{i,k,n,t} < P_{\neq j,k,t} \leq B_{i,t}$. Thus, the respective price $P_{\neq j,k,t}$ lies between the current Willingness-to-Pay $WP_{i,k,n,t}$ and the personal disposable budget $B_{i,t}$. This restriction implies that agent i is able to subjectively improve himself, but is limited due to the maximum of the disposable budget. The information of all available spots is collected by agent i within the set $A_{i,k_{\neq j},t}$, which is a subset of all unoccupied spots $K_{\neq j}$. Thus, $A_{i,k_{\neq j},t} \subseteq K_{\neq j}$.

2.3.2 House Preferences and the Moving Process

The set $A_{i,k_{\neq j},t}$ may contain one or more suitable places, which fit within the individual price range at time t. In the latter case, agent i evaluates each possible spot $k_{\neq j}$ by its potential Willingness-to-Stay and ranks the houses according to the maximum value. Individuals prefer a neighborhood n , where they can mostly identify themselves with the direct neighbors. In economic terms, individuals look for the best house bargain. The agents' motivation is to balance the potential sense of belonging with the buying price of the new accomodation. The location with the highest potential Willingness-to-Stay gets chosen. Note that agent i's evaluation depends on the current constellation of potential neighbors in the new neighborhood. Due to the sequentiality of the simulation process, agent i does not know if the new neighbors j will remain in the neighborhood.

From a computational point of view, agent i follows the steps described in equation (1) in order to quantify his potential happiness in each neighborhood. Agent i uses the numerical expression for his current life satisfaction $\tau_{i,n,t}$, but computes the potential dissimilarities and the house indices newly. This hypothetical dissimilarity from potential new neighbors requires a full set of information, which I assume agents attain from the fictitious housing agent. Accordingly, agent i determines a set $\Delta_{i,K_{\neq j},t}$, in which he gathers information about the dissimilarity of all available spots $\Delta_{i,k_{\neq j},t}$ using the relations from equation (6). Note that $\Delta_{i,K_{\neq j},t} = \{\Delta_{i,k_{\neq j,1},t},\ \Delta_{i,k_{\neq j,2},t},\ \Delta_{i,k_{\neq j,3},t},\ \ldots\}$. The enumeration of the set $\Delta_{i,K_{\neq j},t}$ does not contain any ranking of the numerical values for dissimilarity. It only lists the dissimilarities found in the potential neighborhoods. Thus, $k_{\neq j,1}$ refers to the first housing option, $k_{\neq j,2}$ to the second one etc.

Agent i then follows the process shown in equation (8) by determining the potential house bargain within all suitable neighborhoods. The individuals create a set of hypothetical house bargains $HP^{index}_{i,K_{\neq j},t}$, in which they collect the different indices $HP^{index}_{i,k_{\neq j},t}$. Note that $HP^{index}_{i,K_{\neq j},t} = \{HP^{index}_{i,k_{\neq j,1},t},\ HP^{index}_{i,k_{\neq j,2},t},\ HP^{index}_{i,k_{\neq j,3},t},\ \ldots\}$. $HP^{index}_{i,k_{\neq j,1},t}$ refers to the same potential spot as $\Delta_{i,k_{\neq j,1},t}$. With these information sets, agent i can determine the set of Willingess-to-Stays for all potential neighborhoods. The set is denoted as $WS_{i,K_{\neq j},t}$ and contains the subset $WS_{i,k_{\neq j},t}$, for which agent i predicts the Willingness-to-Stay for each potential spot. Note that $WS_{i,K_{\neq j},t} = \{WS_{i,k_{\neq j,1},t},\ WS_{i,k_{\neq j,2},t},\ WS_{i,k_{\neq j,3},t},\ \ldots\}$.

Agent i moves to the spot, where he determined the maximum Willingness-to-Stay within the set $WS_{i,K_{\neq j},t}$. Due to the sequentiality of the modelling setup, it is unreasonable to assume that agents can "crowd out" other agents in the same period, since agent i performs his ranking before agent j started to compute.

2.4 Model Setup, Initialization and Agents' Endowments

2.4.1 Agents' Characteristics

Individuals get endowed with several characteristics, namely an ethnic affiliation, an employment status, income and educational level. For the ethnic composition, I follow the approach of Schelling (1971), in which individuals get assigned to ethnicity "red" and "green", determined by a uniform distribution. Each individual has a probability of 50% to become part of the home population or to be affialited to the migrated population. Furthermore, the assignment of agents' income follows an exponential distribution with $E[Y_{i,t_0}(X)] = 40.000$.

The value of $E[Y_{i,t_0}(X)] = 40.000$ is the mean over the yearly disposable income (current prices) per capita in 2015 in the United States (OECD, 2017). Since 6.5% of the total amount of employed US households in 2016 earn less than 10.000 USD per year, I assume that the minimum income in the model is equal to 10.000 monetary units, for simplicity reasons(U.S. Census Bureau, 2017). If unemployed, agents get unemployment benefits of 6.000 monetary units[8]. Being unemployed is shown with a dummy variable e_{i,t_0}, which is equal to 0, if the individual is unemployed and equal to 1, if employed. The status gets determined in the initial period and follows a uniform distribution, where all agents have a probability of 5% to be unemployed.

Agents also get endowed with an individual level of education. In this setup, I use years of education for each agent, based on attendance years in educational institutions for the United Stated. The assignment follows a truncated normal distribution, where the minimum is set to 11 years and the maximum to 21.

2.4.2 Initialization of the Housing Market

In this model, I introduce an actual buying price $P_{k,t}$ for patch k at time t and an objective fundamental house value v_k. v_k remains constant over the whole simulation process, whereas $P_{k,t}$ changes according to the market mechanism in each period. During the initialization, the objective fundamental house value v_k and the buying price $P_{k,t}$ are set equal to each other. The assignment follows a one-sided truncated normal distribution. The values are based on data from the American Housing Survey, provided by the U.S. Census Bureau (2015). Note that the mean is $\mu = 220,000$, the standard-deviation $\sigma = 259,972$[9], $a = \Pi_1 = 7,500$ and the parameter and the minimum $min\{P_{k,t_0}\} = 7,500$. The data was extracted by the *AHS Table Creator* and the following criteria: national selected area, 2015; selected variable "Value" under "Value, Purchase Price, and Source of Down Payment", geographic filter is set to "2013, Metropolitan Area - In central cities". Note that v_k and $P_{k,t} \in \mathbb{R}^+$.

[8]This is based on own calculations using data from January 2018 provided by the United States Bureau of Labor Statistics (2018)

[9]The expected value and the standard deviation are based on own calculations using the given data set

2.4.3 Parametrization for model equations

In this paper, the parameters are set to the values shown in Table 1. For future research and sensitivity analyses, the variation of parameters with respect to individual happiness, life-satisfaction and dissimilarity, particularly, will stand in focus in order to answer the research questions with respect to higher agents' heterogeneity.

Table 1: Parameterization of important model equations

	parameter value	**respective function**	**comments**
(i)	$\delta_j = \frac{1}{3}$	Willingness-to-Stay, equation (1)	Individuals weigh life-satisfaction, neighbor similarity and house bargain in the same way
(ii)	$\alpha_m = \frac{1}{3}$	Life-satisfaction, equation (3)	Dissatisfaction, income index and education index have the same weight
(iii)	$\beta_o = \frac{1}{3}$	Dissatisfaction, equation (5)	Similar effect of unemployed time, affordability problems and economic loss
(iv)	$\gamma_p = \frac{1}{3}$	Dissimilarity, equation (6)	Difference according to income, education and ethnicity is similarly valued
(v)	$\rho = 1$	Willingness-to-Pay, equation (9)	The degree of pessimism is normed to 1
(vi)	$\theta = 1$	Mark-Up determination, equation (10)	The mark-up parameter is normed to 1
(vii)	$\psi = 1$	Budget creation, equation (12)	The credit access is normed to 1

3 Model Analysis and Results

3.1 Segregation Indices

For the analyses of the research questions, I introduce two more functions, which measure the segregation outcome according to income, education, house prices and ethnicity. I show a disparity index on the agents' level and present the aggregate segregation function as mean over the individual disparities. My approach does not only mirror the absolute deviations between neighborhoods and society, but also captures the relative degree of homogeneity of neighborhood n to the global level. The approach is based Reardon and Firebaugh (2002), who use the segregation measure as ratio of diversity taking the relation of "within-unit diversity" to "total-population diversity". Equation (13) shows the disparity index.

$$D_{i,c,t}^{index} = \begin{cases} \zeta_1\big(\big|1 - \frac{\mu_{i,n,c,t}}{\mu_{c,t}}\big|\big) + \zeta_2\big(1 - \frac{\sigma_{i,n,c,t}}{\sigma_{c,t}}\big) & \text{with } \sigma_{i,n,c,t} < \sigma_{c,t} \\ \\ \zeta_1\big(\big|1 - \frac{\mu_{i,n,c,t}}{\mu_{c,t}}\big|\big) & \text{otherwise} \end{cases}, \tag{13}$$

where $D_{i,c,t}^{index}$ denotes the degree of neighborhood disparity conducted by agent i at time t with characteristic c. c contains the attributes income, education, house prices and ethnicity, thus: $c = \{Y_{i,t}, E_{i,t}, P_{i,k,t-t_0}, SC_{i,t}\}$. The absolute disparity level is mirrored by the deviation in the expected value $\big(\big|1 - \frac{\mu_{i,n,c,t}}{\mu_{c,t}}\big|\big)$ and the degree of homogeneity is stated by the discrepancy in the standard deviation $\big(1 - \frac{\sigma_{i,n,c,t}}{\sigma_{c,t}}\big)$. If the current neighbors are more similar to the individual, with respect to at least one attribute (so $\sigma_{i,n,c,t} < \sigma_{c,t}$), the fraction converges to 0, thus, the effect on $D_{i,c,t}^{index}$ converges to ζ_2. Then the neighborhood is considered to be rather homogenous [10]. In both cases, the absolute deviation varies between 0 and ζ_1. Note that $\zeta_{1,2}$ are weighting parameters and $\{(D_{i,c,t}^{index}, \zeta_{1,2}) \in \mathbb{R}^+ |\ 0 \leq (D_{i,c,t}^{index}, \zeta_{1,2}) \leq 1\}$ and $(\mu_{i,n,c,t}, \mu_{c,t}, \sigma_{i,n,c,t}, \sigma_{c,t}) \in \mathbb{R}^+$.

The aggregate segregation measure $S_{c,t}$ is the mean over all neighborhood disparities determined by all agents N.

$$S_{c,t} = \frac{1}{N} \sum_{i=1}^{N} D_{i,c,t}^{index} \tag{14}$$

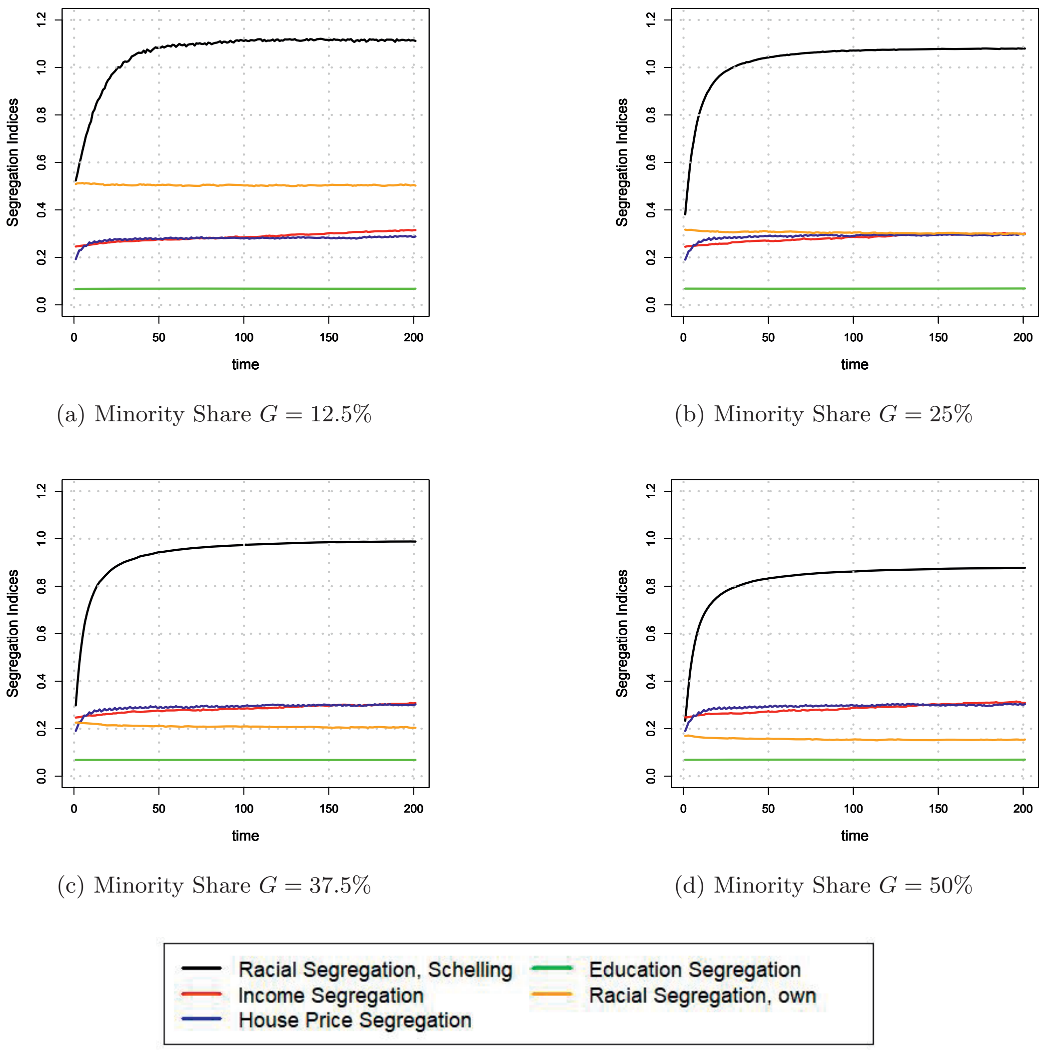
Neighborhoods with higher degrees of disparity are the reason for more observable segregation patterns. Note that $\{S_{c,t} \in \mathbb{R}^+ |\ 0 \leq S_{c,t} \leq 1\}$.

3.2 Racial Residential Segregation and the Effect of Housing Market Processes

In order to answer the question, if housing market interactions reinforce racial residential segregation, I modified Schelling's Spatial Proximity model to the framework I suggest in this paper, only with ethnicity as driving force. Socioeconomic variables are set to 0. The moving decision is identical to Equation (2), but the moving process differs. In Schelling's Proximity Model, agents move randomly to any free spot. For the modification, I kept this assumption.

[10] If $\sigma_{i,n,c,t} > \sigma_{c,t}$, the neighborhood has a greater heterogeneity than society. This case is not of particular interest for segregation research, since segregation can be observed by a variety of homogenous neighborhoods. Thus, if $\sigma_{i,n,c,t} \geq \sigma_{c,t}$, then $\zeta_2\big(1 - \frac{\sigma_{i,n,c,t}}{\sigma_{c,t}}\big) = 0$.

In the baseline scenario (with $\rho = \psi = 1$), the modified Schelling model and the full model with socioeconomic endowments and housing market interactions [11] are computed 50 times to eliminate stochastic noise. The comparison between both models is made by varying the shares of both ethnicities G (=minority population) and $1 - G$ (=majority population), respectively. Note that $G \in [0.125; 0.25; 0.375; 0.5]$. Figure 3 shows this comparison.



(a) Minority Share $G = 12.5\%$

(b) Minority Share $G = 25\%$

(c) Minority Share $G = 37.5\%$

(d) Minority Share $G = 50\%$

Figure 3: Various Segregation Indices in comparison: the *modified model* and the *multi segregation model*

According to Figure 3, racial segregation in the *modified model* is significantly higher than the four segregation indices computed by the *multi segregation model*. The curve takes approximately 20 - 30 periods

[11] From now on, I call the model introduced in this paper the "multi segregation model" and the modified Schelling's Spatial Proximity the "modified model"

to reach its stable state, whereas the segregation indices in the *multi segregation model* are rather stable after a short burn-in phase between the initial period and $t = 1$. In absolute terms, the last values of the computations are more than the double amount of what can be observed in the four segregation indices. The reason behind this outcome is that in the *modified model*, agent clusters form very quickly, since ethnicity is the only driving force. As soon as several potential cluster opportunities are introduced, individuals evaluate their whole situation, so that socioeconomic status becomes more important than only ethnicity. This leads to many integrated neighborhoods.

As soon as the share of the minority population increases, racial segregation denotes a lower absolute value in both models. In the *modified model*, the clusters converge to identical sizes, whereas the *multi segregation model* shows that racial clusters become smaller. Thus, racial segregation, in both models, is driven by the higher amount of ethnic homogenous neighborhoods of the majority population.

Across the four scenarios with varying minority shares, income, house price and education segregation remain at a constant level and are not affected by the change of the population share. In the *multi segregation model* income and house price clusters show a higher relevance, as soon as the share of the minority population becomes larger than 25%. This implies that housing market processes and socioeconomic factors diminish the level of racial segregation rather than reinforcing it. Thus, segregation patterns appear on several dimensions, namely income segregation, house price segregation, racial segregation and education segregation.

These findings go along with the research of Harting & Radi (2018), who introduce a dynamic evolutionary model with heterogenous agents and market prices of housing. The authors find that integrated neighborhoods occur, if ethnic segregation gets counterbalanced by income stratification. Thus, the combination of ethnic and economic factors facilitate integration. Also Pfeiffer (2016) confirms this result stating that the more equal the minorities' incomes are to the White population, the greater the racial equity within the neighborhood. The author uses an econometric analysis with US Census data for 88 regions from 2000 to 2012. There is evidence that an urban area with newer housing stocks is associated with less racial segregation (Pfeiffer, 2016, p.814). In conclusion, racial segregation diminishes if socioeconomic factors and housing market processes are considered.

3.3 Reasons to remain in neighborhoods

In this chapter, I analyze the actual numerical effects on the willingness to stay in a neighborhood. I simulate the model 50 times for each population composition $G \in [0.125; 0.25; 0.375; 0.5]$ and store data from each individual i, who computed a value of $WS_{i,n,t} \geq 0.6$ in neighborhood n at period t. The initialization occurred only once to keep individual endowments across simulation runs. The stored variables are the introduced income and education indices presented in Equation (4), the share of neighbors with different ethnicity from Equation (7) and the house bargain shown in Equation (8). In total, each individual has been satisfied with the current neighborhood, but in different frequencies. Thus, there have been individuals, who were happy during the entire simulation periods and others who were just happy occassionally.

I split the analysis into two parts. The first analysis consists of a multivariate OLS regression, which covers the relative individual standing in the neighborhood combined with the share of other ethnicities. The second analysis is a univariate OLS regression, where I measure the effect of the house bargain. The regression equation for the socioeconomic standing can be seen in Equation (15).

$$WS_{i,n,t} = \beta_0 + \beta_1 IncomeIndex_{i,n,t} + \beta_2 EducationIndex_{i,n,t} + \beta_3 PercentOthers_{i,n,t} + \epsilon_t \tag{15}$$

According to Table 2, the effects for income and education standing within a neighborhood are positive for all four population compositions. This means that individuals tend to remain in the current neighborhood, if they do not only have a high income and high education, but also higher income and a higher education than their peers as presumed by Rickardsson & Mellander (2017) and Nikolaev (2016). However, the absolute effects for the Education Index are larger than the ones for the Income Index, which creates the link to the research of Malik et.al (2015), who find that the interaction amongst individuals dictates the spread of creativity and thus, highly educated individuals.

The effect of other ethnicities becomes stronger with increasing shares of the minority population and counterbalances the absolute effects of the Income and Education Indices. Even though, the Willingness-to-Stay gets reduced if the share of other ethnicities increases, the socioeconomic standing has a larger absolute impact. Thus, the outcome in Table 2 suggests that individual endowment and the relative position to one's neighbors is more relevant for the Willingness-to-Stay than only ethnic differences.

Table 2: Regression Results for Willingness-to-Stay: Individual Standing and Ethnic Composition in neighborhoods

	Dependent variable:			
	willingnessG125	willingnessG25	willingnessG375	willingnessG50
	(1)	(2)	(3)	(4)
IncomeIndexG125	0.037***			
	(0.0001)			
EducationIndexG125	0.051***			
	(0.0001)			
percentothersG125	−0.029***			
	(0.0002)			
IncomeIndexG25		0.024***		
		(0.0001)		
EducationIndexG25		0.029***		
		(0.0001)		
percentothersG25		−0.049***		
		(0.0002)		
IncomeIndexG375			0.019***	
			(0.0001)	
EducationIndexG375			0.069***	
			(0.0001)	
percentothersG375			−0.057***	
			(0.0002)	
IncomeIndexG50				0.017***
				(0.0001)
EducationIndexG50				0.042***
				(0.0001)
percentothersG50				−0.053***
				(0.0003)
Constant	0.714***	0.728***	0.720***	0.720***
	(0.0001)	(0.0001)	(0.0001)	(0.0002)
Observations	3,559,548	3,341,145	3,363,295	3,066,385
R^2	0.070	0.043	0.097	0.048
Adjusted R^2	0.070	0.043	0.097	0.048
Residual Std. Error	0.084	0.082	0.081	0.079
	(df = 3559544)	(df = 3341141)	(df = 3363291)	(df = 3066381)
F Statistic	88,644.740***	50,598.190***	120,157.700***	51,990.740***
	(df = 3; 3559544)	(df = 3; 3341141)	(df = 3; 3363291)	(df = 3; 3066381)

*p<0.1; **p<0.05; ***p<0.01

For the analysis of the house price bargain, Equation (16) shows the regression equation and Table 3 the outcome of this analysis.

$$WS_{i,n,t} = \beta_0 + \beta_1 HouseBargain_{i,n,t} + \epsilon_t \tag{16}$$

The effect of the house price bargain has a higher impact on the Willingness-to-Stay. In all four cases, the effect is larger than 0.3 units on the Willingness-to-Stay, whenever the value for the house price bargain increases. Also the coefficient of determination R^2 is higher than the R^2 in the socioeconomic comparison from Table 2. This suggests that the Willingness-to-Stay gets highly influenced by the market interactions and the subsequent bargain made within a neighborhood. The effect gets reinforced by socioeconomic standing of individuals and diminishes slightly for higher ethnic diversity within a neighborhood [12].

Table 3: Regression Results for Willingness-to-Stay: House Price Bargains in neighborhoods

	Dependent variable:			
	willingnessG125	willingnessG25	willingnessG375	willingnessG50
	(1)	(2)	(3)	(4)
houseindexG125	0.322***			
	(0.0001)			
houseindexG25		0.326***		
		(0.0001)		
houseindexG375			0.363***	
			(0.0001)	
houseindexG50				0.345***
				(0.0001)
Constant	0.497***	0.486***	0.451***	0.461***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Observations	3,559,548	3,341,145	3,363,295	3,066,385
R^2	0.683	0.740	0.775	0.759
Adjusted R^2	0.683	0.740	0.775	0.759
Residual Std. Error	0.049 (df = 3559546)	0.043 (df = 3341143)	0.041 (df = 3363293)	0.039 (df = 3066383)
F Statistic	7,674,950.000***	9,502,051.000***	11,592,515.000***	9,679,460.000***
	(df = 1; 3559546)	(df = 1; 3341143)	(df = 1; 3363293)	(df = 1; 3066383)

*p<0.1; **p<0.05; ***p<0.01

[12] These analyses have only been conducted to distinguish the absolute effects. The fact that each variable is highly significant is trivial, since the variables were used to predict the Willingness-to-Stay in the simulation model.

3.4 The inability of moving to favored locations

Due to the introduced market mechanism, agents need to have a suitable budget to afford the favored house, if they decide to move. The individual budget is described in Equation (12) and shows the dependency of individual income. Thus, it can occur that individuals make an active moving decision, but cannot move to one of the prefered locations, since their income is too low. The individuals need to remain in the neighborhood, in which they are unhappy. The concept of being locked-in is analyzed in this chapter.

In the baseline scenario, the variables for locked-in agents, the objective house prices and the actual selling prices are computed 50 times to eliminate stochastic noise. As in Chapter 3.2, the analysis is done by considering different minority shares with $G \in [0.125; 0.25; 0.375; 0.5]$. Figure 4 shows the absolute number of lock-ins.

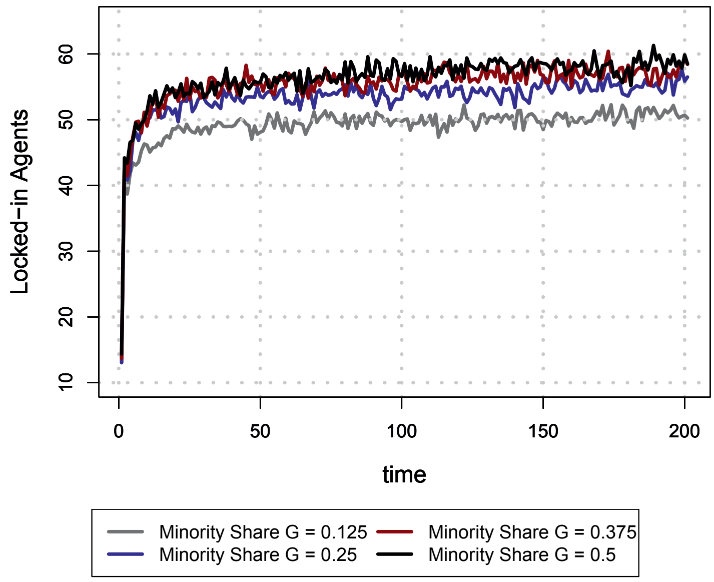


Figure 4: Lock-In effect over time with different minortiy shares

According to Figure 4, there are individuals, who cannot move to another location due to affordability problems. Each curve increases slightly over time, so that an absolute level of 50 locked-in agents can be observed in case of a minority share of 12.5%. This accounts for approximately 10% of the entire population. The absolute values for locked-in agents increase by 2%-points if the minority share increases from 12.5% to 50%, which leads to an absolute level of roughly 60 locked-in agents, or 12% of the total population. The reason for this raise is that the dissimilarity across neighborhoods gets affected more strongly by neighbors with a different ethnicity. Thus, the Willingness-to-Stay becomes lower than in the case with a lower minority share. This leads to more moving decisions, but not necessarily to more actual movings, due to affordability problems. In order to visualize and strengthen this argument, Figure 5 shows the development of house prices with different minority shares.

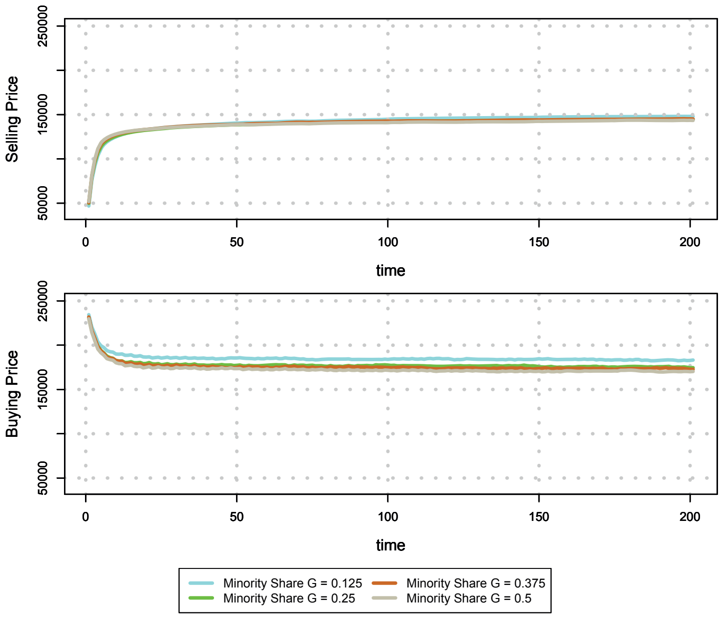


Figure 5: Price Development over time with different minority shares

The upper graph in Figure 5 shows the mean over the selling prices and the lower graph the mean over the buying prices. After a short burn-in phase, the buying prices and the selling prices remain at a constant level, where the buying prices drop and the selling prices increase. The selling prices remain at lower absolute levels than the buying prices. The reason can be found in the individual budget, which does not only depend on the selling price of the current house, but also on the individual income and the credit access. This spread is the reason, why there are several individuals, who cannot afford a new house, because the individual income is too low to match the buying prices of the favored houses. There is no evidence that the minority share in the population has a significant effect on the house price development.

Due to the deterioration of house prices caused by agents' undervaluations, the resulting economic interpretation could be *negative equity*, where the real estate property falls below the outstanding balance used to purchase the property. Ferreira et.al (2010) find that negative equity in one's house lead to less mobility rates and thus, to locked-in agents. The authors used a empirical analysis with data from the *American Housing Survey* between 1985 and 2007. This results gets confirmed by Bloze & Skak (2016), who run an empirical analysis on the Danish administrative register panel data between 2003 and 2010. As a conclusion, a lock-in effect can be observed for individuals, who interact on the housing market, due to affordability problems and due to *negative equity.*

3.5 Sensitivity analysis: Effects of various levels for Pessimism and Credit Access

In this section, the model's sensitivity is tested by analyzing the segregation outcome by changes in credit access (parameter ψ) and pessimism (parameter ρ). For this purpose, the two paramters get varied between 0 and 2 with an increment of 0.5. With this setting, I create an interval around the original parametrization. Here, the order in which the parameters are changed needs to be set. For each value of ρ all potential values of ψ are tested (e.g. if $\rho = 0.5$, then ψ gets varied between 0 to 2, before ρ gets increased). Each setting is run 50 times and averaged to eliminate stochastic noise. Thus, the model is tested with 25 parameter constellations for each of the 4 minority shares $G \in [0.125; 0.25; 0.375; 0.5]$. In total, there are 100 different parameter settings and 5.000 simulation runs.

The four aggregate segregation variables, the prices and the lock-in variable are used to determine the output of this sensitivity analysis. Since segregation patterns evolve only slowly over time and are considered to be an observable state of an urban area, the focus lies on the last values of each simulation run. The visualization is done in a 3D framework. Figure 6 shows the ethnicity segregation variable in all minority share settings with the variation of credit access (ψ) and pessimism (ρ).

The variation of credit access and pessimism do not show substantial changes on the last values of the racial segregation measure. The values increase slightly, as soon as the pessimism parameter ρ is non-zero, however the values remain at a constant level. Changes in credit access lead to no variation in the segregation outcome. The only observable changes are connected to the minority share. If the share is low (G=12.5%), racial segregation is at its highest absolute level. If the society has 2 population groups with similar size

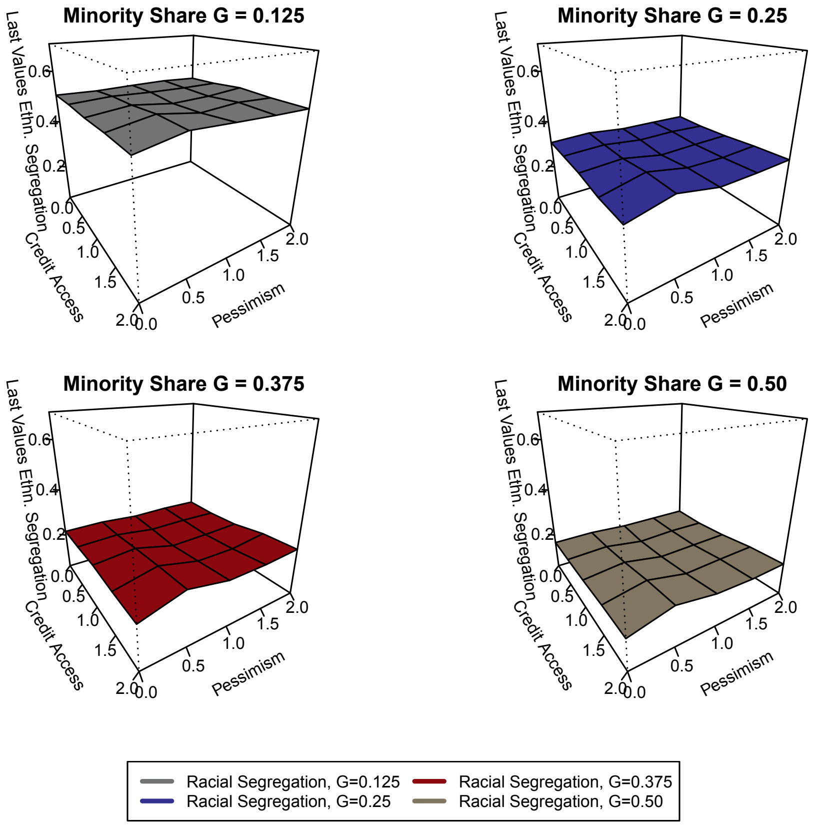


Figure 6: Last Values of Racial Segregation with varying ψ and ρ across different Minority Shares

(G=50%), racial segregation is at its lowest level. A reason for this behavior may be that the amount of racially homogenous neighborhooods decreases as soon as a higher share of another ethnic group is present in the urban area.

Figure 7 shows the house price segregation, shown in one plot. The graph shows that a varying minority share has no influence on House Price Segregation. The curves cover each other. However, credit access and pessimism affect House Price Segregation. It is mainly driven by the individual house price depreciation process of agents denoted by the parameter ρ. As soon as the parameter becomes larger, the plot shows a continuous increase of house price segregation, which leads to a higher amount of homogenous house price clusters. The dynamics level out at approximately 35% due to a lower bound for house prices at 7500 monetary units and a limited number of neighborhoods within the simulation.

On the other hand, the credit access parameter ψ has only minor effects on the segregation effect itself. Lower credit access, and thus lower disposable budget, leads to a steeper increase in house price segregation,

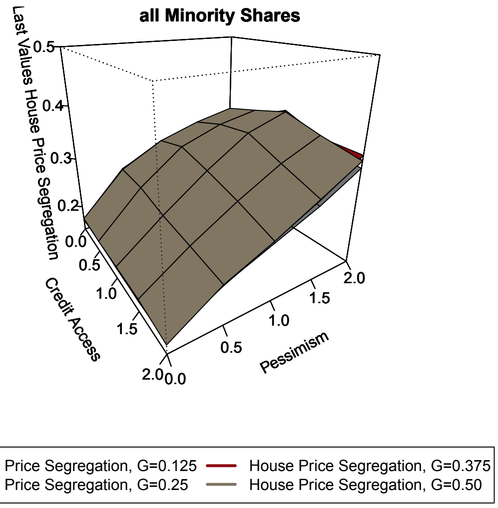


Figure 7: Last Values of House Price Segregation with varying ψ and ρ across different Minority Shares

since individuals depreciate their houses, but cannot afford a new accomodation, for which reason they keep depreciating. Thus, the set $A_{i,k\neq j,t}$ is poorly filled or even empty. The steepness of the house price segregation decreases with rising pessimism, as soon as individuals have better access to credit [13]. In this context, it is necessary to investigate on the sensitivity of locked-in agents and the respective prices. Figure 8 shows the sensitivity for the locked-in agents.

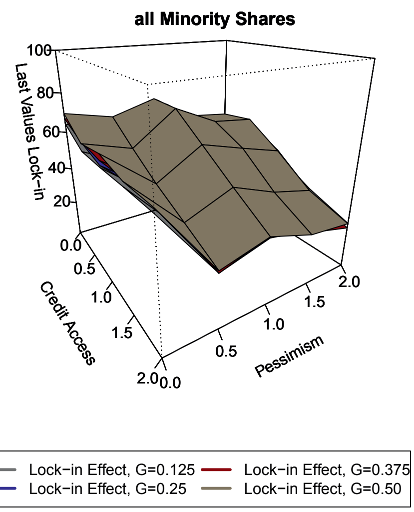


Figure 8: Last Values of Lock-in effect with varying ψ and ρ across different Minority Shares

Figure 8 shows that the number of locked-in agents decreases if the values for ρ and for ψ increase

[13]Since Income and Education show no substantial changes at all, the plots can be found in the Appendix

simultaneously. The local maxima be found at $\rho = 1$ and $\psi \in [0; 0.5]$, where the last values account for roughly 70 locked-in agents, which accounts for $\sim 13.92\%$ of the total population. The wedge at $\rho = 0.5$ is the result of minor individual house price depreciation. Thus, more agents have higher disposable budgets, because they can sell their houses more expensive than they bought them. This leads to a reduction in the spread between buying and selling prices. The effects of the increasing minority share is barely noticeable. Figure 9 shows the last values of the buying and selling prices.

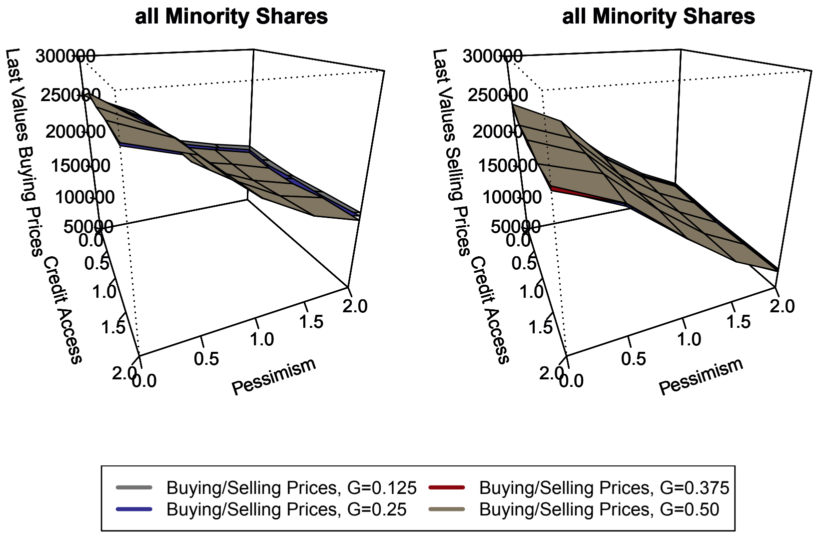


Figure 9: Last Values of House Prices with varying ψ and ρ across different Minority Shares

Figure 9 shows that individual credit access has minor effects on the buying and selling prices, per se. This lies in the fact that agents who cannot afford any new house simply do not participate in the market process. However, if parameter ρ increases, the buying and the selling prices decrease, the selling prices even stronger. This creates a larger wedge between low-income and high-income individuals. The described wedge in the lock-in effect at $\rho = 0.5$ and $\psi \in [0; 0.5]$ can also be seen in Figure 9, where the last values of the selling prices are higher than the respective buying prices. The minority shares have no noticeable effect.

4 Conclusion

This paper introduces a theoretical agent-based model for segregation patterns in urban areas and housing market interactions. My model is inspired by Schelling's Proximity Model, which is well known in the social sciences. The model here contains three main features, namely agents' endowments with socioeconomic factors like yearly income and level of education, the quantification of one's Willingness-to-Stay within a neighborhood and housing market interactions if an agent decides to move.

The analysis shows that housing market interactions and the valuation of socioeconomic factors with the direct neighbors do not reinforce racial segregation. In comparison between the *multi segregation model* and the *modified model*, racial segregation diminishes, as soon as socioeconomic endowment and house prices were introduced. However, the analysis also showed that segregation patterns occur on various levels, namely income segregation, house price segregation, racial segregation and education segregation.

The OLS regressions showed that the socioeconomic standing of individual i in neighborhood n plays an important role and outweighs the negative effect of the increasing share of other ethnicities in the neighborhood. The strongest effect on the Willingness-to-Stay has the House Index, which quantifies the relative bargain of individual i for house k in neighborhood n. In consequence, agents have a strong preference to remain in the current neighborhood, if they have good socioeconomic endowments and if they bought an affordable house in a rather expensive neighborhood.

These economic effects lead to a lock-in effect for low-income individuals, since they cannot afford to buy a new house. The spread in the selling and buying prices shows that even if low-income agents can sell their house, they are lacking the necessary credits to purchase a new home. The reason for this goes along with the principle of *negative equity*, where the real estate property falls below the outstanding balance used to buy the property. This effect occurs in this model by the deterioration of prices by higher degrees of individual pessimism.

The sensitivity analysis provides evidence that the change in minority shares has only an effect on racial segregation, whereas the other variables are not affected. Racial segregation reduces if the share increases, because the amount of homogenous neighborhoods decreases. On the other hand, income, education and racial segregation do not vary, if the individuals have higher degrees of pessimism or higher access to credits.

This only affects the actual housing market interactions and leads to an increase in house price segregation. Due to higher house price depreciation, the lock-in effect reduces with increasing credit access, since house prices become cheaper and affordable.

These findings suggest that the aggregate occurrence of segregation patterns and spatial inequality is not only the result of preferences towards other individuals with one's own ethnicity, but is strongly affected by socioeconomic endowment in absolute and relative terms. The market interactions and the possibility of owning a house in an expensive neighborhood lead to a strong Willingness-to-Stay and to various house price clusters. Thus, residential segregation is a more complex pattern than presumed by Schelling's Spatial Proximity Model or the *White Flight Hypothesis*.

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Appendix: Sensitivity Analysis for Income and Education Segregation

Income Segregation:

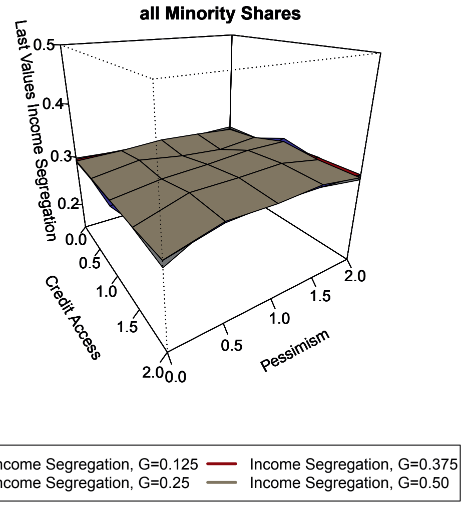

Figure 10: Last Values of Income Segregation with varying ψ and ρ across different Minority Shares

Education Segregation:

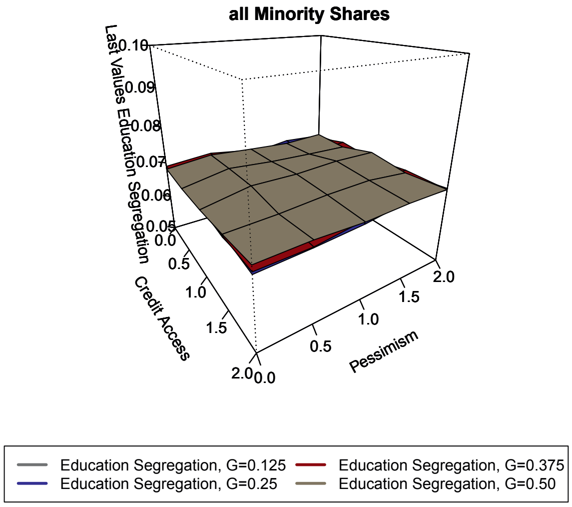

Figure 11: Last Values of Income Segregation with varying ψ and ρ across different Minority Shares