IMPACT OF INCOME INEQUALITY ON INCOME SEGREGATION

by

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B.S., Industrial Engineering, Boğaziçi University, 2011

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science

Graduate Program in Industrial Engineering
Boğaziçi University
2015

ACKNOWLEDGEMENTS

I would like to thank *Gönenç Yücel* for being my thesis advisor and guiding me throughout almost all phases of this study as well as others. His wisdom in modeling was truly an indispensable asset for me. Besides, (he might not be aware that) he has been exemplifying that pragmatism and idealism does not have to be in conflict. Our conversations were influential in critical junctions of my life. I am grateful for his sincere friendship and all his supports.

I am indebted to *Yaman Barlas* for being my ex-thesis advisor; doing almost the whole conceptual work of a different master's thesis with him was a valuable experience. More importantly, he has been one of my role models as being a renaissance man, a polymath. Every conversation we had significantly influenced me. It is impressive that I sometimes find myself having these conversations on my own!

I would like to thank *Tuna Kuyucu* for being in my committee, for his comments, and for his frankness. I am also thankful to him for initiating me to sociology with having me in his class and for having valuable conversations together.

I would like to thank the professors of industrial engineering department though some deserve special thanks. I always admire *Taner Bilgiç*'s excellent communication skills, his teaching style as well as his rigorous approach. His course "Decision Analysis" was one of my best experiences in my whole industrial engineering formation.

Kuban Altınel has been an inspring figure for me with his enthusiam to teach and for research. I am indeed grateful to him for holding classes even when I was literally the only student in the classroom. Learning the math from him was a privilege.

I thank *Aybek Korugan* for having me in his office in a hot summer day in which I ran away from the plaza I was working and talking about academia. Additionally, his "e-fırça" to all my cohort for finding some probabilities less than zero and greater than one in the final exam will remain as a dear memory; I still keep that e-mail.

I would like to express my gratitude to my parents *Handan* and *Ömer*, and to my elder sister *Betül* for their unconditional support.

I want to thank my colleagues in SESDYN; *Can*, *Nisa*, *Onur*, and *Oylum*. With them, SESDYN turned out to be an ideal lab environment for research. I specially thank *Oylum* for her technical helps and supportiveness, and for our hilarious chats.

I thank the members of CIQLE workshop at Yale's sociology department for their comments. Presenting this work's early version there was indeed very helpful.

Studying industrial engineering became joyful with *Çağlar*, *Şafak*, *Edip*, and *Mete*. I am also very happy that we got tired and learnt together during my graduate education with my companion *Gizem*.

The privilege of being able to talk with *Ürün* about a plethora of topics has been and will be invaluable for me. I am grateful to *Cihan* for being my dear companion since high school and for being the perfect housemate. There is not enough space here to detail my thanks to him. I also thank *Gökhan* for being an ideal housemate, and yes, *Coo*! was indeed the best(!) band ever. I am indebted to *Nuray teyze* for her friendship and all of the delicious meals. Although we were kept deliberately away from each other, I thank *Can* for being there whenever I need.

Finally, words are not enough and I am helpless to express my gratitude to *Dolunay*. Articulating that would be an endavour in vain.

ABSTRACT

IMPACT OF INCOME INEQUALITY ON INCOME SEGREGATION

In this study, an agent-based model is built to investigate how income inequality affects income segregation and its characteristics. The model is capable of demonstrating the expected positive relationship between income inequality and income segregation both statistically and visually. In addition, it is found that income inequality conditions the possible levels of income segregation although its positive impact tends to saturate at higher levels. In order to study the characteristics of income segregation, a typology of its profiles is elaborated and the impact of the shape of income inequality on them is studied. It is found that formation or expansion of affluent neighborhoods or gated communities has a positive impact on formation or expansion of ghettos or slums in a city, and vice versa. Furthermore, this study suggests that distribution of economical and status-seeking movements among different segments of population can be interpreted as the material cause of the shape of income segregation profiles. This inquiry is further enriched by focusing on the segregation of the poorest and the richest households that form homogeneous groupings at the extremes of income percentile. Size of the neighborhoods, natural mixing of the households, and housing market inefficiency are discussed as influencers of them.

ÖZET

GELİR DAĞILIMINDAKİ EŞİTSİZLİĞİN GELİR TECRİDİ ÜZERİNDEKİ ETKİLERİ

Bu çalışmada, gelir dağılımdaki eşitsizliğin gelir tecridi ve onun karakteristik özelliklerini nasıl etkilediğini araştırmak için etmen temelli bir model kurulmuştur. Kurulan model gelir dağılımındaki eşitsizlikle gelir tecridi arasındaki tahmin edilen doğru orantılı ilişkiyi hem istatistiksel hem de görsel olarak gösterebilmektedir. Buna ek olarak, gelir dağılımındaki eşitsizliğin gelir tecridinin alabileceği değerleri belirlediği bulunmasına rağmen, aradaki pozitif ilişki, gelir dağılımındaki eşitsizlik arttıkça doygunlaşmaktadır. Gelir tecridinin karakteristik özelliklerini çalışmak adına onun profillerinin bir tipolojisi çıkarılmıştır ve gelir dağılımındaki eşitsizlik şeklinin gelir tecridi profilleri üzerindeki etkileri çalışılmıştır. Bir şehirde zengin mahallelerin ve güvenlikli sitelerin oluşumunun ve genişlemesinin, getto ve varoşların oluşumu ve genişlemesini arttırıcı bir etkisi olduğu bulunmuştur. Aynı arttırıcı etki getto ve varoş oluşumunun ve genişlemesinin zengin mahallelerin ve güvenlikli sitelerin oluşumu ve genişlemesine olan etkisinde de gözlemlenmiştir. Ayrıca, bu çalışma, ekonomik motivasyonlu ve statü kovalayan taşınmaların toplumun farklı bölümlerine dağılımının, gelir tecridi profilini belirlediğini önermektedir. Bu araştırma, gelir dağılımının ekstrem uçlarında homojen gruplaşmalar oluşturan en fakir ve en zengin kesimlerin tecridine odaklanarak derinleştirilmiştir. Mahallelerin kapasiteleri, doğal karışmalar, ve emlak piyasasının verimsiz ve etkisiz çalışması bu tecritlerin belirleyenleri olarak tartışılmıştır.

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1. INTRODUCTION

The word "segregation" has been usually associated with racial segregation and studied extensively in social sciences from many different angles. However, other forms of segregation, although mostly impossible to decouple from racial or ethnic ones, deserve attention, too. Most notably, income or wealth of a person, family, or household has been a significant driver of social stratification in various aspects of life. In this study, the focus is on the residential distribution of income among households over neighborhoods, which is referred as income segregation.

The motivation to study income segregation is obvious and well discussed, particularly in the context of how neighborhoods affect the life-course of individuals (Durlauf 1995, 2004). However, after reviewing the important works of residential segregation literature (Bruch and Mare 2006; Denton 2001; Fossett 2006a; Massey and Denton 1988; Massey 1990; Sethi and Somanathan 2004; Winship 1977), it can be argued that the reasons of income segregation—as an explicit phenomenon distinct from racial segregation—received relatively less attention. When income segregation is mentioned, it is usually discussed either implicitly or tangentially. Most of the time, the emphasis has been on its effects which are consequential for various individual and social aspects from health conditions to crime rates, from income inequality to life-course outcomes. In this study, however, the causes of income segregation will be discussed instead of its effects. More precisely, our interest is in how income inequality is transformed into income segregation and what mechanisms are responsible for that.

Majority of residential segregation studies stress that racial segregation is coupled with income inequality (Clark and Fossett 2008; Durlauf 1995, 1996; Massey 1990; Mayer 2001; Quillian 2012; Reardon and Bischoff 2011; Sethi and Somanathan 2004; Sharkey 2008). However, whenever the impact of income inequality became a concern, the researchers have been concentrating on the reasons and outcomes of racial segregation instead of treating income segregation as a separate layer of reality.

Reardon & Bischoff's study (2011), however, focuses on income segregation as a distinct object of research. They study how contemporary trends in income inequality affected income segregation and its character as well as its racial and geographic-scale dimensions. Introducing a sophisticated income segregation measure, they analyze not only the overall level of income segregation—the classical way of studying segregations—but also they portray a panorama of segregation experienced by all income percentiles, which they call as income segregation profile. By means of that they can address the segregation of different economic segments of society such as the poorest and richest groups and elaborate on the kind of segregation experienced in that city. For instance, they argue that segregation of affluence, "the extent to which the highest-income households are isolated from the rest of the population," has increased more than segregation of poverty "the extent to which the lowest-income households are isolated from the rest of the population" in the past forty years in the United States (2011). They claim that this specific change in the income segregation profile of US, in addition to its overall increase, is due to a particular kind of increase in income inequality, namely the disproportionate increase in the incomes at the top percentiles.

There are still unexplored aspects of income segregation, and there is still room for improvement in elucidating how income inequality affects income segregation. Common sense implies that income inequality is a necessary condition of income segregation. Yet, maybe because of its alleged lucidity, the relationship between the two has not been studied thoroughly. With this study, it is sought to shed light on the following questions: To what extent, can income inequality dictate greater income segregation? What kinds of income segregation profiles are possible to observe? How do changes in inequality level affect segregation profiles? How different kinds of inequality shape characteristics of income segregation and through what mechanisms?

Additionally, a secondary set of questions are investigated as scenario analyses: How does urban density affect income segregation? What is the impact of rent-control policies on income segregation? How does the influence of income on rents affect income segregation? How sensitive are modeling approaches to study income segregation to the assumptions of perfect information and *homo economicus*?

2. RESEARCH METHODOLOGY

In this study, agent-based modeling (ABM) is used to answer the questions mentioned above. Before going into detail, why it is fruitful to study income segregation with ABM, let us briefly cover what it is. ABMs are models consisting of *agents* which are *unique* and *autonomous* entities that both *interact with each other* and *the environment* that they act in, and they do both *locally* (Epstein and Axtell 1996; Gilbert and Troitzsch 2005; Railsback and Grimm 2011). In an ABM, agents are usually different from each other in two respects. First, there can be different breeds of agents such as fish and fishermen in an ABM that is built for studying commons problem. Second, although two agents can belong to the same breed, they can be different with respect to other characteristics such as there are altruistic fishermen and selfish ones or they differ with respect their equipment, and the like. In an ABM, agents are autonomous to the extent they are not managed from a single center. Rather, each have a set of routines that determine their behaviors. Interacting locally means that when an agents interact with other agents, it does not interact with all. Similarly, interacting locally with its environment, an agent can change a part of the whole environment that it acts in. By interaction, mutually affecting each other is meant. In other words, agents can influence each other's behavior; an agent can yield a change in its environment.

Schelling's residential segregation model is a very nice example of an ABM (Schelling 1971). It approximates a city with a number of houses more than total number of agents. There are two kinds of agents in it: green and red agents representing two different races living in the city. All of them have a criteria of living in a neighborhood where a certain fraction of their neighbors should be of their own color. If that criteria is satisfied they remain where they are and if it is not satisfied, then they randomly move to an empty house. Although the agents act locally with the others and their environment, segregation between reds and greens is observed as a macro level phenomenon.

ABM turns out to be a useful tool in this analysis for several reasons. First and most important, the income segregation problem at hand, a macro-level outcome, has micro-dimensions; the macro outcome is significantly driven by micro-level actions as well as indirect interactions. ABM is proved fruitful for such problems: Schelling's segregation study, which is nothing but an agent-based model, which performed by hand rather than microchips, initiated a new line of inquiry, particularly in residential segregation studies.

Note that with this study, we definitely do not mean that, these micro level interactions are the primary causes of income segregation. Rather, we acknowledge that there are more than what is represented in this study. First, in almost all societies, there are ethnic issues that can be approximated by racial segregation that we omit in this thesis. Second, urban policies of the states and municipalities, particularly under the rubric of “urban renewal,” including how they handle the immigration issue both from rural and foreign countries, shape and drive income segregation directly. Therefore, the state seems to be the primary actor of income segregation and its transference to more social stratification by means directly influencing relevant processes at macro scales. We humbly argue that there are also other issues—maybe of secondary importance and although minor—which can be decoupled from the above significant effects and can be studied in isolation, later to be juxtaposed to other arguments. We believe that Schelling in his seminal work, stresses a similar attitude (1971), which is usually neglected or at the very best chosen to be unspoken. We would like stress our position more clearly.

Second, ABM is particularly useful in dealing with problems that have spatial dimensions in it. By means of visualization, let alone being able to draw certain conclusions which are otherwise impossible, it also helps to build intuition about the object of research.

Third, simulation modeling provide an experimental platform for researchers, boosting their cognitive capacity against the complexity of the problems. More sophisticated theorizing becomes possible as the (simulation) modeler (or theoretician) has the luxury to focus on the parts and the relations among them since simulation is in charge on the synthesis of all. In addition, they enable us to conduct perfectly controlled experiments most of which are impossible in real life, hence, offering opportunities for more mechanism-based explanatory remarks by means of tracing the events down to their origination. Such a use is adopted in this study.

We also think that ABM might be more helpful for income segregation studies than it has been for racial segregation, since the category leading to segregation in the former is a continuous variable, income, rather than discrete variables such as race or ethnicity. Having a continuous variable adds another layer of complexity to the problem, particularly the measurement of income segregation.

Finally, it is particularly useful to use agent-based simulation modeling since it enables us to retrieve complete information of each agent, in our case each household. That makes it possible to generate the complete empirical segregation curves, describing the level of segregation for each segment of society, instead of approximating it with a polynomial function as Reardon & Bischoff (2011) did since their available data only consists of information about whether households’ income lay in a certain thresholds or not. Although they have argued that the available amount of thresholds usually provides sufficient data to predict the income segregation profiles (Reardon and Bischoff 2011; Reardon and Firebaugh 2006; Reardon 2011), evidence is still needed to connect the dots in their findings, particularly for extreme values of segregation curve, which represents segregation of the poorest and the richest. Although in the calculation of the overall segregation measure, they weight segregation of the poorest and the richest least, focusing on these parts is still important to provide a complete segregation curve. Moreover, as it will be demonstrated, focusing on these extremes can tell us more about the income segregation profiles since segregation at each levels are all interrelated as well as the mechanisms that mediate the relation between income inequality and segregation in general.

3. LITERATURE REVIEW

3.1. Agent-Based Models of Residential Segregation

ABM gets more and more appreciation in social sciences and particularly, analytical sociology school of thought treats it as an opportunity to shed light on the processes yielding macro outcomes via micro-level interactions (Breen 2009; Hedström and Bearman 2009; Hedström and Swedberg 1998; Hedström and Ylikoski 2010; Hedström 2005; Manzo 2010; Squazzoni 2010). Schelling's seminal work (1971) has been trend setting and the guiding research of many residential segregation studies, both inspiring many researchers and limiting their vision as well, which have been recently challenged by many works (for example, Elizabeth Bruch's studies (2006, 2009a, 2009b, 2012) and (Rijt, Siegel, and Macy 2009a)). Our work also builds on the same line of research. We think that, however, a good deal of knowledge and insight have been constructed with such studies about racial segregation, and armed with them, now it is time to move beyond that, particularly to other forms of segregation.

Such studies have already begun to be published. In 2006, the Journal of Mathematical Sociology held a special issue dedicated for Mark Fossett's significant work as well as a debate around it (Skvoretz 2006). The issue also has an article by Fossett, replying the comments raised by others in the issue (Fossett 2006b). His 90 pages-length paper is important for various reasons. First, it provides a sophisticated and thorough overview of the literature on residential segregation as well as the related modeling studies. Second, more importantly, it describes his ambitious simulation model, *SimSeg*, a product of a decade-long effort (Fossett 2006a). The simulation model is a significant one and deserves attention for our study. However, he is aware that although very detailed and realistic, "*The results of the simulation experiments provide empirical evidence about the behavior of this model,*" not real cities (Fossett 2006a).

With his very detailed model, Fossett identifies some real-world scenarios and uses the model for explorative purposes; to what extent segregation can emerge and sustain itself even in the absence discrimination in housing market. What is relevant in his model for our study is that he incorporates the affordability for housing, a necessary condition to observe income segregation, in the form of socioeconomic status. Yet, he does not decouple the desirability of a neighborhood from the affordability, which is a serious limitation. Additionally, the affordability of houses are constant throughout the model, which is another serious limitation to study income segregation properly since the dynamic aspect of prices is the heart of a housing market. More importantly, even though he mentions about socioeconomic segregation, he neither explains it nor gives measures of it; he exclusively focuses on racial segregation. However, his model has been inspiring for us and his studies represent brilliant examples of explorative use of agent-based models for sociology.

Feitosa (2010), however, focuses primarily on income segregation, dismissing race and ethnicity. Her model is even more detailed than Fossett's model. Her dissertation incorporates real geographic, socioeconomic, and demographic data into an agent-based model via GIS. Nevertheless, her studies focus only on real-world scenario and policy analysis for Sao Paulo, Brazil, and miss theoretical explanations.

Benard & Willer's research is closest to our aims (2007). They demonstrate a very simple model, excluding race as it has been studied widely. Moreover, unlike Fossett's *SimSeg* model, they decouple the desirability of the neighborhoods (status) from the affordability of housing (price). Furthermore, they experiment on different levels of endogeneity in housing pricing. By endogeneity in housing pricing it is meant that incomes of residents affect the prices in that neighborhood, which is a key mechanism creating or sustaining income segregation.

In their analysis, Benard & Willer show that as the correlation between wealth and status increases, status segregation increases as well. Price endogeneity also turns out to be positively related to further segregation. An interesting issue in there is that the wealth distribution in their analysis follows normal distribution. In a footnote, they state that they also tried exponential distribution and the results turned out to be identical, which seems very interesting. After all, exponential distribution points to a very uneven distribution and should necessarily lead to more income segregation. This might stem from over-simplicity of their model. Alternatively, they might have meant that their qualitative findings are insensitive to the distribution of wealth, which sounds better. Yet another alternative, it might be really the case making the link between income inequality and income segregation blurred. Anyhow, further research is compulsory to enlighten the relation between the two.

Moreover, they report the wealth and status segregation by using the measures used for racial segregation, namely a revised version, developed by Winship (1977), of Massey & Denton's (1988) index of dissimilarity, and revised index of isolation. However, this covers only a small aspect of the segregation where you identify people as either poor or rich, based on their location with respect to median income. Income, unlike gender or race, is continuous, rendering the segregation problem even more difficult, yet also more interesting. Their findings, even though sounding reasonable, might even change when a more calibrated measure is used such as Reardon's rank order information theory index (2011).

3.2. Measuring Segregation

Measuring segregation is addressed in a number of studies and there is a well-established literature such as (Massey and Denton 1988; Reardon and Firebaugh 2006; Reardon and O'Sullivan 2004; Reardon 2011; Winship 1977). The interest has been usually on the overall level of segregation rather than its distribution among different segments of population or qualitative nature of the income segregation. However, it has been well known that income inequality studies amenable to suffer from this single number measures such as Gini coefficient, which reduces the complex phenomenon of income distribution to an oversimplified scalar. We adopt the motivation of focusing on the shape of income distribution and apply it in the study of income segregation, inspired by the study of Reardon & Bischoff (2011).

Among all, Reardon & Firebaugh's *rank-order information theory index* proved to be more useful for our purposes in this study, which enables us to draw segregation levels for each segment of population (Reardon and Firebaugh 2006).[1] This is possible by focusing on

[1] As in the case of income inequality, a plethora of measures are available for segregation. This shows not the confusion of researchers but the complexity of the phenomenon to be studied. Yet, focusing on and weighting differentially distinct aspects of segregation, the researchers should be conscious of them and pick the one fitting their research questions. However, for a double check, we also use the famous revised index of dissimilarity (Winship 1977), and report the results of some experiments in the analyses chapter.

the *H(p)* curve which exhibits income segregation profile of a city, which is computed along the way of calculating H^R, the overall level of income segregation in that city (Reardon and Bischoff 2011:1110–1):

$$E(p) = p \times \log_2 \frac{1}{p} + (1 - p) \times \log_2 \frac{1}{1 - p}$$

(3.1)

$$H(p) = 1 - \sum_j \frac{t_j \times E_j(p)}{T \times E(p)}$$

(3.2)

where p is income-percentile ranks, T is total population, t_j is the population in neighborhood j, $E(p)$ is the entropy of the population divided into two as below and above p, and $E_j(p)$ is the entropy within the neighborhood j. Then, the interpretation of a point on the *H(p)* curve is as follows: the level of segregation between households with income percentile below p and above p. The overall income segregation measure H^R is calculated as follows:

$$H^R = 2 \ln 2 \int_0^1 E(p)H(p)dp$$

(3.3)

H^R ranges from a minimum value of zero when there is no income segregation[2] to a maximum value of 1 when there is complete income segregation[3]. *E(p)* is used as a weight where the extremes has a lower value than in the middle: it is maximized for $p=0.5$ and minimized for $p=0$ and $p=1$. This weighting tells us that segregation between above and below median is most informative. Another important aspect of this measure is that it is independent of changes in income distributions since it only takes rank order of household

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[2] It occurs when the income distribution of residents in each neighborhood mirrors of the city as a whole.
[3] It occurs when there is no income variation in any of the neighborhoods. Put differently, all the residents of a neighborhood have the same income, and this is true for all neighborhoods.

incomes not incomes *per se*. By means of that, confounding impacts of monetary changes on income kept away from income segregation measure.

Let us operationalize and exemplify the use of this measure on an empirical case from Reardon & Bischoff (2011). Figure 3.1 is taken from their study which shows the evolution of income segregation profile of the hundred largest metropolitan areas[4] from 1970 to 2000.[5] In these, *H(10), H(50)* and *H(90)* are marked. For example, *H(10)* value gives us how segregated the poorest 10% of population from the rest of the society or the richest 90% of population. Likewise, *H(90)* value is the level of segregation of the richest 10% from the rest. Reardon & Bischoff interpret *H(10)* and *H(90)* as segregation of poverty and affluence, respectively. Note that segregation of poverty and affluence they do not mean the segregation of the poor from the rich or vice versa. Instead they address the segregation of the poor or the rich from all the rest.

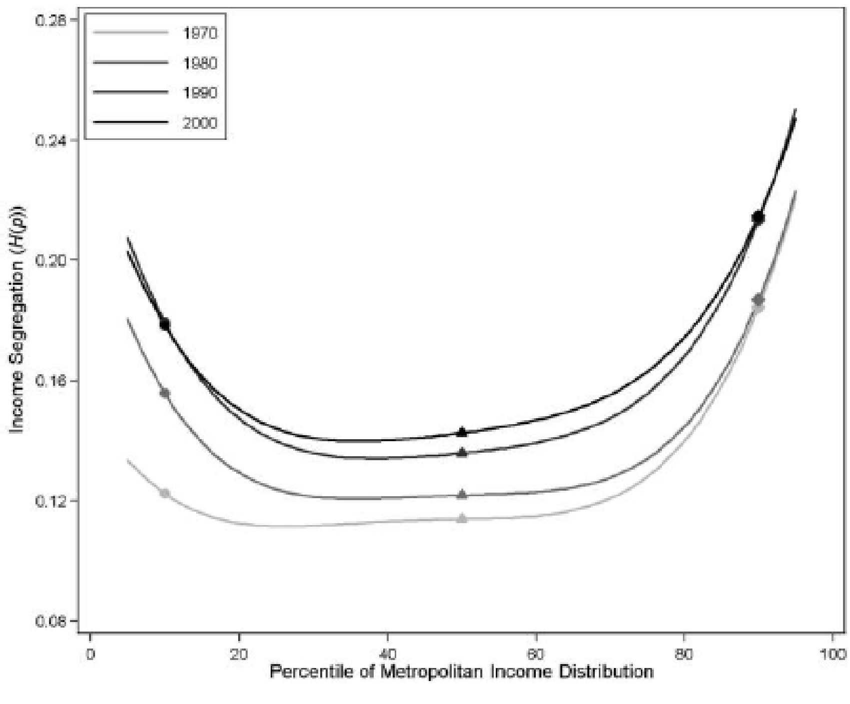

Figure 3.1. Empirical examples of income segregation profiles.

[4] The segregation profiles in this figure represent an average large American metropolitan area. Think of it as a single city.
[5] Note that these are *H(p)* curves are approximated by fitting polynomial functions to available data which does not cover the whole percentiles of income.

The distinction of segregation of poverty and segregation of affluence is fruitful for several reasons. First, keeping track of it over the years can describe what accounts for the most of the change in the overall income segregation. For instance, comparing the segregation profiles of 1970 and 1980, it is seen that segregation of affluence has not changed dramatically. However, segregation of poverty increased significantly. This means that the increase in the overall income segregation in an average US city was due to an increase in segregation of poverty. It tells us that the poor lost contact with the rest of the society significantly during that decade whereas the segregation of rich from the rest of the population has not changed. A researcher or policy maker who is only interested in overall level of income segregation and using single scalar measures would miss such a point. Without rank order information theory index such an analysis would not be possible.

Second, segregation of the poor from the rest of the society is a much more important issue than the segregation of the poor from the rich. The traditional measures cover the latter where rank order information theory index is capable of accounting the former. Distinguishing the two can be crucial to act earlier.

Another interesting observation about Figure 3.1 is that the overall shape of *H(p)* curves or income segregation profiles are U-shaped curves. A U-shape, ideally, with its two hills, suggests that the harshest income segregations are held at the lower and higher extremes of income pyramid. Empirical examples usually take U-shapes, though with different styles (Reardon and Bischoff 2011; Reardon and Firebaugh 2006; Reardon 2011). Even though this is intuitive and expected, theoretically and practically, an *H(p)* curve can take any shape and it will be explained why it is so as well as what different shapes mean later in the thesis. Moreover, we will shed light on how changes in income inequality affect the shape and characteristics of income segregation profiles.

4. MODEL DESCRIPTION

In order to study the impact of the income distribution on income segregation, an agent-based model[6] is built to raise an artificial society. Note that the model is constructed with respect to our purpose of determining the impact of income distribution on income segregation, and the aim is definitely not to represent reality fully, which is neither possible nor useful.

4.1. Households

The most important element of our model is the households. Each of them has a constant budget and socioeconomic status (SES). The budgets are determined by a statistical distribution. Lognormal, Gamma, and Dagum distributions are frequently used in literature to replicate empirical income distributions. In the benchmark case, Lognormal distribution is used. SES, on the other hand, is calculated as Benard & Willer (2007) did; SES is a function of the income[7]. For a household *i*, income and SES are determined as follows:

$$Income_i = a, \tag{4.1}$$

where a is a random variate following Lognormal distribution.

$$SES_i = \beta \times Income_i + (1 - \beta) \times b, \tag{4.2}$$

where b is a random variate following Lognormal distribution.

[6] We built our model in Net Logo (Wilensky 1999).
[7] In our model, the budget and the income of a household equal to each other for the sake of simplicity.

In order to gain analytical leverage in our understanding of income segregation, the other determinants of SES are not specified such as race or ethnicity, jobs, family, and the like in our model. Instead, they are consciously ignored by the modeler and all of them are combined in a single random variate *b* following similar distributions to income distribution.

Benard & Willer (2007) found that for higher values of the correlation between income and SES, higher levels of segregation is realized. Although its impact on the overall level of segregation is known as such, how it affects the shape of income segregation is not explored. For instance, without decoupling SES from income, observing gentrification—rich people moving in cheap and low status neighborhoods—dynamics becomes impossible. Similarly, without distinguishing SES and income, it is not possible to have "nouveau riche," which can create unpredictable dynamics. Following Benard & Willer (2007), different values of income SES correlation are experimented and its impact is analyzed in scenario analyses section.

In the benchmark case, the coefficient β is taken as 0.7, yielding a correlation between income and SES of 0.90[8] on average. After determining budget and SES, both values are standardized such that all lie between 100 and 0, where the richest person has a budget of 100 and the person with highest status has an SES of 100.

4.2. Neighborhoods and Houses

The other significant part of the model constitutes the houses and neighborhoods with constant boundaries. Following from decoupling of SES and income discussion above, affordability and desirability of a house are differentiated as well: each house has a dynamic rent and status. The status of a house is the perceived decency of it where that perception is a function of the SESs of residents living in its close vicinity.

There are two important and *a fortiori* assumptions: first, it is assumed that the (material) quality of the houses are equal or our agents are insensitive to it. This would simply multiply the resulting income segregation by imposing an already stratified housing

[8] In their study, they probably mixed the value of the coefficient β with the resulting correlation value.

set (Fossett 2006a:246). Our aim is not to achieve numerical accuracy to *estimate* the level of income segregation, but to *understand* and eventually to *explain* the complex quantitative relations between income distribution and income segregation. To be able to do so, we selectively leave out such details of which we can assess their impacts. Second, the desirability of a house does not change with respect to its location, be it in the center or periphery. Similarly, this would also create more segregation and the spatial patterns of income segregation are beyond the scope of this study.[9]

Our artificial city is a 60x60 checkerboard (not a torus as in Benard & Willer's model) with 3600 houses. There are 3060 households, yielding 85% urban density (or 15% vacancy rate). All neighborhoods cover a 5x5 space, yielding 144[10] neighborhoods. [11]

4.3. How do Households Move?

To determine how households' move, a hierarchical approach is adopted to replicate the searching and moving patterns in reality. In our model, first, the households check whether they need to change their current houses or not. They do not want to move and stay on, as long as the rent is lower than their budget and the status of their house is higher than their SES. [12] If they are happy with the rent but not with the status, then they look for a house with a higher status. If they are happy with the status but not with the rent, then they search for a house with a cheaper rent. If they are unhappy with both, then they give priority to what

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[9] However, it is very easy to implement such a feature to our model.

[10] The number of neighborhoods is determined such that the distortion in the extreme ends of income segregation profile (the $H(p)$ curve) is minimized. The reason of doing is to ensure that 1% of population can fill a neighborhood (so that any $H(p)$ value can practically hit its maximum value of 1). This, in turn, yields smaller sized capacities for neighborhoods which yield higher degrees of income segregation (Reardon and Bischoff 2011). Having income segregation upward biased due to small neighborhoods is a drawback. However, this does not interfere with our aims of focusing on how changes in income inequality lead to changes in income segregation.

[11] An array of different number of neighborhoods is tried out. The findings represented in this thesis are insensitive to the number of neighborhoods, except for the ones related to the segregation values at the extreme ends of income percentile; they are particularly sensitive for large neighborhoods. Nevertheless, it is a natural feature of segregation measure used in this study.

[12] Actually, the households in my model, as in reality, have some tolerance of residing in a house in which they would not prefer. More specifically, each has a tolerance of x%, that is, if the rent is less than (100+x) % of their budget and the status is higher than (100-x) % of their SES, then the household is happy and does not need to move to somewhere better. However, if any of these two conditions are not satisfied, then the household wants to move to a better (according to their budget and SES) house. In this thesis, the tolerance level is determined as 20%. Other values are tried and findings are persistent. However, they are clearer when it is around 20%. For the sake of clarity, we dropped the tolerance expression from the text and simply referred to the budgets and statuses as if they are absolute.

bothers them most and this is captured by having their search preference as probabilistic such that (Bruch and Mare 2006, 2012):

$$\Pr(searching\ for\ lower\ rent\ house) = \frac{\frac{Budget - Rent}{Budget}}{\frac{Budget - Rent}{Budget} + \frac{Status - SES}{SES}} \tag{4.3}$$

$$\Pr(searching\ for\ higher\ status\ house) = \frac{\frac{Status - SES}{SES}}{\frac{Budget - Rent}{Budget} + \frac{Status - SES}{SES}} \tag{4.4}$$

After a household decided what kind of a move they want, first, they attempt to choose a neighborhood among others based on neighborhoods' average rents and statuses. Note that the households' scopes and access to information is limited. More precisely, the household picks (arbitrarily) only a single neighborhood from their candidate list satisfying the search criteria of the household. If the aim is to find a cheaper/higher status place, then the neighborhoods with average rent/status less/more than the present tolerable rent/status are put to the candidate list.

Afterwards, the household looks for empty houses in the chosen neighborhood. Among them, the appropriate choice is made if there is any: the appropriate candidate is a cheaper and empty house if the aim is to move to somewhere cheaper, and the appropriate candidate is a higher status and empty house, which the household can afford, if the aim is to move to a higher status place. If the household finds such an appropriate candidate, the household moves there. If not, then the household simply waits for another round. Note that the household can fail to find an appropriate house although there exists some since their scope and access to information is limited.

Motivated by Bruch's challenge to Schelling's choice functions and debates around it (Bruch and Mare 2006, 2009a; Rijt, Siegel, and Macy 2009b), different choice functions, that is, agents' having different kinds of rationality is experimented. In our base model, our households are not pure *homo economicus* kind of people: first, if they are happy, they continue to stay where they are. They are not programmed for always seeking for better or best. Second, they are imperfect; they cannot search for the best, but for a better place. In other words, they do not have the perfect/infinite computing capacity and time to find and choose the best option. Third, they have limited information, that is, they do not know the rents and statuses of all houses or they do not know if a neighborhood is full or not, and the like. At a time, they can only focus on a single neighborhood. Based on these criteria, our households are not perfectly rational actors. Instead, they have bounded rationality, which is much more plausible. Note that this is in contrast with the majority of the existing models of segregation, where agents usually seek and are able to find the best available choice. More importantly, to the best our knowledge, the researches of income segregation using agent-based models have not tried to model the agents with bounded rationality (Benard and Willer 2007:156; Fossett 2006a:232). It will be shown how unrealistic assumptions of rationality, which can be calibrated to bounded rationality with little effort, lead to erroneous results.

4.4. Housing Market

After all households checked their conditions and acted accordingly one by one, the rents and statuses of all houses are updated. To update the rents, a composite weighting equation is used. The average rent of the neighborhood, the average income of the residents of the neighborhood, as well as the average rent of the Moore neighborhood, and the average income of the Moore neighbors are weighted to determine an implied rent. It is assumed that the weight of Moore neighborhood and *the* neighborhood are equal and 0.5. The weight of income in determining the rents is calibreated to be 0.2[13]. The rents are updated by the anchor & adjust heuristic, where the anchor is the implied rent such that[14]:

[13] An experimentation will follow up in the next sections about how this weight coefficient influences segregation.

[14] If there is no one in the Moore neighborhood of a household, than the weight becomes 0.33 instead of 0.25.

$$
\begin{aligned}
&Implied\ Rent_t \\
&= Weight\ of\ Income\ \times 0.5 \\
&\times (avg.budget\ of\ all\ \ neighbors \\
&+ avg.budget\ of\ Moore\ neighbors) + (1 - Weight\ of\ Income) \times 0.5 \\
&\times (avg.rent\ of\ the\ neighborhood \\
&+ avg.rent\ of\ the\ Moore\ neighborhood)
\end{aligned}
\tag{4.5}
$$

$$
Rent_t = \frac{Implied\ Rent_t - Rent_{t-1}}{Rent\ Adjustment\ Time} + Rent_{t-1} \tag{4.6}
$$

In our model, to approximate the supply & demand effects on prices in housing market, the rents of empty houses are updated by the following equation[15]:

$$
Rent_t = \frac{Implied\ Rent_t - Rent_{t-1}}{Rent\ Adjustment\ Time} + Rent_{t-1} - (Empty\ House\ Multiplier \times Rent_{t-1}) \tag{4.7}
$$

In sum, the rent of a house increases when richer people move closer to it and/or move in the same neighborhood, and when poorer people move away from it and/or move out to a different neighborhood. On the other hand, the rent of a house decreases when it remains empty, and when poorer people move closer to it and/or move in the same neighborhood, and when richer people move away from it and/or move out to a different neighborhood.

[15] The empty house multiplier is approximated by the amount of excess housing supply. More precisely, it is equal to one minus the urban density, which is the ratio of population over all houses.

To update the statuses of houses, again an anchor & adjust heuristic is used. The anchor is determined as the weighted average SES of all the residents in the neighborhood and Moore neighbors[16]:

$$Implied\ Status_t = (avg.SES\ of\ all\ neighbors + avg.SES\ of\ Moore\ neighbors) \times 0.5$$

(4.8)

$$Status_t = \frac{Implied\ Status_t - Status_{t-1}}{Status\ Adjustment\ Time} + Status_{t-1}$$

(4.9)

In sum, similar to the rents, the status of a house increases when higher SES people come closer to it and/or move in the same neighborhood, and when lower SES people move away from it and/or move out to a different neighborhood. On the other hand, the status of a house decreases when lower SES people come closer to it and/or move in the same neighborhood, and when higher SES people move away from it and/or move out to a different neighborhood.

[16] If there are no Moore neighbors, then only average SES of all neighbors is used.

5. MODEL ANALYSIS

To initialize the rents and statuses of the houses, a perfect correspondence between the rents and budgets, and statuses and SESs of the households is assumed: initially, the rent of each house is equal to its residents' budget, and the status of it is equal to the residents' SES. Put differently, all households start happy with their current houses. The rents and statuses of vacant houses are determined as if they have residents. The initial distribution of households to our city is arbitrary. Hence, the initial level of income segregation is almost zero.

After initialization, holding the budgets and SES of the households constant, the simulation models are run for 500 iterations, long enough that they reach an equilibrium[17]. Figure 5.1 illustrates a typical evolution of overall level of income segregation after 500 iterations where the output belongs to the run with benchmark parameters; the Gini coefficient is 0.45 with seed equals to 1988. Note that it is exactly what Susan Mayer (2001:10) hypothesized: "All the hypotheses about why families sort into neighborhoods by income suggest that if economic inequality were fairly constant over a long period, a stable level of economic segregation would evolve based on the distribution of income and individual preferences."

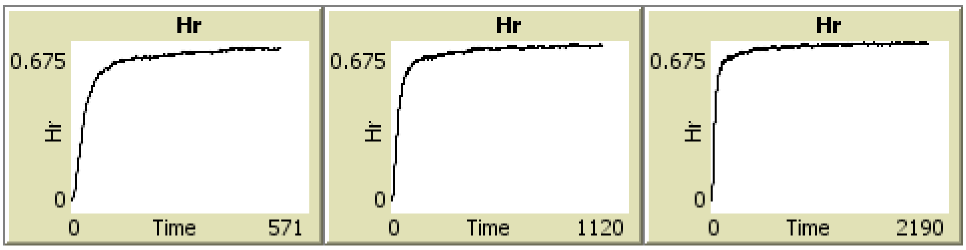

Figure 5.1. A typical evolution of overall income segregation level (H^R).

An iteration consists of asking each household whether they want to move and if they want, moving them, and after all movements are realized one by one, updating the rents and

[17] By equilibrium, we mean that the model is reaching a state such that the circulation in the model becomes negligible since the outcomes of interests change only infinitesimally.

statuses of all houses.[18] 50[19] replications are held for each experiment, and the averaged outcomes is reported to get rid of the confounding effect of randomness. Moreover, appropriate t-tests are done to check whether our findings are statistically significant.

5.1. Benchmark Case

In the benchmark experiment, the impact of income inequality on income segregation is analyzed. To produce an artificial income distribution, lognormal distribution is used. Choosing lognormal distribution, among other candidates known to replicate empirical income distributions accurately, was due to sake of its simplicity of use. However, the other distributions will be compared to lognormal, such as gamma, to see how different income distributions shape income segregation levels as well as profiles differently.

In Figure 5.2[20], the relationship between income inequality and overall income can be seen segregation measure. Here, each point represents the result of a simulation run. There are 50 observations around each Gini index value, between 0.25 and 0.55 with increments of 0.05. The outcomes are the average H^R values of the last 50 ticks. As it is expected, a positive relationship between the two is observed: as the income inequality increases, income segregation increases as well. However, it is also seen that the impact of income equality saturates, suggesting that after some certain level of inequality, the income segregation reaches a plateau. Moreover, a second-order polynomial is fitted and the respective equation provides statistical evidence for that.

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[18] Updating the rents and statuses after everyone moves is an example of asynchronous update. We also tried the synchronous update, that is updating all rents and statuses after each move, which takes more time to simulate, and our findings did not change.

[19] We also tried to have more replications than 50. However, 50 turns out to be enough to reach statistical significance where taking many simulation runs is very costly since it takes (a lot of) time.

[20] The range of income inequality is determined to be between 0.25 and 0.55. Below 0.25 of Gini is rarely experienced in the world. To go beyond 0.55, we think, requires a different approach and model since such an income distribution implies different patterns of urban structure, housing market, as well as social structure. For instance, even in the case Gini=0.55, the housing market, as it is modeled, yields an outcome where it is impossible for some people to find housing due to their too low budget.

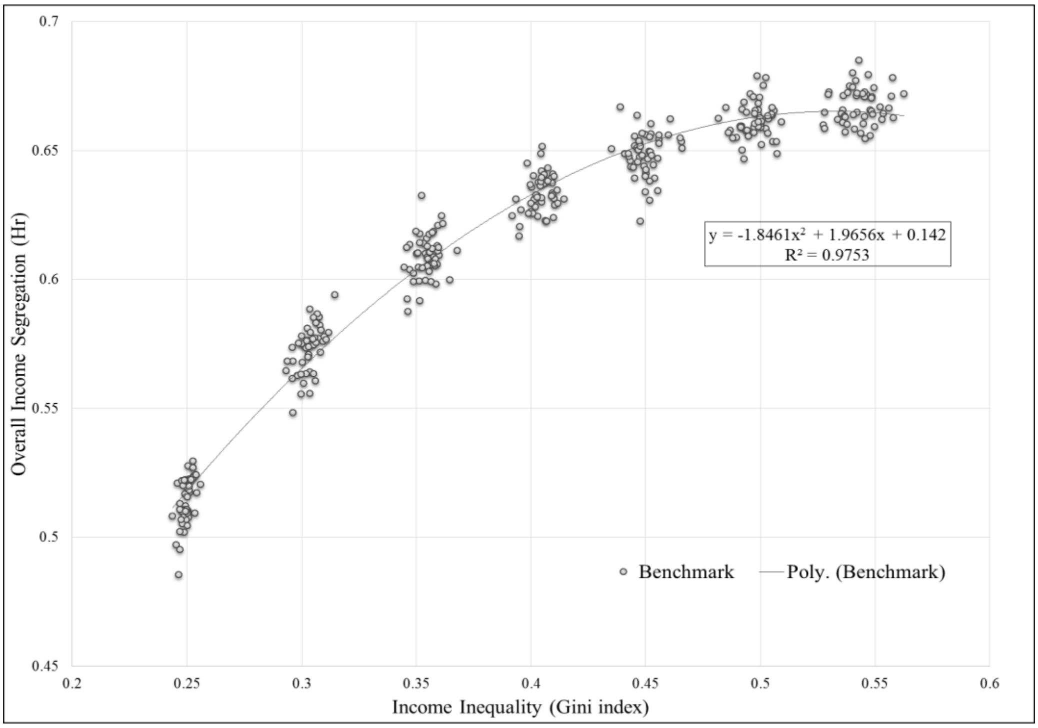

Figure 5.2. The impact of income inequality on the overall income segregation.

The saturating effect of income inequality is also captured with other segregation measures such as revised dissimilarity index (D*). What is more, the saturating effect is so strong that one-tailed t-tests for the D* reveals that the resulting income segregation when Gini coefficient is around 0.55 (0.50) is not significantly greater than when Gini coefficient is around 0.5 (0.45) for significance level of 0.975. The p-values of the aforementioned the t-tests are in Table 5.1. It shows the statistical significance of the relationship between income inequality and income segregation (as noted IS below) for the two different segregation measures.

Table 5.1. Results of one-tailed t-tests between different measures of segregation.

One-talied t-tests		
	p-values	
Alternative Hypothesis	H^R	D*
IS(0.55)>IS(0.50)	0.0001	0.0496
IS(0.50)>IS(0.45)	0.0000	0.0298
IS(0.45)>IS(0.40)	0.0000	0.0220
IS(0.40)>IS(0.35)	0.0000	0.0000
IS(0.35)>IS(0.30)	0.0000	0.0000
IS(0.30)>IS(0.25)	0.0000	0.0000

From Figure 5.2, it is also observed that the variation of overall income segregation level for a certain level of income inequality is not huge. This implies that level of income inequality conditions income segregation such that *ceteris paribus*, overall level of income segregation can take values in a certain range determined by the income inequality, as Susan Mayer (2001) speculated. Note that a different kind of initialization of the model where each house's rent is (almost) zero and status is maximum (that is 100) is tried out, depicting a dream country. Our findings are robust to the initial conditions, reinforcing the argument above.

To illustrate the spatial outcomes better, in Figure 5.3, a typical initial condition can be seen where there is almost no income segregation. Here, each agent in this visual represent a household and each patch stands for a house with capacity of a single household. The red agents represent the poorest 25%, the blue ones represent the richest 25% of the population. The rest, arguably the middle class, are the green agents. The color of each house signifies its rent: as it gets darker/lighter, the rents becomes cheaper/more expensive and the darkest/lightest colored house has the cheapest/most expensive rent. Note that the coloring as well as dividing population into quarters is a heuristic to illustrate the segregation more clearly. In Figure 5.4[21], on the other hand, the resulting spatial outcomes for two extreme conditions for very low (where Gini coefficient is around 0.25) and very high (around 0.55) levels of income inequalities can be seen. Income segregation is higher in the second figure, thus more homogenous neighborhoods emerge compared to low income inequality case.

[21] Note that the capacity of each neighborhood 25 houses (5x5) and there are 144 neighborhoods. They, the squares of size 25 households with almost distinct colors, are identifiable from the figures below.

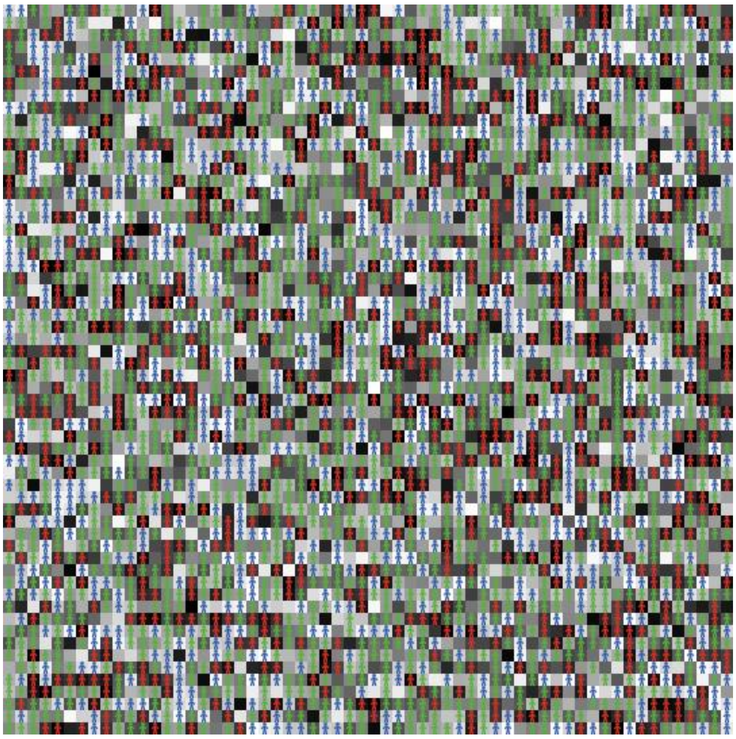

Figure 5.3. A typical initial condition of the model where there is almost no income segregation.

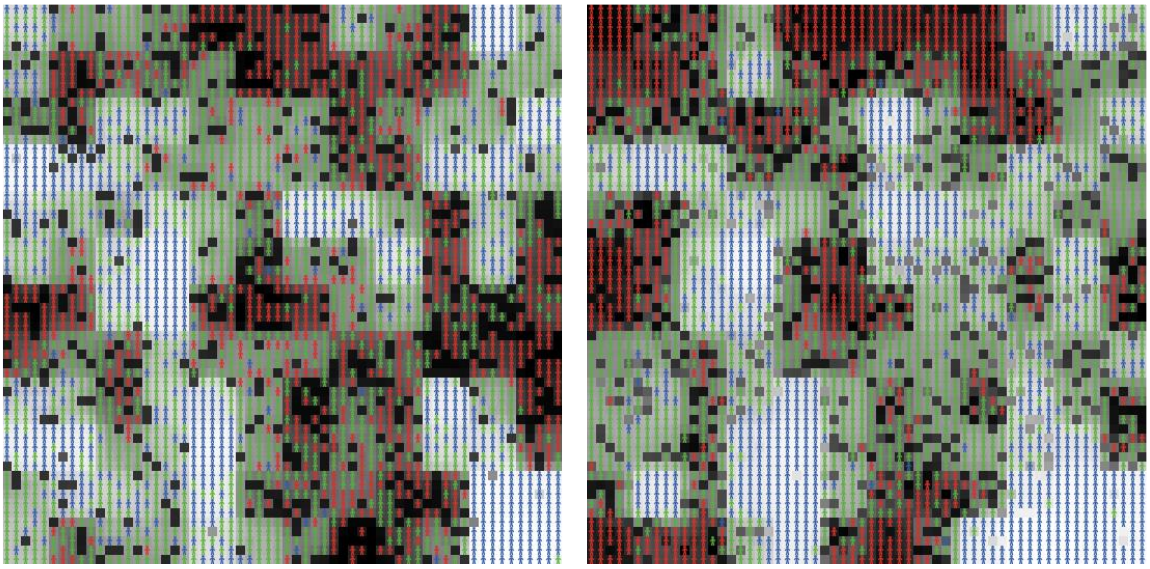

Figure 5.4. The spatial outcome of the models at time 500 where Gini coefficient is 0.25 on the left and 0.55 on the right with seed equals to 1988.

A more comprehensive analysis going beyond the overall level of income segregation is possible via Figure 5.5. It displays the resulting *H(p)* curves or income segregation profiles for different income inequality levels. Note that as it is observed in reality, most of them are U-shaped, implying that our model is capable of generating empirical income segregation profiles (for empirical examples, see (Reardon and Bischoff 2011; Reardon and Firebaugh 2006; Reardon 2011)). As it is discussed in section 3.2. *H(p)* curves can take different shapes than a U-shape. For instance, when Gini coefficient is around 0.55[22], the left tail of the curve violates a perfect U-shape, and it will explained why it is so later in the thesis.

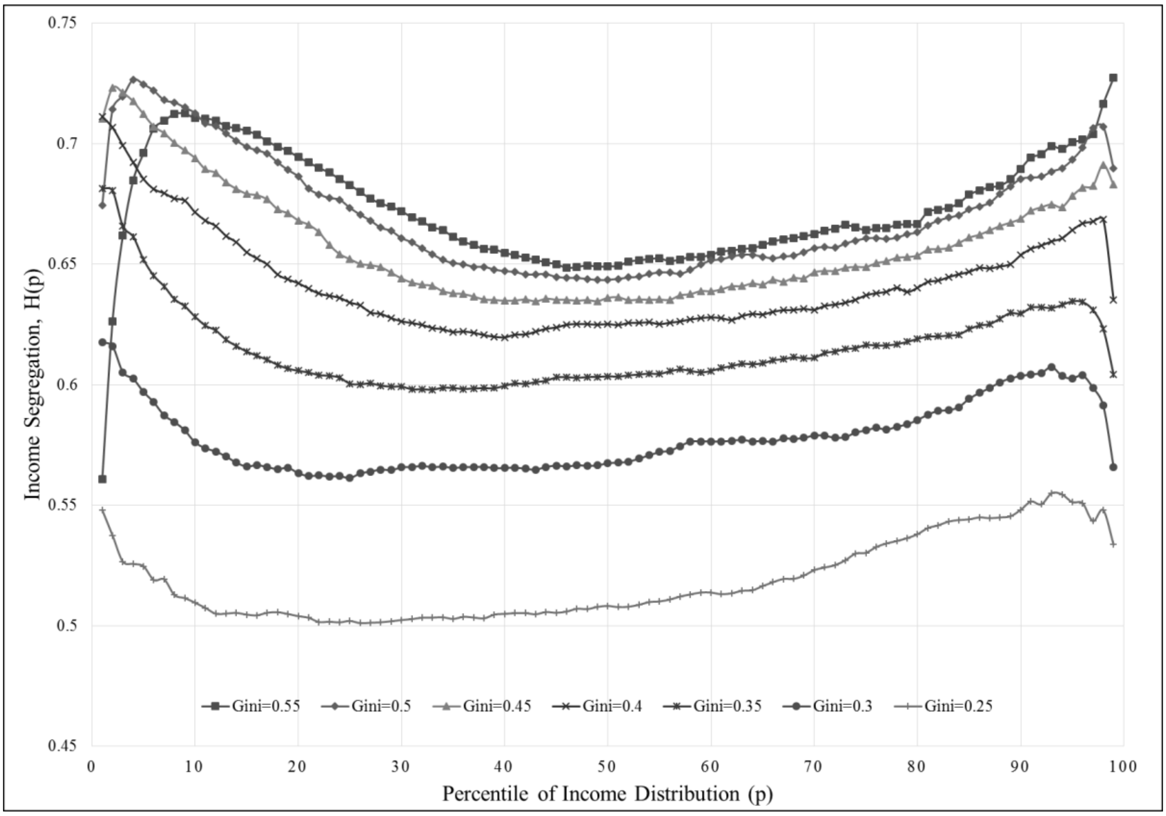

Figure 5.5. Income segregation profiles for different levels of income inequality.

In this graph, the relation between income inequality and segregation is also visible as well as the saturation effect that is discussed above. Nevertheless, there is more on the

[22] Note that in our models, we do not generate an income distribution with, say Gini=0.55, exactly. Rather, we specify the parameters of the income distribution such that, on average, we have Gini=0.55. For convenience, we mention them as if they are exactly equal. In Figure 5.2, the exact values of Gini coefficients for each experiment are displayed.

characteristics of income segregation. For instance, from $H(p)$ curves the levels of segregation of poverty and affluence, the left and right tails of the curve, can be assessed simultaneously.

In their latest study, Reardon & Bischoff (2011) interpreted $H(10)$ and $H(90)$ as segregation of poverty and affluence, respectively. Their attitude is adopted here as well. However, we also take segregation values for p-values less than 90 (for affluence) and more than 10 (for poverty) into account, although we do not discuss about the values separately. Adopting simulation approach is superior over real-data analysis to the extent that available data sets have incomplete information whereas simulations enable a researcher to access all the data related to all households. Although this allows the researcher to produce empirical values of $H(p)$ for extreme values of p, we still prefer not to compare the extreme portions of $H(p)$ curve *numerically*. Because, as it is visible from Figure 5.6, $H(p)$ curve is very unstable for the extreme values of p, particularly $p< 10$ and $p>90$. Although the model is calibrated such that even 1% of the population fill a neighborhood all together (and thus can achieve $H(p)$ can achieve its maximum value of 1 for all values of p and thus, any point on *H(p)* is reliable), the extremes have still higher standard errors compared to the moderate values of p. Nevertheless, we propose some explanations about why the tails can take different shapes later in this chapter.

Different from Reardon & Bischoff, we also propose to focus on the whole region of the left and right tails for an analysis of segregation of poverty and affluence, respectively. Moreover, one can also look at the slopes of left and right tail, taking $H(50)$, the middle of the curve as the starting point. Throughout this thesis, when we use the concepts of segregation of poverty and affluence, we refer to the totality of all these definitions.

From Figure 5.5, it is understood that higher levels of income inequality boost segregation of poverty more than segregation of affluence, and vice versa for lower levels of income equality. However, it is difficult to understand why this is the case and not the reverse. In order to shed light on this and even going beyond to understand why $H(p)$ curve takes certain shapes, our simulation model is utilized as an experimental platform to support our cognitive capacity by decreasing the complexity of reality even further. The model is run under some extreme and unrealistic conditions where it is impossible to realize such things in reality.

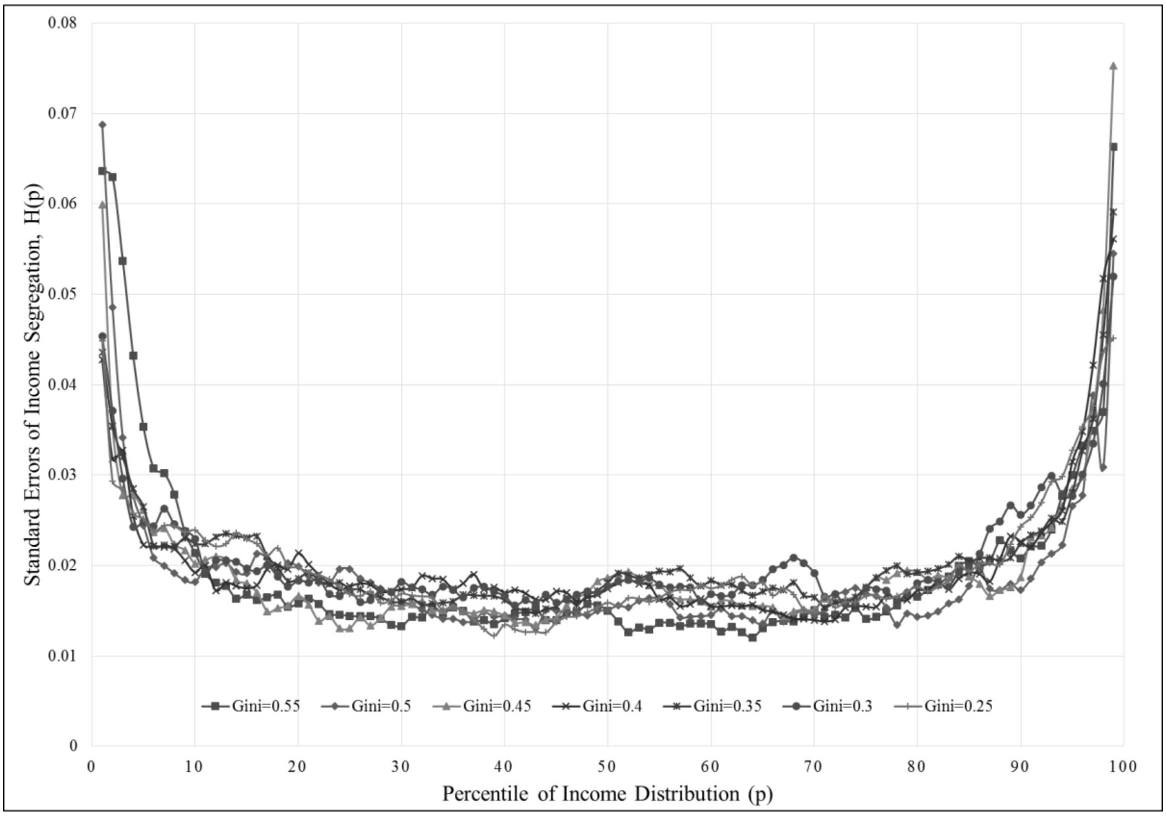

Figure 5.6. Standard errors for the graph at Figure 5.5.

5.2. Detailing Income Segregation Profiles

Figure 5.7 and Figure 5.8 illustrate such efforts where some portions of population are made to act as we specified, and paralyzed the rest of the households. For example, in Figure 5.7, the poorest 25% of population is made to pursue economical moves, meaning that they tried to move to cheaper houses while keeping everyone else immobile. Respectively, the richest 25% pursued status-seeking moves, that is, they tried to move higher status houses while keeping everyone else immobile. What we did here is actually, isolating a layer of realty and analyzing how it affects income segregation profiles. Put differently, we want to understand the impact of status-seeking moves of the richest households and economical moves of the poorest ones on the overall profile of income segregation in this part of experimentation.

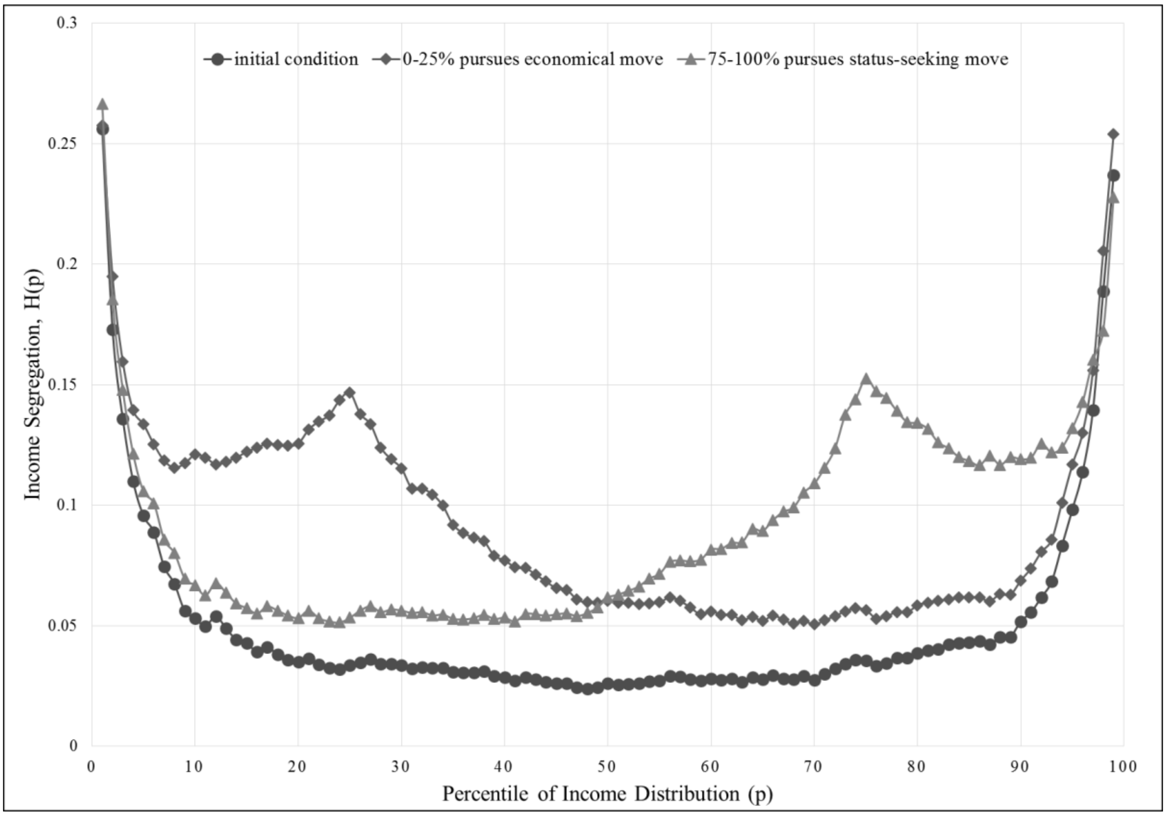

Figure 5.7. Cases with 1st quarter pursuing economical and 4th quarter pursuing status-seeking moves, while keeping everyone else immobile.

It is important to mention that focusing on quarters is simply a heuristic and by no means the only way of analysis. However, it has the advantage of being interpreted as low, lower-middle, upper-middle, and upper class. In addition, having more parts would make the analysis more difficult by complicating and having less parts might be insufficient to explain certain shapes of *H(p)*. Of course, one can conduct a different analysis by changing the sizes of such bins with assumptions on the sizes of these classes, instead of using quarters. Still, we think that having quarters as our unit of analysis is sufficient for our purposes in this study.

Figure 5.7 exhibits that status-seeking moves of the richest class increase the segregation of affluence significantly. It also raises the left part of the curve, meaning that the segregation of poverty also increases, though less than segregation of affluence. Since the rest of the households are immobile, the following explanation dictates: the moves of the affluent households to more affluent neighborhoods increase not only segregation of affluence but also segregation of poverty by leaving the poor neighborhoods much more homogeneous in terms of income. In other words, a move has an impact on its target as well as its destination, which is usually overlooked. It is also this feature of segregation problems that renders them as analytically complex phenomena.

From the observation and the argument above, it is hypothesized that formation or expansion of affluent neighborhoods or gated communities has a positive impact on formation or expansion of ghettos or slums in a city, and vice versa. Thus, studying segregation of poverty or affluence should not be done isolation since income segregation, as it is shown above, requires a more holistic approach due to the reciprocal relations of its elements.

The other interesting observation is the U-shape observed at the right tail. Since only richest 25% were trying move, it is not absurd that $H(p)$ values where $p > 0.75$ are higher than $H(p)$ values where $p \leq 0.75$. However, as p increases, $H(p)$ decreases. The reason of this decrease is although the richest 25% of population segregated from the rest, they are still mixed among themselves. For instance, $H(80)$ is less than $H(75)$ because the richest 20% of the households shares the same neighborhoods more with the rest than the richest 25% of the households' sharing the same space with the rest due to the fact that the households with $75 < p < 80$ live among the richest 20%. The similar analysis can be done for the case where poorest 25% pursues economical moves.

With this exercise, we build an intuition about the complex nature of income segregation problem. However, the impact of each kind of move on the income segregation profile depends on who is doing what. In other words, the impact of a rich household's status-seeking move is different from of a middle class household's status-seeking efforts, to the extent that the sources of the move as well as the possible targets differ. In Figure 5.8, it is seen that status-seeking moves of the upper-middle quarter of the population increase segregation of poverty and actually, decrease the segregation of affluence by being mixed with the richest households. Vice versa is valid for economical moves of the lower-middle quarter of population.

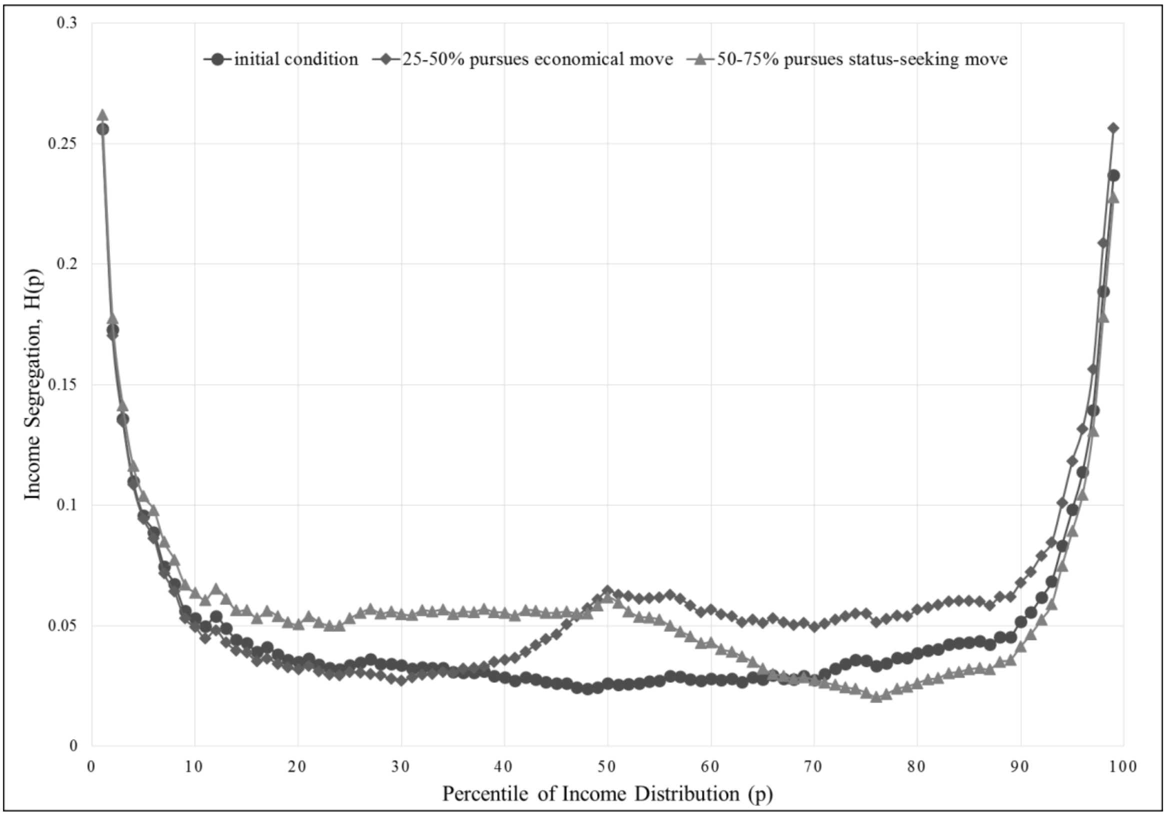

Figure 5.8. Cases with 2nd quarter pursuing economical and 3rd quarter pursuing status-seeking moves, while keeping everyone else immobile.

The above analyses boils down to the following argument: in Aristotelian sense, as wood being the material cause of a table, each move constitutes the material cause of income segregation. Two kinds moves are considered here related to income segregation: economical move and status-seeking move. As it is discussed above they have distinct impacts, which is further differentiated by the actor of the move. Put differently, her position in income pyramid determines her move's impact on income segregation profile. Moreover, the macro level outcome called income segregation is this complex combination[23] of all these differentiated effects that is observed in real life. Given this understanding, let us focus on the analyses of moves to shed more light on how income equality affects income segregation profiles.

[23] We also conducted other experiments where everyone is required to do economical or status-seeking moves. The results were very similar and there is almost zero segregation in both. Put differently, if everyone tries to go in the same direction, upward or downward in the income pyramid, the initial condition is simply preserved.

5.3. How Income Inequality Conditions Income Segregation?

Table 5.2 shows that the total attempts to moves as well as moves themselves decreased as inequality gets alleviated. In the light of the insight raised above, then it is obvious why the income segregation decreases. More specifically, overall, people become happier with their houses and neighborhoods, and want to move less as inequality decreases.

Table 5.2. Macro-level distribution of moving attempts, moves, and success ratios for lognormal distribution.

	Total Attempts to Move:		Total Moves:		Success Ratio:	
GINI	Economical	Status-Seeking	Economical	Status-Seeking	Economical	Status-Seeking
0.55	41636	32005	25160	12414	60.4%	38.8%
0.50	29943	28067	19223	9756	64.2%	34.8%
0.45	21973	24975	14554	7599	66.2%	30.4%
0.40	16147	21530	10740	5807	66.5%	27.0%
0.35	11902	19286	7942	4273	66.7%	22.2%
0.30	7837	16792	5387	3147	68.7%	18.7%
0.25	5041	14268	3625	2237	71.9%	15.7%

In addition, the amount of economical moves is always more than the status-seeking moves. Notice that, however, the ratio of status-seeking over economical moves increases as inequality gets lower. Finally, it is also interesting that the distribution of attempts to move changes for the cases where Gini coefficient less than 0.50. For the cases with income inequality lower than 0.50, in total, there is more demand of status-seeking moves than economical ones whereas it is vice versa for Gini values larger than 0.5. This implies that although reducing income inequality leads to less income segregation, its shape might take different forms.

As it is elucidated how *H(p)* curve, that is, income segregation profile changes with respect to moves of certain portions of population, the same explanatory tactic/heuristic is adopted here. Figure 5.9 and Figure 5.10 shows the distribution of moves realized by quarters of population as bar graphs of Table 5.3. Looking at both figures, having U-shaped *H(p)* curves is no surprise: majority of the economical moves are performed by the lower quarters and majority of the status-seeking moves are realized by the upper quarters.

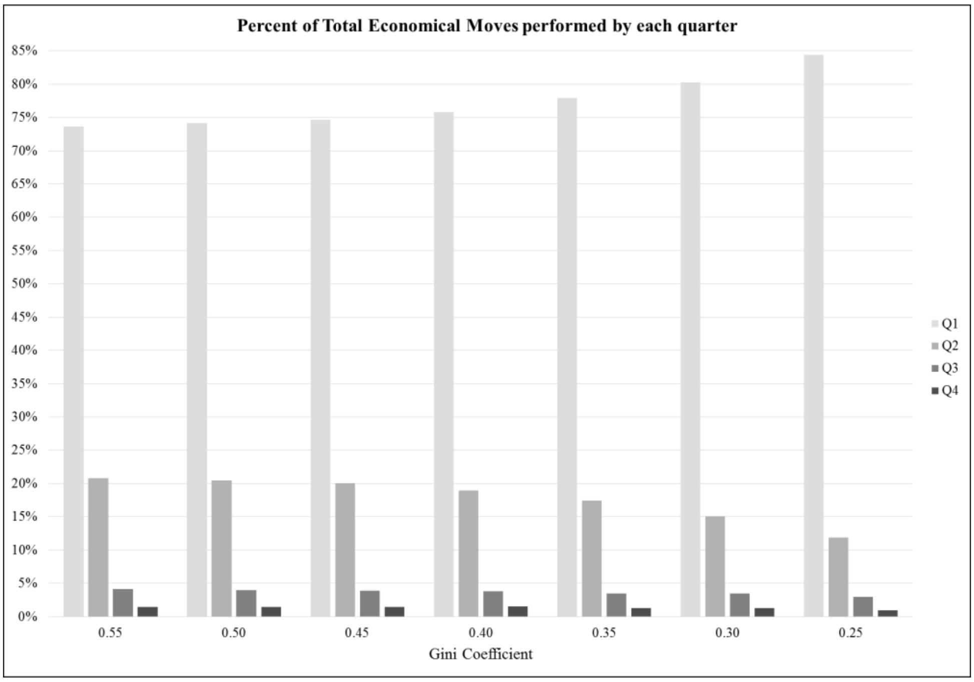

Figure 5.9. Composition of total economical moves performed by each quarter for varying levels of income inequality.

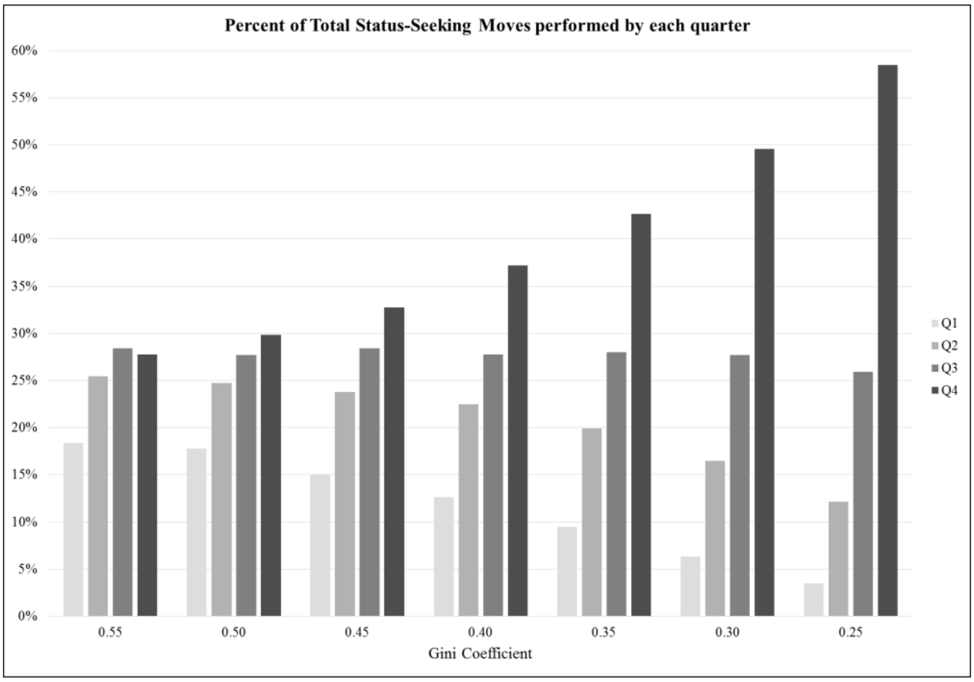

Figure 5.10. Composition of total status-seeking moves performed by each quarter for varying levels of income inequality.

Table 5.3. Messo-level distribution of moving attempts, moves, and success ratios among the quarters of population for log-normal distributed income.

Percent of Total Economical Moves performed by each quarter					Percent of Total Status-Seeking Moves performed by each quarter				
GINI	Q1	Q2	Q3	Q4	GINI	Q1	Q2	Q3	Q4
0.55	73.6%	20.8%	4.1%	1.4%	0.55	18.4%	25.5%	28.4%	27.7%
0.50	74.1%	20.5%	4.0%	1.5%	0.50	17.8%	24.7%	27.7%	29.8%
0.45	74.7%	20.0%	3.9%	1.5%	0.45	15.0%	23.8%	28.4%	32.7%
0.40	75.8%	19.0%	3.8%	1.5%	0.40	12.6%	22.5%	27.7%	37.2%
0.35	77.9%	17.4%	3.4%	1.3%	0.35	9.4%	19.9%	28.0%	42.7%
0.30	80.3%	15.0%	3.5%	1.2%	0.30	6.3%	16.4%	27.7%	49.5%
0.25	84.4%	11.8%	2.9%	0.9%	0.25	3.4%	12.1%	25.9%	58.5%

Total Economical Moves performed by each quarter					Total Status-Seeking Moves performed by each quarter				
GINI	Q1	Q2	Q3	Q4	GINI	Q1	Q2	Q3	Q4
0.55	18528	5229	1040	363	0.55	2285	3162	3524	3444
0.50	14245	3934	765	279	0.50	1732	2410	2703	2911
0.45	10865	2909	567	213	0.45	1143	1809	2160	2487
0.40	8139	2035	404	162	0.40	731	1305	1611	2160
0.35	6186	1384	272	100	0.35	404	850	1196	1823
0.30	4325	810	186	67	0.30	199	518	872	1559
0.25	3059	429	105	32	0.25	77	271	580	1308

Percent of Successful Economical Moves performed by each quarter					Percent of Successful Status-Seeking Moves performed by each quarter				
GINI	Q1	Q2	Q3	Q4	GINI	Q1	Q2	Q3	Q4
0.55	58.6%	67.9%	60.4%	60.4%	0.55	53.5%	61.8%	52.6%	21.6%
0.50	63.0%	68.8%	64.2%	64.2%	0.50	57.7%	62.4%	50.1%	18.4%
0.45	64.8%	72.3%	66.2%	66.2%	0.45	62.2%	62.1%	47.5%	15.9%
0.40	64.1%	78.4%	66.5%	66.5%	0.40	65.9%	61.8%	46.7%	14.5%
0.35	63.7%	85.1%	66.7%	66.7%	0.35	69.7%	62.3%	47.2%	12.3%
0.30	65.9%	89.6%	68.7%	68.7%	0.30	72.8%	64.5%	47.3%	11.2%
0.25	69.9%	90.3%	71.9%	71.9%	0.25	76.0%	68.1%	50.0%	10.4%

Another interesting pattern that is seen in Figure 5.5 is that segregation of poverty decreases faster than of affluence as the inequality decreases. Figure 5.9 reveals that the majority of economical moves are performed by the first quarter whereas the contributions of third and fourth quarters are almost negligible. Moreover, the total share of the lower quarters stays almost the same although the share of the first quarter increases with equality. However, this should be interpreted in relation to the change in the composition of status-seeking moves among quarters. Figure 5.10 shows that the share of upper quarters (lower quarters) increases (decreases) as inequality drops. These two observations together explain why segregation of affluence becomes higher than segregation of poverty for more even income distributions.

5.4. Typical Income Segregation Profiles

In Figure 5.5, it is seen that a *perfect* U-shape is never attained; either right-most or left-most ends always distort the U-shaped look of income segregation profiles by introducing local maxima. It is important to stress that (perfect) U-shape is not the only form of an income segregation profile. Yet, it is the most intuitive one; the poorest or the richest should be the most segregated one. Moreover, from Reardon et al's empirical studies, it is known that segregation curves approximate (recall that their data do not allow them to draw complete *H(p)* curve) some sorts of U-shape. However, as we extensively experimented with our simulation model, U, A, M, reverse-N, or N-shaped[24] *H(p)* curves are frequently observed. Among all, we argue that M-shape can be seen as the generic form with its having two hills. As the locations of two hills move, a variety of shapes of income segregation profiles, namely, U, A, reversed-N, and N are observed. Put differently, an income segregation profile is characterized by the locations as well as heights of these two hills.

What is important here is the meaning of a hill in an *H(p)* curve. Having a hill implies a relatively more homogeneous group within themselves—though distinct from the rest. Accordingly, a hill on the left-hand side can be interpreted as the pointer of the population living in ghettos, which are distinctively different from the rest. Likewise, a hill on the right tail and its vicinity would correspond to the unreachable affluent neighborhoods where only richest households reside in though mixed within themselves.

To illustrate, let us focus on Figure 5.5, and particularly on the curves when Gini is around 0.55 and 0.25. When Gini is around 0.55, the resulting income segregation profile has an N-shape with its hill around p=5. This tells us that the segregation of the poorest 5% from the richest 95% of the population is higher than the segregation of the poorest 2.5% from the richest 97.5%. In other words, the poorest 5% are mixed very well among themselves although they are significantly separated from the rest of the population. Figure

[24] Deploying letters to visualize the different shapes of income segregation profiles are based on the locations of the hills in them. For example, we interpret the curve when Gini=0.55 in Figure of H(p) has an N-shape because, starting from p=0, it first makes a hill, then decreases, and finally makes the second hill at p=100. An example to a reversed-N-shape is the curve when Gini=0.25. In a U-shape, the hills are at p=0 and p=100. With an A-shape, we mean that there is a single hill and it is relatively in the middle. M-shape has two hills and they are relatively at the extremes.

5.11 illustrates this visually by exhibiting the same outcome by emphasizing different portions of it. Here, the agents with larger sizes represent poorest 5% (the first figure) and 2.5% (the second figure). It is seen that the spread of the poorest 2.5% of the population coincides with the spread of the poorest 5% to a large extent, explaining why left extreme of *H(p)* has that particular shape.[25]

Then, one of the reasons of observing a hill at an extreme end can be due to the size of neighborhoods calculated in *H(p)*, justifying further Reardon & Bischoff's effort to delineate geographical scale of income segregation. To illustrate, imagine a large neighborhood such that it can accommodate 5% of the population and suppose that poorest 4% of population lives in the same neighborhood. Recalling the calculation of *H(p)*, inevitably, *H(4)* will be lower than *H(5)*. Yet, the hills in our model do not stem from the previous explanation since it is eliminated by having neighborhood sizes around 1% of population.

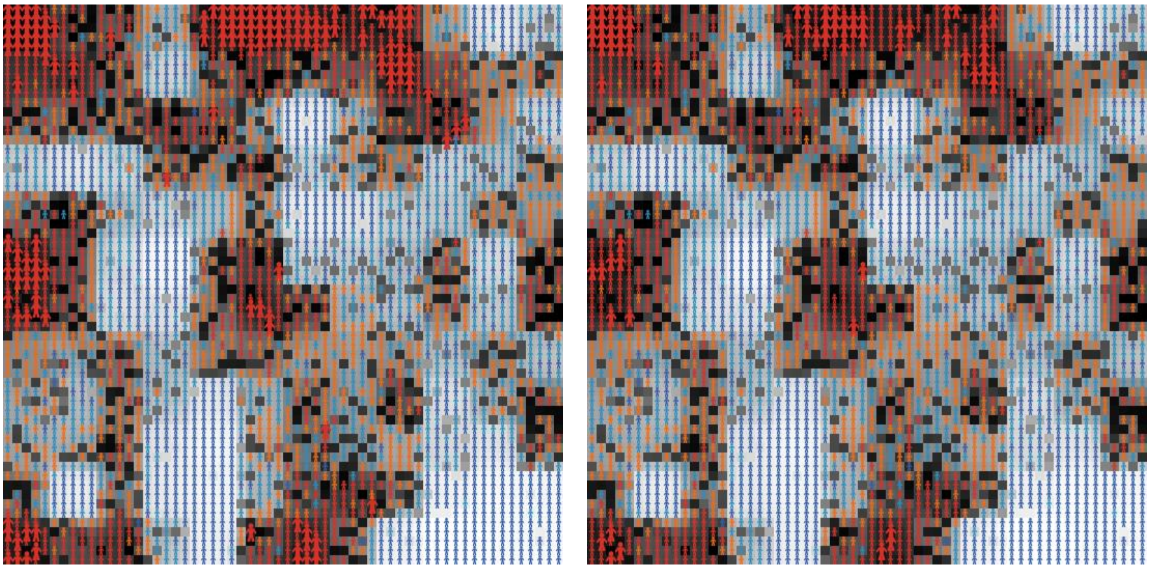

Figure 5.11. The spatial output of the run with benchmark parameters where Gini coefficient is 0.55 with seed equals to 1988.

[25] Recalling the calculation of H(p), the more selected people (for the corresponding p-value) fills a neighborhood, the higher H(p) values we have since it is the ratio of the selected people in a neighborhood that matters. Hence, if the poorest 2.5% spread to the same neighborhoods with the poorest 5%, then H(2.5) will inevitably be lower than H(5).

A second reason of a hill at an extreme end of H(p) can be some natural mixing due to several reasons. For instance, there may be some low quality houses in affluent neighborhoods and high quality ones in poor neighborhoods. Another example is that on the poverty side, gentrifiers with high income move in poor neighborhoods and on the affluence side, the poor tenants with a long history in a house such that their intimate relationship with the landlord preventing the rent skyrocket although their neighborhood is becoming more and more expensive. Note that these two examples represent huge jumps in income-percentiles. Another more expected explanation for our simulation model is represented by smaller jumps in income-pyramid that can be found from the discussion of the U-shapes in Figure 5.7. Sometimes further stratification might be deemed unnecessary. For example, beyond the richest 95%, the affluent households may not mind whether they reside in the richest neighborhood or one below.

Finally, it might be due to market's inability to match the households and houses properly, yielding lock-ins for some households to find better alternatives and imposing on them to live in the neighborhoods which they would not prefer, decreasing segregation locally (and eventually, globally). Here, the characteristics of the excess housing supply is critical. When inequality is high, a buffer zone around the rich households' residential areas may emerge in the form of vacant houses since the rents in their neighborhoods become very high such that even some rich cannot afford. For example, the share of expensive houses (the average rent-percentile[26] of vacant houses) among the empty houses is higher in high inequality cases, as it is seen from Table 5.4. Since the amount of empty houses is constant throughout simulations, expensive houses constitution of higher proportion of empty house automatically means that there are lower number of low-cost housing. This can be interpreted as a low-cost housing shortage leading to less mobility for lower income households. That may result in lock-ins, where people have to live in houses with rents beyond that they can tolerate.

[26] By rent-percentile, the rank order of houses with respect their rents is meant.

Table 5.4. Statistics regarding poorest and richest 5%, rent and status percentiles of vacants, and standard deviations of rents in the case of log-normal distribution.

GINI	% of poorest 5% residing in houses of which rent is higher than they can tolerate	% of richest 5% residing in houses of which status is lower than they can tolerate	Avg rent-percentile of vacants	Avg status-percentile of vacants	standard-deviation of all rents	standard-deviation of avg rents in neighborhoods
0.55	42.69	11.01	0.213	0.440	3.662	3.583
0.50	16.12	11.56	0.171	0.403	4.373	4.273
0.45	5.07	10.99	0.143	0.375	5.084	4.951
0.40	1.44	10.18	0.120	0.349	5.969	5.783
0.35	0.42	10.33	0.101	0.328	7.391	7.089
0.30	0.27	9.78	0.092	0.328	7.800	7.400
0.25	0.13	10.08	0.083	0.324	8.870	8.248

A symmetric argument, following from the above one, is possible for the low inequality cases: as inequality gets lower, the financial barriers for lower strata becomes less effective, leading more households into affluent neighborhoods. This would inevitably decrease the average status of the affluent neighborhoods, leading the affluent households to search for better alternatives. However, the mobility for the affluent would be less since the share of the high status and empty houses constitutes less of all empty houses. Again, that may result in lock-ins, where people have to live in houses with statuses lower than they can tolerate.

In our model, the second and the third reasons are the causes of having hills since the first one is eliminated as it is discussed above. Accounting for the second one would be very laborious and costly with respect to coding efforts and memory considerations. However, the presence of the third one, the market’s inefficiency can be tracked. It is also, arguably the most important of all since there is room for policy making, and a possibility to ameliorate the income segregation problem.

In Table 5.4, the amount of poorest households who live in houses that they cannot tolerate because they fail to find a better alternative is seen; a cheaper one, either due to such an alternative does not exist or they fail to find one. Note that as inequality drops, it is seen that amount decreases so the hill moves leftwards and finally disappear.

A similar argument can be made for the relatively little hills on the affluent side (see Figure 5.5), particularly for the ones with Gini coefficient less than 0.40[27]. It is seen that a persistent and non-negligible amount of the richest households remain unhappy with the

[27] For the ones above 0.40, the depth and the location of the hill are negligible.

perceived statuses of their neighborhoods. Note that the depth of the hill is smaller compared to the ones on the poverty side, probably because the unhappy portion of the richest is smaller than the poorest one.

5.5. How Income Distributions Condition Income Segregation?

Here, we are extending our argument about income inequality to income distribution since we only focused on lognormal distribution so far. How do overall income segregation and its profiles change when there is a different kind of income distribution although they have the same level of income inequality? Comparing two such income distributions would enlighten how the distribution of income operates in creating income segregation.

Figure 5.12 shows the relation between overall income segregation and income inequality where income follows a gamma distribution compared to the benchmark case. The relation is very similar to the one with lognormal distribution. Hence, the argument that the level of income inequality conditions the level of overall income segregation is robust.

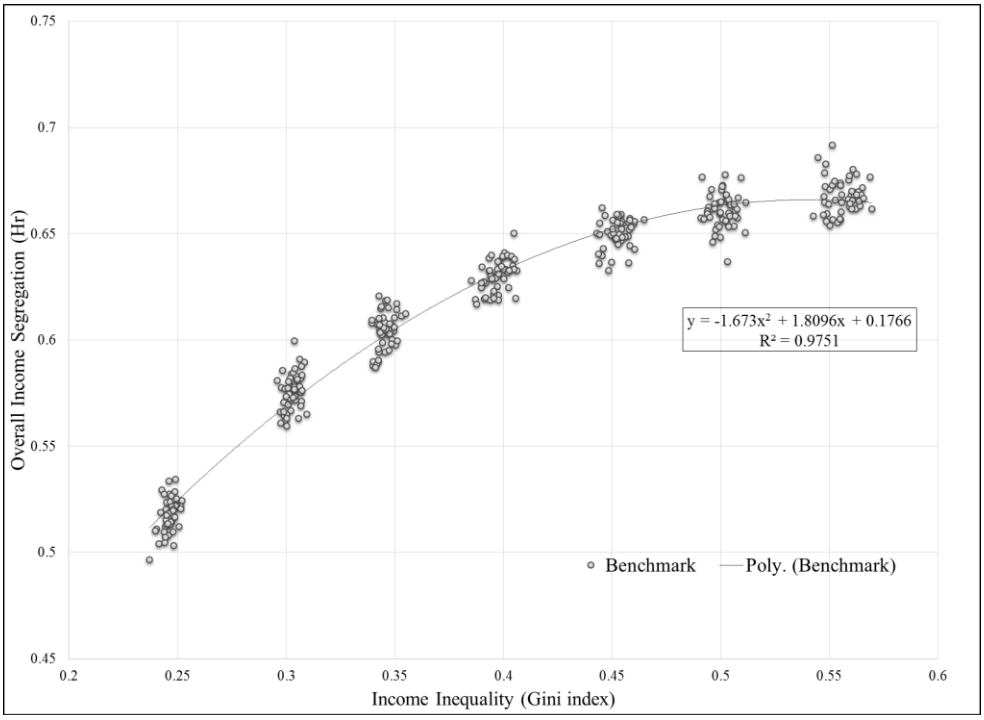

Figure 5.12. Income segregation profiles for different levels of income inequality where the income follows gamma distribution.

Figure 5.13 shows, however, although the overall income segregation follows a similar pattern, its shape is strikingly different. Compared to Figure 5.5, M-shaped curves can be clearly seen. Moreover, in contrast to lognormal distribution of income, with gamma distribution it is seen that segregation of affluence is higher than segregation of poverty for high inequality cases and lower for low inequality cases. Therefore, it is deduced that the shape of income segregation profile is determined by the shape of income distribution.

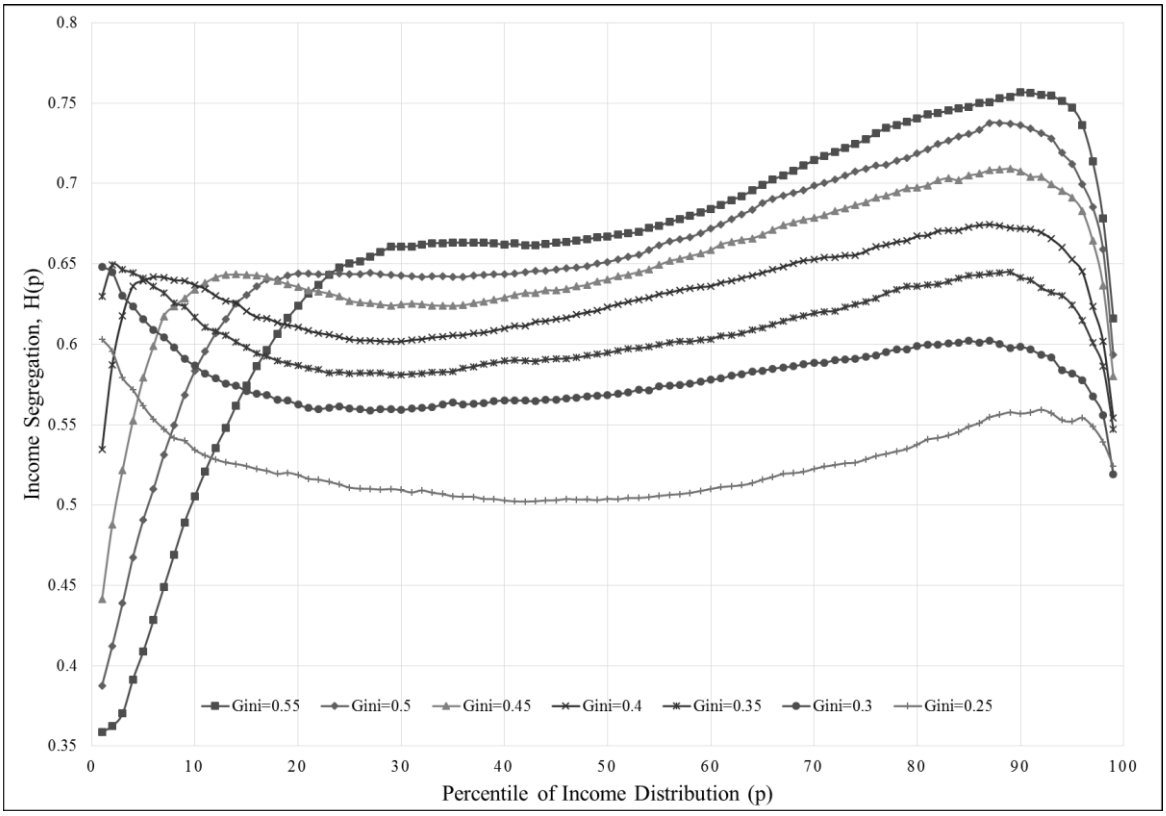

Figure 5.13. Income segregation profiles for Gamma distributed income.

Note that for low levels of inequality, their shape become similar to each other as it is seen in Figure 5.14. This is also true for the shape of two income distributions: they approximate the same distribution, namely, normal distribution, as inequality decreases (that is, as shape parameter for gamma increases and standard deviation for lognormal increases). Therefore, the important part is to explain the differences for the high and mid-level inequality cases.

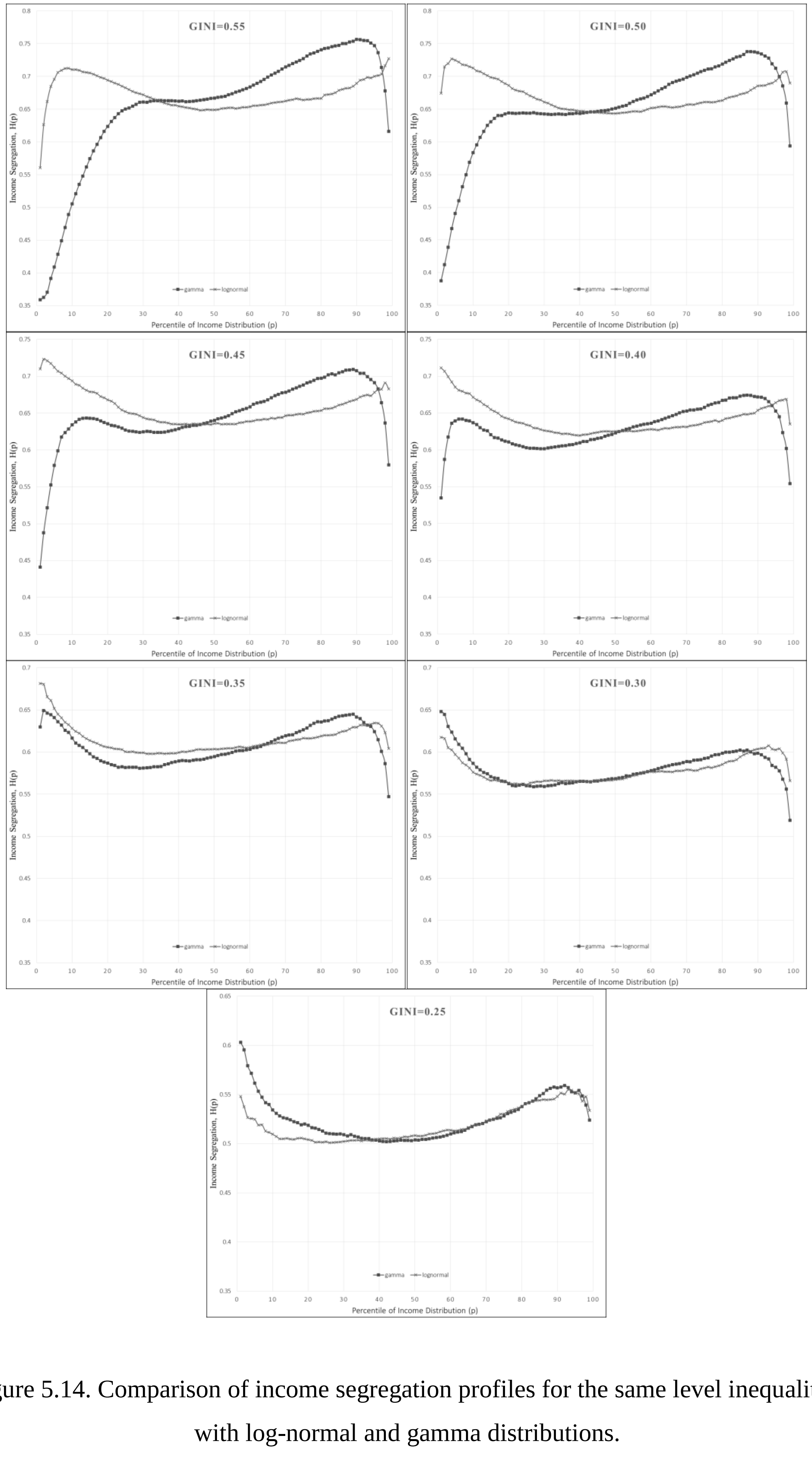

Figure 5.14. Comparison of income segregation profiles for the same level inequalities with log-normal and gamma distributions.

A column wise comparison of Table 5.2 and Table 5.5 reveals that the ratios of the economical moves and status-seeking moves are not that different: in both, economical moves are more than status-seeking ones. Notably, in gamma distribution economical moves constitute a higher proportion of all moves. Moreover, the success ratios, particularly of economical moves, are significantly lower for gamma than lognormal. Overall, gamma distribution yields more moves and hence, it is expected to see more segregation. However, that is not the case, which suggests that after some certain level of segregation is achieved, moves of the household can be redundant in terms of segregation.

Table 5.5. Macro-level distribution of moving attempts, moves, and success ratios for gamma distribution.

	Total Attempts to Move:		**Total Moves:**		**Success Ratio:**	
GINI	**Economical**	**Status-Seeking**	**Economical**	**Status-Seeking**	**Economical**	**Status-Seeking**
0.55	93522	47288	37394	14485	40.0%	30.6%
0.50	66267	44660	32967	13609	49.7%	30.5%
0.45	46577	40522	27320	12148	58.7%	30.0%
0.40	29317	33684	19314	9430	65.9%	28.0%
0.35	17911	26648	12569	6639	70.2%	24.9%
0.30	11522	21508	8224	4522	71.4%	21.0%
0.25	6186	15377	4446	2502	71.9%	16.3%

When Table 5.3 and Table 5.6 are compared, it is seen that the lower quarters constitute more of economical moves than the lower quarters of lognormal distribution. From this, it is expected to have higher level of segregation of poverty. In addition, in gamma distribution, the proportion of status-seeking moves of upper quarters are lower than the ones in log-normal distribution, telling that in gamma the lower quarters perform more status-seeking moves than log-normal. From this observation, a lower level of segregation of affluence is expected. However, both of our expectations turn out to be wrong. Segregation of affluence is almost always higher than segregation of poverty, in contrast to what is expected.

Recalling the second reason of having a hill, namely the discussion of the U-shape for Figure 5.7, increase in the economical moves of the lower quarters and the status-seeking moves of the upper quarters might also bring about a natural mixing within themselves. Nevertheless, a much more explicit accounting for this puzzle is possible.

An explanation of the low level of segregation of poverty again comes from whether housing market worked fine in allocating houses to households or not. In Table 5.7, when inequality is highest, it is seen that almost all of the poorest 10% of households pays rent more than they can tolerate. Put differently, almost all of the poorest 10% live in more expensive houses than they can tolerate. Of course, this decreases the segregation of poverty. Note that similar to lognormal case, as inequality drops, the hills move leftwards and disappear eventually as the amount of overpaying households diminishes. Nevertheless, for high and mid-level of inequality cases, the unhappy amounts of households are significantly higher for gamma distribution, justifying having a lower segregation of poverty than expected.

Table 5.6. Messo-level distribution of moving attempts, moves, and success ratios among the quarters of population for gamma distributed income.

Percent of Total Economical Moves performed by each quarter				
GINI	Q1	Q2	Q3	Q4
0.55	79.1%	19.3%	1.4%	0.3%
0.50	83.8%	14.6%	1.3%	0.3%
0.45	86.0%	12.2%	1.4%	0.3%
0.40	86.7%	11.3%	1.6%	0.4%
0.35	87.2%	10.6%	1.8%	0.4%
0.30	87.2%	10.5%	2.0%	0.4%
0.25	88.6%	9.1%	2.0%	0.3%

Percent of Total Status-Seeking Moves performed by each quarter				
GINI	Q1	Q2	Q3	Q4
0.55	25.0%	38.8%	20.3%	16.0%
0.50	36.1%	31.4%	16.9%	15.5%
0.45	42.5%	26.5%	15.2%	15.8%
0.40	44.8%	22.2%	14.8%	18.2%
0.35	42.3%	18.7%	15.8%	23.2%
0.30	33.9%	16.9%	18.0%	31.2%
0.25	16.5%	13.6%	21.1%	48.7%

Total Economical Moves performed by each quarter				
GINI	Q1	Q2	Q3	Q4
0.55	29572	7209	511	102
0.50	27612	4812	440	104
0.45	23501	3344	383	92
0.40	16750	2188	304	71
0.35	10961	1335	220	52
0.30	7172	859	162	32
0.25	3939	404	87	15

Total Status-Seeking Moves performed by each quarter				
GINI	Q1	Q2	Q3	Q4
0.55	3620	5613	2940	2311
0.50	4912	4274	2306	2116
0.45	5165	3216	1849	1918
0.40	4226	2089	1395	1720
0.35	2810	1242	1047	1540
0.30	1532	766	815	1410
0.25	414	340	529	1220

Percent of Successful Economical Moves performed by each quarter				
GINI	Q1	Q2	Q3	Q4
0.55	36.3%	68.4%	40.0%	40.0%
0.50	47.3%	70.8%	49.7%	49.7%
0.45	57.0%	73.9%	58.7%	58.7%
0.40	64.4%	79.8%	65.9%	65.9%
0.35	68.7%	85.7%	70.2%	70.2%
0.30	69.7%	88.7%	71.4%	71.4%
0.25	70.5%	88.6%	71.9%	71.9%

Percent of Successful Status-Seeking Moves performed by each quarter				
GINI	Q1	Q2	Q3	Q4
0.55	31.8%	52.7%	44.1%	12.4%
0.50	38.9%	52.2%	41.4%	11.6%
0.45	43.1%	51.5%	41.6%	10.7%
0.40	47.3%	52.2%	41.7%	9.9%
0.35	51.2%	51.7%	41.8%	9.5%
0.30	55.3%	53.2%	42.5%	9.2%
0.25	64.3%	58.9%	47.0%	9.4%

Note that this explanation also justifies the unexpected negative relation between income inequality and the segregation of the poorest as it is visible in Figure 5.13. This does not tell us that the higher income inequality is better for the poor since it yields lower segregation between them and the rest of the population. Rather, it is an illusionary alleviation since the poorest part cannot find a cheaper housing in the model. It should be stressed that this unexpected negative relation would not happen if immigration to other cities, expansion of the city, or homelessness are included in the model.

Similarly, the persistent hills on the affluent side can be explained by the market's inefficient allocation at the top. It is seen that compared to log-normal distribution, a higher proportion of affluent households are unhappy with the status of their neighborhoods.

Table 5.7. Statistics regarding poorest 10% and richest 5%, rent and status percentiles of vacants, and standard deviations of rents in the case of gamma distribution.

GINI	% of poorest 10% residing in houses of which rent is higher than they can tolerate	% of richest 5% residing in houses of which status is lower than they can tolerate	Avg rent-percentile of vacants	Avg status-percentile of vacants	standard-deviation of all rents	standard-deviation of avg rents in neighborhoods
0.55	98.89	19.82	0.250	0.440	7.991	7.840
0.50	80.92	18.56	0.212	0.404	8.869	8.683
0.45	53.10	18.46	0.178	0.373	9.297	9.075
0.40	23.80	17.97	0.147	0.345	9.664	9.371
0.35	8.20	16.41	0.121	0.322	10.666	10.261
0.30	2.79	13.49	0.104	0.317	11.042	10.496
0.25	0.37	9.96	0.085	0.320	11.523	10.633

The arguments above can be supported by success ratios seen in Table 5.6. The poorest quarter's success ratio of economical moves for high inequality cases are significantly lower compared to lognormal case's values. Likewise, the richest quarter's success ratio for status-seeking moves for high inequality cases are significantly lower compared to lognormal case's values.

6. SCENARIO ANALYSES

6.1. Impact of Income's Influence on Rents

In the above analyses, it is assumed that weight of income in determining rents is 0.2, which is decided after extensive experimentation. It can be argued that it is an accurate approximation within the boundaries of this study since the model is able to produce stylized facts about real world.

Willer & Benard (2007) identifies the impact of the neighbors' wealth on a house's price as endogeneity as opposed its exogeneous component which is a constant price regarding the house. They find that as endogeneity increases, that is, as the price of a house is determined more by the wealth of neighbors, segregation increases as well.

It is also found that the overall level of segregation is higher when the weight of income is higher. Table 6.1 shows that indeed both segregation measures are higher when weight of income is higher. However, when weight of income is one, which means the rents are completely based on income, the impact of inequality disappears. When weight of income is zero, on the other hand, although segregation is less, the relation between inequality and segregation is preserved.

Table 6.1. The impact of weight of income on overall segregation measures.

GINI	Weight of Income			
	0		1	
	H^R	D*	H^R	D*
0.55	0.488	62.154	0.631	72.228
0.50	0.460	59.613	0.634	72.907
0.45	0.444	58.134	0.635	73.195
0.40	0.407	53.831	0.637	73.848
0.35	0.368	48.485	0.640	74.533
0.30	0.325	42.636	0.637	74.352
0.25	0.267	35.364	0.616	71.983

Figure 6.1 and Figure 6.2 shows the curves at two extremes when weight of income is zero and one, respectively. It is seen that weight of income has a positive impact on segregation of affluence: when it is one, it is seen that segregation of affluence is always significantly higher than segregation of poverty. On the other hand, when it is zero, it is seen that segregation of affluence is not preserved, and for almost all inequality levels, it converges to a similar value. Moreover, it is seen that segregation of poverty is always higher than segregation of affluence. In other words, when it is zero, the financial barrier that yields segregating the affluent from the rest becomes down. Thus, they are always surrounded by non-affluent households.

This analysis tells us that the impact of income on rents is in favor of segregation of affluence and has little to explain segregation of poverty.

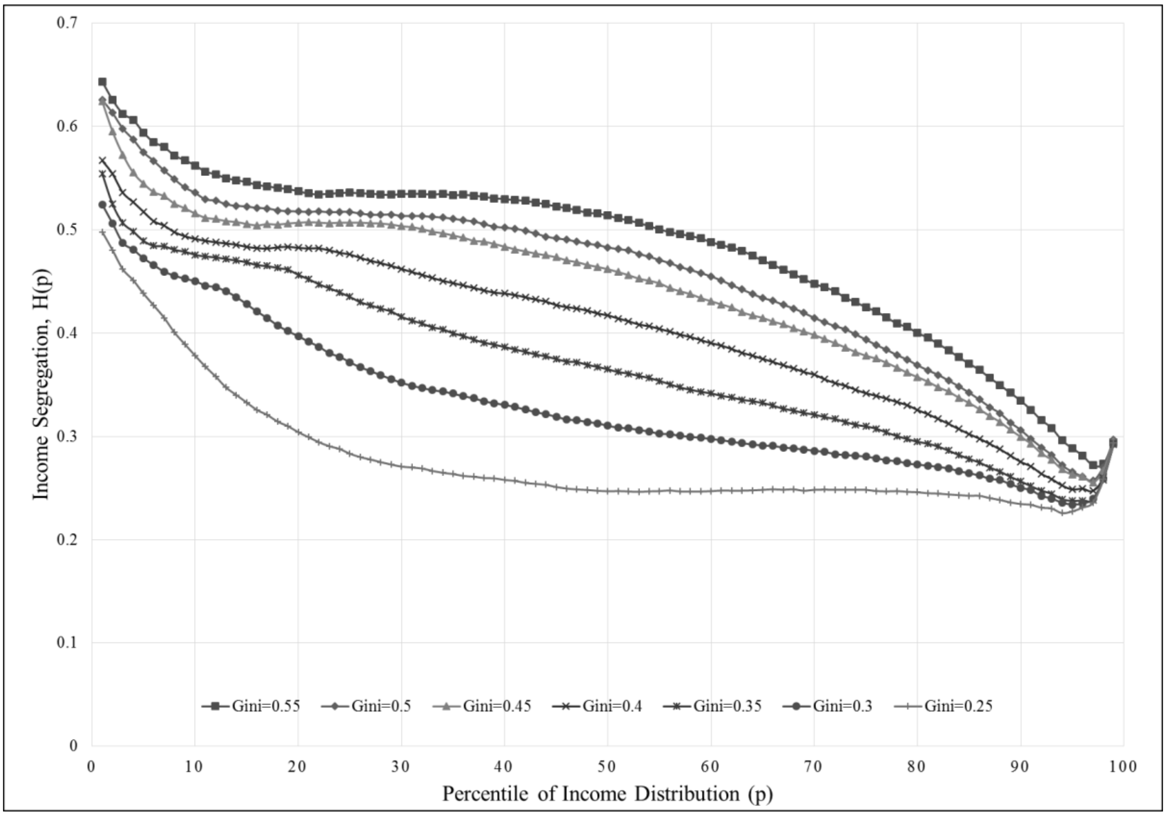

Figure 6.1. Income segregation profiles when income has no weight in determination of rents.

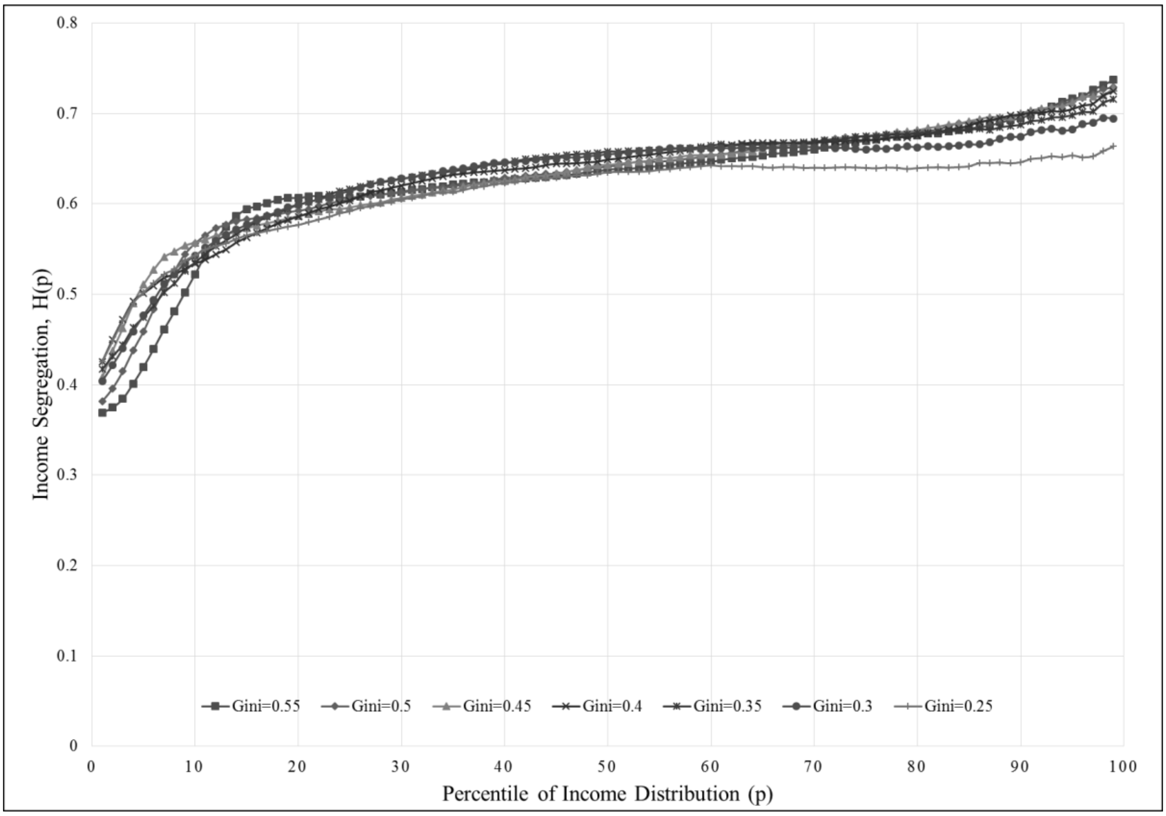

Figure 6.2. Income segregation profiles when income is the only factor that determines of rents.

6.2. Impact of Income & SES Correlation

Following Willer & Benard (2007), experiments on how correlation between income and SES affects income segregation are conducted. Table 6.2 shows similar results to theirs; as the correlation between the two decreases, segregation decreases as well. Figure 6.3 shows the resulting income segregation profiles for lower correlation. It is obvious that segregation of affluence seems to be very vulnerable to correlation between income and SES such that even mild decrease in correlation leads to significant decrease in it, which also pushes overall income segregation down as well. It might stem from the fact that lower correlation yields more people with low income but high SES that are co-opted by high income and SES people.

Another interesting change compared to benchmark, Figure 5.5, the hills on the left are located more inwards, meaning more people at the bottom live in intolerably expensive houses. This is related to the households with low SES but high income whom are avoided by the high SES households.

Table 6.2. The impact of correlation between income and SES.

GINI	Correlation between Income & SES			
	0.83		0.92 (Benchmark)	
	H^R	D*	H^R	D*
0.55	0.513	60.84	0.667	72.31
0.50	0.502	59.71	0.662	71.77
0.45	0.493	58.50	0.649	71.10
0.40	0.481	57.20	0.634	70.33
0.35	0.457	55.00	0.609	68.31
0.30	0.427	51.82	0.573	65.13
0.25	0.382	46.97	0.514	59.78

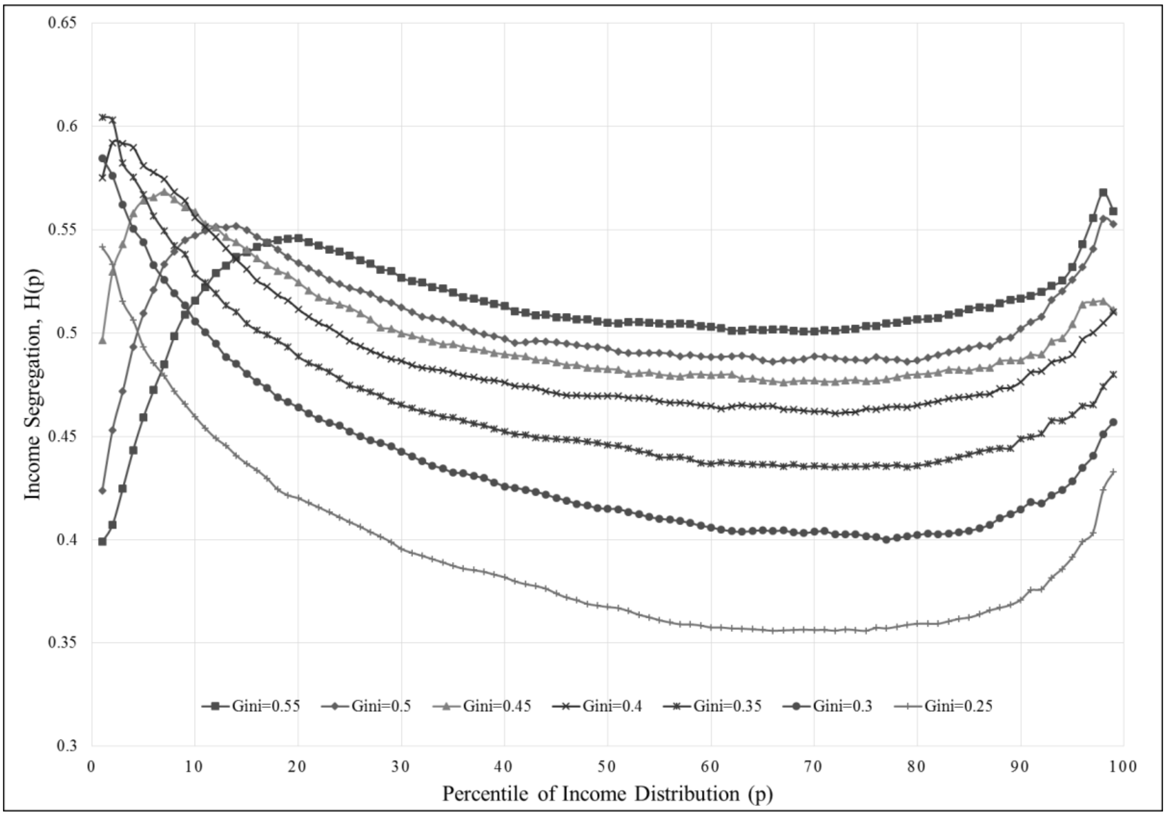

Figure 6.3. Income segregation profiles when correlation between income & SES is 0.83.

Then, the correlation between SES, desirability in general, and income turns out to be related to not only level of income segregation but also shape of it.

6.3. Impact of Rent Control Policy

In some countries, rent-control policies are implemented to control the rents to protect tenants. Some of them take form of price ceilings whereas others determine maximum possible increase in a year or years. Here, the second one will be focused on.

Figure 6.4, Figure 6.5, and Figure 6.6 shows that cases where the maximum increase in rents limited to 1, 2.5[28], and 10% in a single iteration. It is seen that such policies significantly alleviates segregation of poverty and have negligible impact on segregation of affluence. Note that in benchmark case, there is no such policy and results are almost equal to a scenario with the rent-control of 25%. In sum, rent-control policies seem effective to drive income segregation down, particularly by decreasing segregation of poverty.

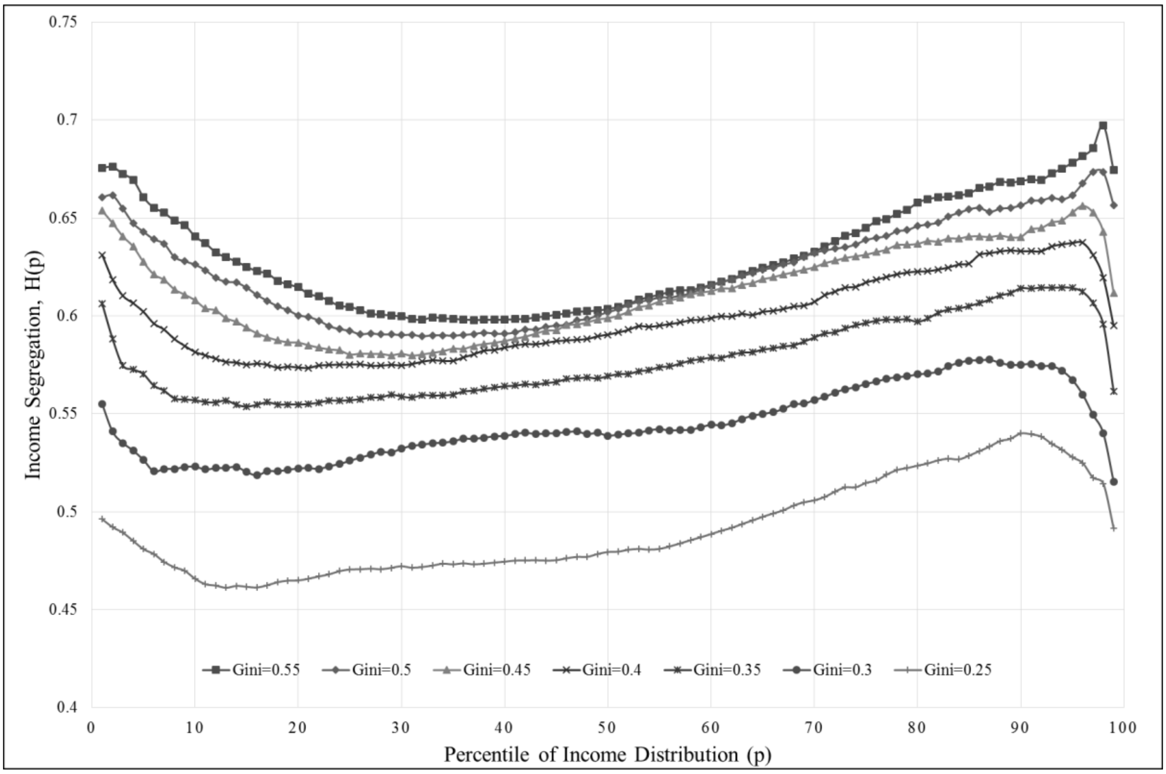

Figure 6.4. Income segregation profiles when the maximum increase in rents is 1%.

[28] For example, in Canada, it is 2.5% per year. In Germany, it can be no more than 20% increase in total in three years. (Source wikipedia)

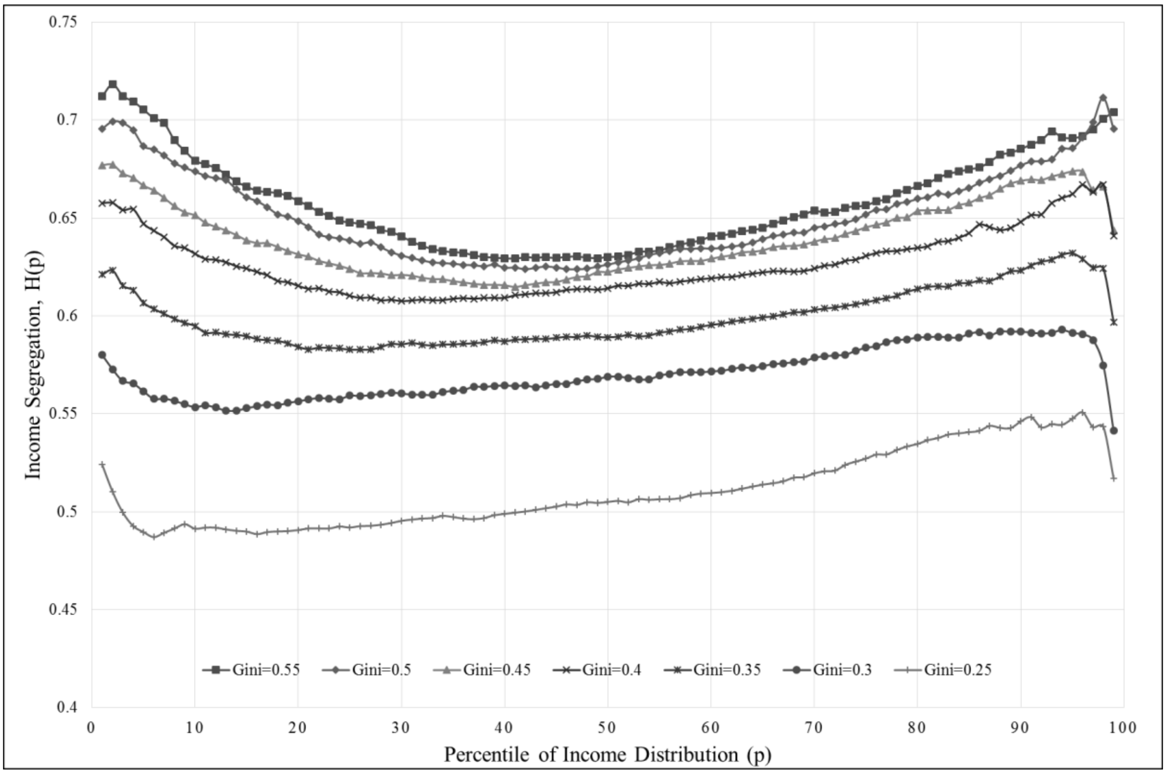

Figure 6.5. Income segregation profiles when the maximum increase in rents is 2.5%.

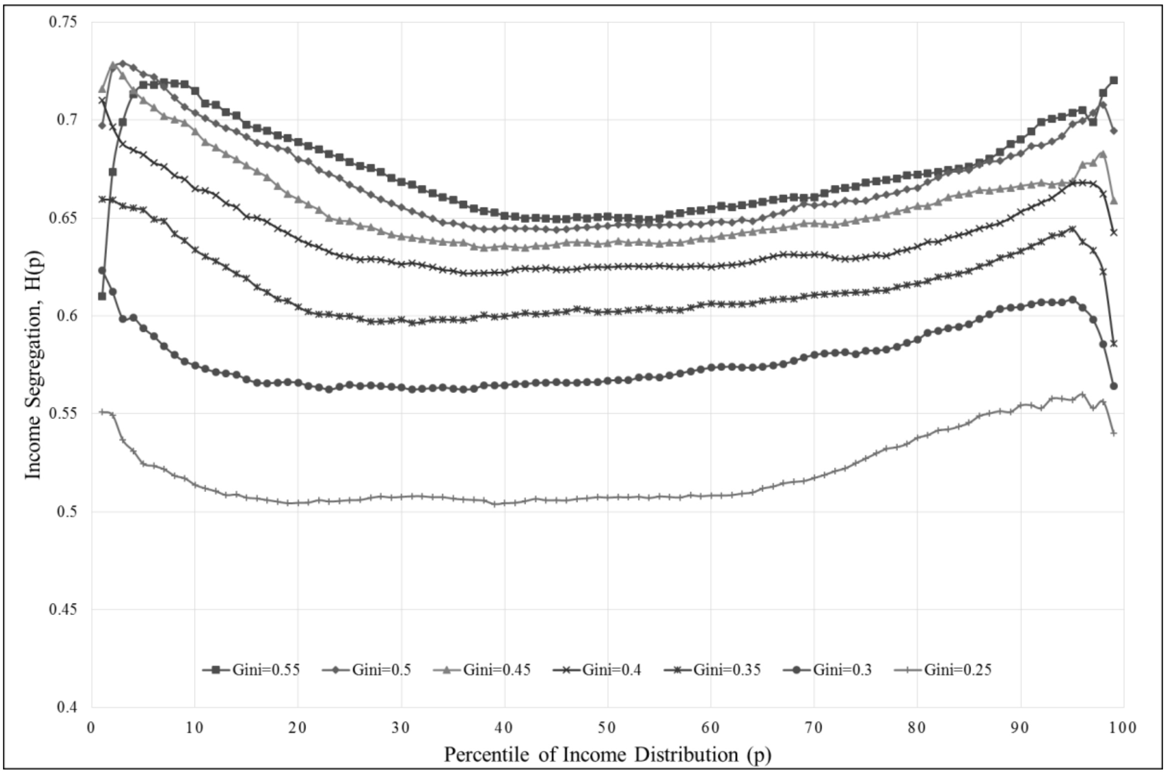

Figure 6.6. Income segregation profiles when the maximum increase in rents is 10%.

6.4. Impact of Urban Density

Here, the impact of urban density on income segregation is analyzed. Urban density, which is equal to one minus vacancy ratio in our model, can affect it via two ways: first, lower excess housing might decrease overall mobility of the households. Second, by means of supply & demand, it affects the rents such that lower excess housing yields higher rents.

Table 6.3 shows that as urban density increases level of income segregation increases as well. However, contrary to what is expected, the mobility increased with urban density. The main reason of that is the second cause that is mentioned above, that is, the rents becomes higher, urging more households to move. It is visible from the percentage of overpriced households, who reside in houses with rents higher than they can tolerate. Note that the increase in economical moves is significantly more than the increase in status-seeking moves.

Table 6.3. The impact of urban density on overall income segregation level.

GINI	Urban Density											
	0.8				0.85 (benchmark)				0.9			
	H^R	Total economical moves	Total status-seeking moves	% of overpriced households	H^R	Total economical moves	Total status-seeking moves	% of overpriced households	H^R	Total economical moves	Total status-seeking moves	% of overpriced households
0.55	0.660	17848	10882	0.87	0.667	24707	12314	2.52	0.671	31587	13432	7.54
0.50	0.652	13722	8736	0.49	0.661	19186	9916	1.13	0.663	27512	11191	5.19
0.45	0.638	10394	6847	0.26	0.651	14385	7593	0.53	0.659	22327	8875	3.06
0.40	0.619	7925	5205	0.14	0.632	11000	5724	0.26	0.650	17111	6588	1.28
0.35	0.593	5655	4005	0.06	0.609	7930	4310	0.12	0.627	12564	4760	0.56
0.30	0.556	3883	2898	0.02	0.571	5518	3089	0.06	0.597	8572	3415	0.16
0.25	0.494	2472	2105	0.01	0.515	3540	2233	0.03	0.541	5646	2385	0.09

Figure 6.7 and Figure 6.8 illustrate cases with lower (0.80) and higher (0.90) urban density cases compared to the benchmark (0.85) in Figure 5.5. From these, it is seen that segregation of affluence is affected very little compared to segregation of poverty as well as segregation for the middle level income percentiles when inequality is high. The hills on the left move inwards as urban density increases mainly due to inability of the market in creating affordable houses for the poor households (see Table 6.3). When the inequality is lower, it is seen that segregation of poverty becomes higher for higher urban density cities.

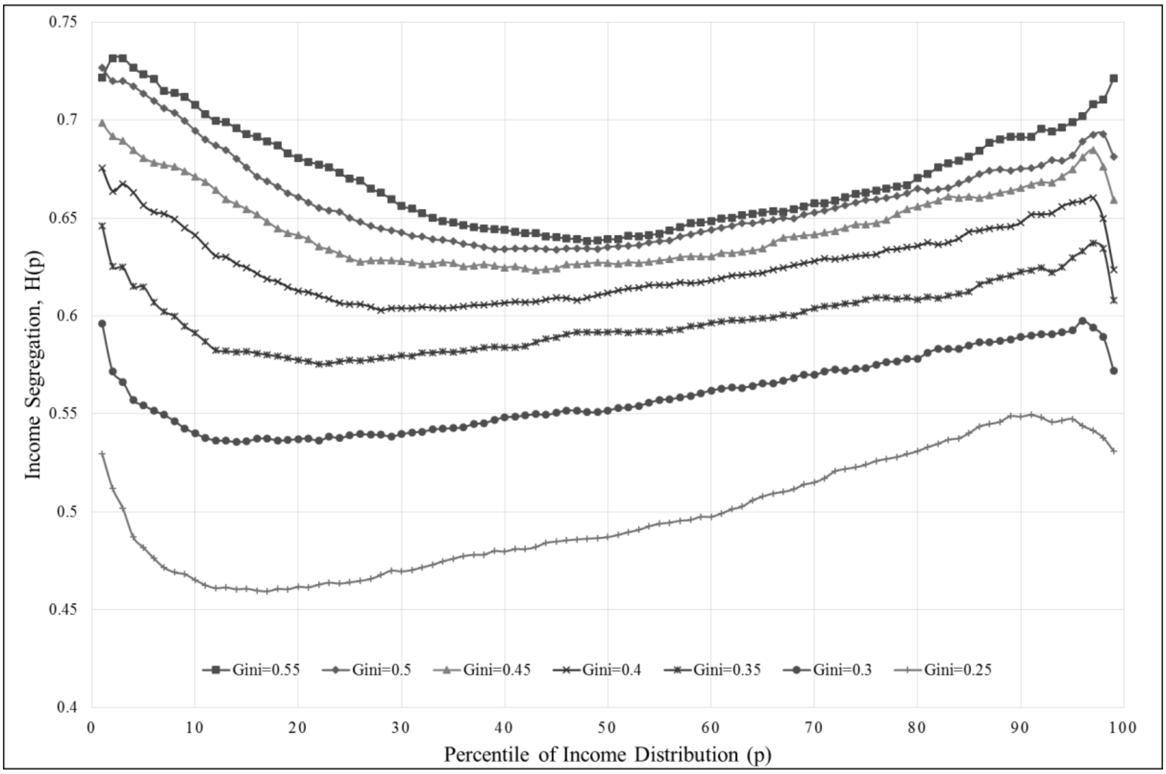

Figure 6.7. Income segregation profiles when urban density is 0.80.

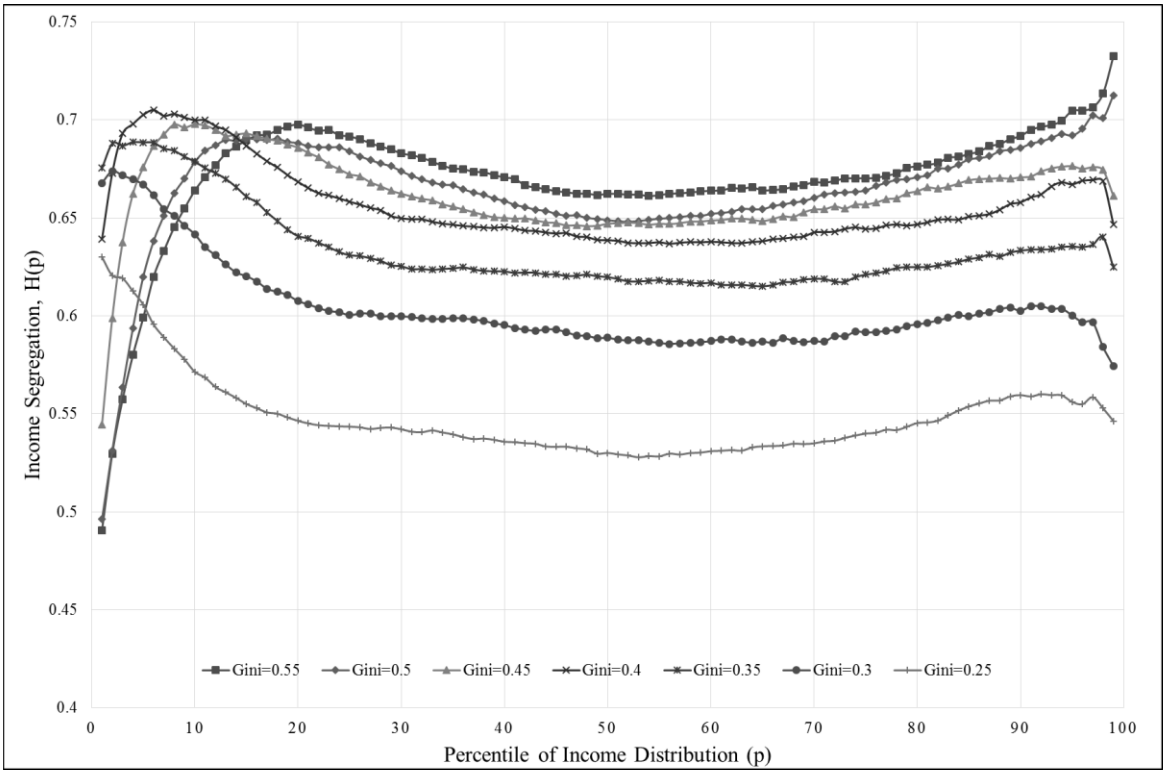

Figure 6.8. Income segregation profiles when urban density is 0.90.

6.5. Impact of Perfect Information

In our benchmark case, it is assumed that our households made their searches over neighborhoods to approximate reality. In this scenario, on the other hand, the impact of perfect information about the housing market is tried to be assessed. In other words, in these cases, our households know all the vacant houses and pick their houses accordingly. Note that they still pick a better one with respect to their need, not the best possible. In a sense, this scenario can be interpreted as investigating the impact of online searches.

Figure 6.9 shows the resulting income segregation profile. Comparing it to Figure 5.5, it is seen that having such information is most beneficial for the poor. Overall level of income segregation is lower mainly due to lower level of segregation of poverty; segregation of affluence seems to be affected infinitesimally.

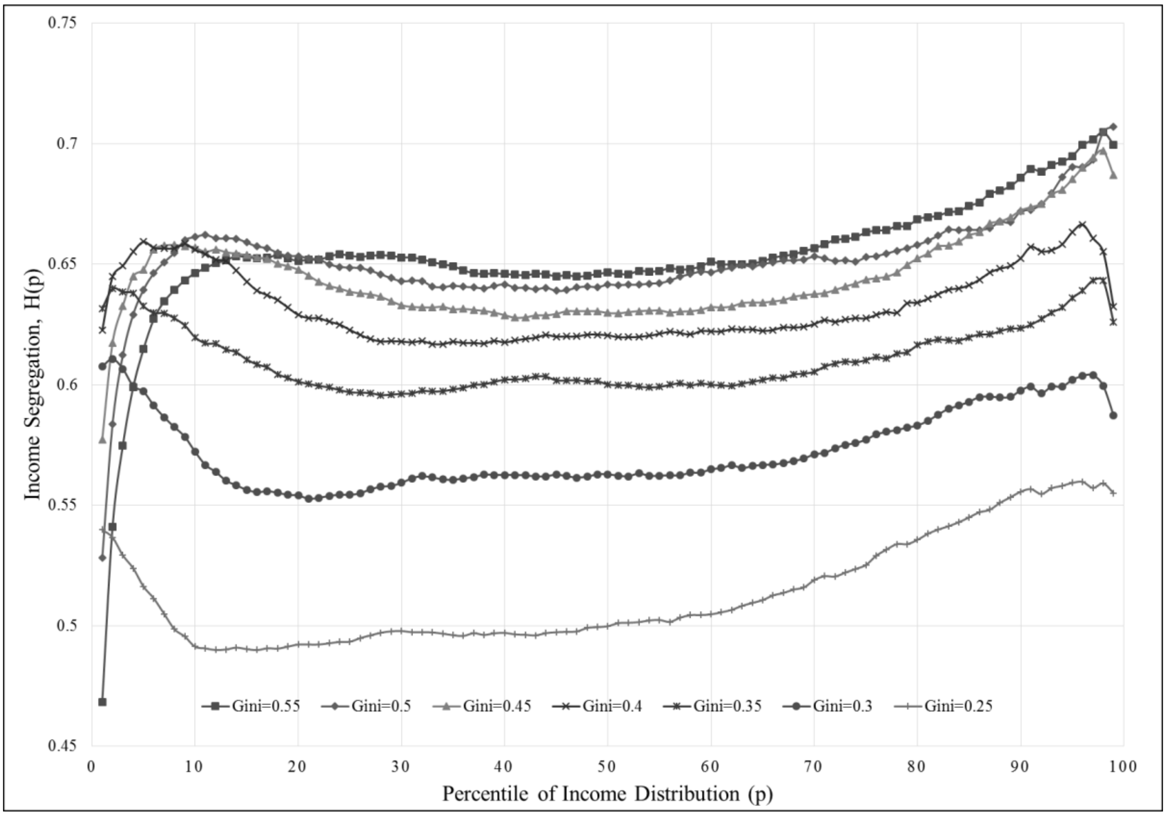

Figure 6.9. Income segregation profiles when households has the access to information of all vacant houses.

6.6. Impact of Homo Economicus Assumption

Here, how the famous assumption of *homo economicus* affects the income segregation studies is demonstrated see. In contrast to the previous examples, in this scenario our households have not only perfect information, but also infinite time and computing capacity such that they pick the best available housing to their needs. Moreover, they aim to maximize their utilities, that is, they are never satisfied and hence, always search for better alternative, as if it is not moving to a new house but changing their brand of candy.

Figure 6.10 illustrates the resulting income segregation profile of such households. Note that the impact of income inequality diminishes with such a case. More importantly, segregation of poverty drops significantly and it is always lower than segregation of affluence. In sum, bounded rationality assumptions proved to be necessary since perfect rationality distorts the reality significantly.

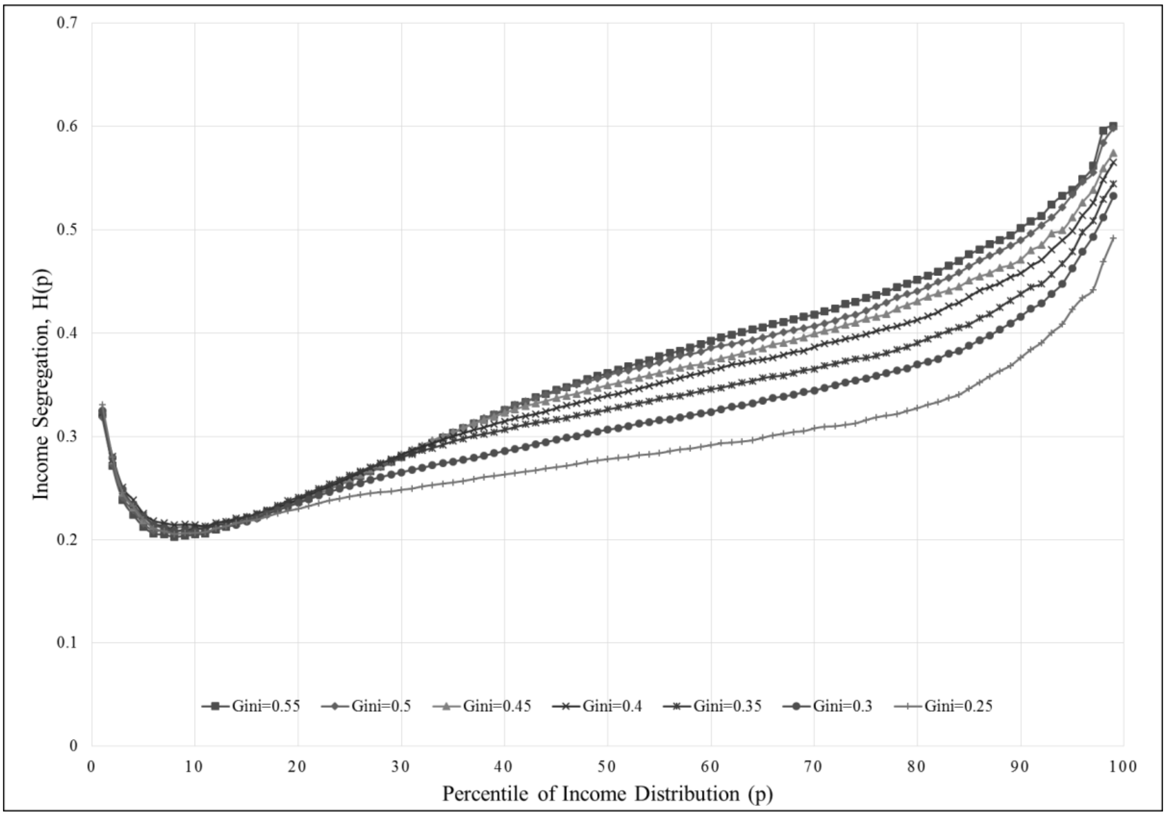

Figure 6.10. Income segregation profiles when households are *homo economicus*.

7. CONCLUSION

In this study, to shed more light on income segregation, an agent-based model that can generate stylized facts about income segregation is built. The model is capable to demonstrate the expected positive relationship between income inequality and income segregation both statistically and visually. More specifically, overall, people become happier with their houses and neighborhoods, and want to move less as inequality decreases. However, it is also shown that the impact of income equality saturates, implying a non-linear relation between the two. Moreover, it is found that level of income inequality conditions income segregation by determining a narrow range of values of income segregation can take for a given level of inequality. Nevertheless, it is illustrated that the shape of income segregation profile is determined by the shape of income distribution.

The distinctive feature of segregation studies, namely a move has an impact on its target as well as its destination, which is usually overlooked renders them as analytically complex phenomena. Two kinds of moves are considered here driving income segregation: economical move and status-seeking move. Their distinct impacts are further differentiated by the moving household’s position in income ranking as well as the source and target neighborhood of the move.

By exposing that the moves of the affluent households to more affluent neighborhoods increase not only segregation of affluence but also segregation of poverty, it is argued that formation or expansion of affluent neighborhoods or gated communities has a positive impact on formation or expansion of ghettos or slums in a city, and vice versa. There seems to be two driver of this interconnection. First, a move consists of not only a target neighborhood but also a source neighborhood. Focusing only on a move’s impact on the target neighborhood is not enough. Leaving a neighborhood also affects that neighborhood as well. For example, when a rich household leaves a poor neighborhood, it becomes more homogenous in terms of income and thus increasing segregation of poverty while the rich households move to an affluent neighborhood increases segregation of affluence.

Second, there is an emergent aspect of the dynamics in segregation of affluence and poverty. Continuing the example above, when a rich household leaves a poor neighborhood and moves to an affluent one, the concentration of rich people in affluent neighborhoods render them as repellent cores in the city; repelling the poor and middle income class due to affordability constraint. Additionally, eliminating some neighborhoods for the poor leaves them less neighborhoods to choose and encouraging the increase of segregation of poverty. Considering these two points explicating the interconnection between segregation of affluence and poverty, studying them should not be done isolation from one another to account for important feedbacks.

As we extensively experimented with our simulation model, a broader understanding of the possible shapes of income segregation profile, $H(p)$, are elaborated. We argue that M-shape can be seen as the generic form with its having two hills of which their locations determines the shapes of $H(p)$. We speculated about the interpretation of the hills in $H(p)$ curve and detailed three reasons: the size of neighborhoods, natural mixings, and housing market inefficiency yielding lock-ins for households.

By utilizing agent-based modeling to its full extent, we tried to provide action-based explanations for the market's inefficiency by tracking down what agents did throughout the model. We hope to contribute to the analytical sociology school of thought by illustrating such a use of agent-based modeling to bridge the micro-macro gap. By means of such an effort, we suggest researchers to collect movement-related data for empirical analysis to shed light on the trends and characteristics on income segregation. Our findings will remain as mere hypotheses until they are proven by empirical data analyses.

The thesis also reports some scenario analyses. First, it is found that as the influence of income on rents gets stronger, overall income segregation becomes higher. Moreover, the segregation of affluence becomes much higher than segregation of poverty since finding affordable and high status housing becomes much rarer. Second, parallel to Benard & Willer (2007), it is also found that lower income-SES correlation leads to lower income segregation due to increasing rate of natural mixings. Third, it is illustrated that the rent control policy is an effective tool to fight against the segregation of poverty. Fourth, higher urban density leads to higher income segregation overall. It is seen that it has little to do with the segregation of affluence; it remains almost unchanged as urban density increases. However, segregation of poverty as well as segregation in the middle levels increase significantly with urban density since the rents are higher due to lower excess housing. Fifth, it is observed that as the households have more information regarding the housing market, there are lower segregation of poverty since it enables poorer households to find affordable housing in non-poor neighborhoods. Finally, it is shown that the well-known *homo economicus* assumption for agents distorts the reality significantly.

A shortcoming of this study is that it fails to address how a society with gamma distributed income yields a less efficient housing market than log-normal distribution. We suspect that it is something to do with characteristics of income distribution such as skewedness, or standard deviation conditioning market in such a way to yield the observed outcomes. However, we fail to put our finger on how they translate into market inefficiencies.

An important further research direction, which is mentioned tangentially in literature (Quillian 2012; Sethi and Somanathan 2004; Sharkey 2008), but not yet covered by agent-based modeling studies[29], is to include the impact of income segregation on income inequality into analyses, yielding a positive feedback loop on the macro level. However, whether it is going to work well via a chain of events at the micro level is not so obvious. More importantly, if the conclusions would be significantly different from the ones without this feedback, such a study would be crucial to guide the residential segregation studies.

Another further research direction of segregation studies would be to recall Schelling's (1971:167) words: "'Residence' in this model can therefore just as well, perhaps even better, be interpreted as membership or participation in a job, an office, a university, a church, a voting bloc, a club, a restaurant, or a hospital." Then, focusing on whether the insights that are gained with models of segregation are transferable or not to other kinds of segregation in different contexts can be fruitful.

[29] It has been studied mathematically by Durlauf (1995, 1996) which begs for further analysis.

APPENDIX A: CODE OF AGENT-BASED MODEL

```
globals
[
   max-income
   max-SES
   max-price
   max-quality
   sorted-income ; sorted list of income of all people
   sorted-prices-for-neighborhoods
   sorted-quality-for-neighborhoods
   income-of-neighborhoods ; avg income of the people living in each
neighborhood, to calculate GINI of the neighborhoods
;  avg-price-over-income-ratio ;average rents with respect to average income
i.e. avg price / avg income
   neighborhoods ;list of neighborhoods
   richest-nhoods-income/poorest

   ;indices for segregation
   index-of-dissimilarity; D*
   index-of-dissimilarity-based-on-Moore-nhood; D* based on small neighborhoods
   avg-D
   avg-D-Moore
   Hr ;rank-order information theory index
   Ep
   Hp
   Hr-Moore
   Hp-Moore
   avg-Hr
   avg-H10
   avg-H50
   avg-H90
   Hr-precision-level ;number of data points
   gini-index-reserve-for-neighbors
   lorenz-points-for-neighbors

   ;indices for income inequality
   gini-index-reserve
   lorenz-points
   eightieth/twentieth
   ninetieth/tenth
   fiftieth/tenth

;  fraction-of-quality-lowerbound-to-be-happy ;fraction of SES that people are
willing to live in a residential area without being unhappy
;  fraction-of-price-upperbound-to-be-happy ;fraction of income that people are
willing to pay for rent without being unhappy
   ;utility-threshold-to-move ;the critical threshold determining whether to
move or not
   ;max-tolerance ; how much % worse neighborhoods you are looking for during
the search

   unsuccessful-max-SES-nhood-search
   unsuccessful-cost-min-nhood-search
   rent-control-counter
]
turtles-own
[
   income
   income-percentile
   SES ;socio-economic status
   utility
   income-price-tradeoff ;a component of utility including income vs. price
   SES-quality-tradeoff ;a component of utility including SES vs. quality
   price-tolerance
   quality-tolerance
   time-to-check-neighborhood ; when to look for a neighborhood (it is periodic
but each agent has her own specific time)
   max-SES-counter
```

```
   min-cost-counter
   max-SES-moves
   min-cost-moves
   min-cost-not-found-since-full
   max-SES-not-found-since-full
]
patches-own
[
  price
  quality
  neighborhood-index
  price-percentile
  quality-percentile
]
;;;;;;;;;;;;;;;;;;;;;;
;INITIALIZATION BEGINS
;;;;;;;;;;;;;;;;;;;;;;
to setup
  clear-all
  if random-seed?
  [set seed new-seed]
  random-seed seed

  setup-globals
  ; create turtles on random patches.
  ask patches
  [
    sprout 1 [ setup-turtles]
  ]

  ;ask turtles [set SES 100]


  setup-neighborhoods
  if perfect-initialization?
  [ask patches [set quality 100 set price 0.001]]

  ask n-of ((max-pxcor + 1) ^ 2 - population) turtles [die]
  normalize-income-SES
  sort-incomes
  calculate-income-percentiles

  setup-tolerances-of-turtles

  ask turtles
  [
    set utility calculate-utility
    update-turtle-color
  ]

  update-D*-based-on-Moore-nhood
  update-index-of-dissimilarity
  update-lorenz-and-gini
  update-Hr
  update-ratios
  update-patch-color

  update-neighborhoods-prices
  update-neighborhoods-quality

  set avg-H10 lput item 9 Hp avg-H10
  set avg-H50 lput item 49 Hp avg-H50
  set avg-H90 lput item 89 Hp avg-H90

  reset-ticks
end
to setup-globals
  ;set utility-threshold-to-move 0
  set Hr-precision-level 100
  set avg-Hr []
  set avg-H10 []
  set avg-H50 []
  set avg-H90 []
```

```
  set avg-D []
  set avg-D-Moore []
  set income-of-neighborhoods []
  set richest-nhoods-income/poorest 1

  ;initialization of H(p)
  set Hp []
;  set Hp-Moore []
  repeat (Hr-precision-level - 1)
  [
    set Hp lput 1 Hp
    ;set Hp-Moore lput 1 Hp-Moore
  ]
  ;initialization of E(p)
  set Ep []
  let p 1 / Hr-precision-level
  repeat (Hr-precision-level - 1) [set Ep lput (p * (log (1 / p) 2) + (1 - p) *
(log (1 / (1 - p)) 2)) Ep set p p + (1 / Hr-precision-level)]

  set unsuccessful-max-SES-nhood-search 0
  set unsuccessful-cost-min-nhood-search 0
  set rent-control-counter 0
end
to setup-tolerances-of-turtles
  ask turtles
  [
   ifelse personal-tolerance?
   [
     set price-tolerance max-tolerance * income-percentile
     set quality-tolerance max-tolerance * (1 - income-percentile)
   ]
   [
     set price-tolerance max-tolerance
     set quality-tolerance max-tolerance
   ]
  ]
end
to setup-neighborhoods
  set neighborhoods[]
  let j 1
  let divider (max-pxcor - min-pxcor + 1) / sqrt number-of-neighborhoods
  repeat sqrt number-of-neighborhoods
  [
    let i 1
    repeat sqrt number-of-neighborhoods
    [
      set neighborhoods  fput (patches with [pxcor >= min-pxcor + (i - 1) *
divider AND pxcor < min-pxcor + i * divider AND pycor <= max-pycor - (j - 1) *
divider AND pycor > max-pycor - j * divider]) neighborhoods
      set i i + 1
    ]
    set j j + 1
  ]
  setup-patches
  let i 0
  repeat number-of-neighborhoods
  [
    set income-of-neighborhoods lput mean ([income] of turtles-on patches with
[neighborhood-index = i]) income-of-neighborhoods
    set i i + 1
  ]
end
to setup-patches
  ask patches
  [
    let i 0
    repeat number-of-neighborhoods [if member? self item i neighborhoods [set
neighborhood-index i] set i i + 1]
    determine-price&quality
  ]
;NORMALIZATION
  set max-price max [price] of patches
  set max-quality max [quality] of patches
```

```
  ask patches
  [
    set price (price / max-price) * 100 * avg-price-over-income-ratio
    set quality (quality / max-quality) * 100
  ]
end
to setup-turtles
  distribute-income&SES
  set shape "person"
  set time-to-check-neighborhood random min-stay-period
  set utility 0
  set max-SES-counter 0
  set min-cost-counter 0
  set max-SES-moves 0
  set min-cost-moves 0
  set min-cost-not-found-since-full 0
  set max-SES-not-found-since-full 0
end
to determine-price&quality
  if distribution = "gamma"
  [
    ifelse any? turtles-here
    [
      set price (avg-price-over-income-ratio * one-of [income] of turtles-here)
      set quality one-of [SES] of turtles-here
    ]
    [
      set price avg-price-over-income-ratio * random-gamma alpha (beta ^ -1)
      set quality price-quality-corr * (price / avg-price-over-income-ratio) +
(1 - price-quality-corr) * random-gamma alpha (beta ^ -1)
    ]
  ]
  if distribution = "lognormal"
  [
    ifelse any? turtles-here
    [
      set price (avg-price-over-income-ratio * one-of [income] of turtles-here)
      set quality one-of [SES] of turtles-here
    ]
    [
      set price avg-price-over-income-ratio * exp (random-normal mean-income
std-income)
      set quality price-quality-corr * (price / avg-price-over-income-ratio) +
(1 - price-quality-corr) * exp (random-normal mean-income std-income)
    ]
  ]
end
to distribute-income&SES
  if distribution = "gamma"
  [
   set income random-gamma alpha (beta ^ -1)
   set SES income * income-SES-corr + (1 - income-SES-corr) * random-gamma alpha
(beta ^ -1)
  ]
  if distribution = "lognormal"
  [
   set income random-normal mean-income std-income
   set SES income * income-SES-corr + (1 - income-SES-corr) * (random-normal
mean-income std-income)
   set income exp(income)
   set SES exp(SES)
  ]
end
to normalize-income-SES
  set max-income max [income] of turtles
  set max-SES max [SES] of turtles
  ask turtles
  [
    set income (income / max-income) * 100
    set SES (SES / max-SES) * 100
  ]
end
to calculate-income-percentiles
```

```
  ask turtles[set income-percentile (position income sorted-income) /
population]
end
to calculate-price-quality-percentiles
  ask patches[set price-percentile (position price sort [price] of patches) /
count patches]
  ask patches[set quality-percentile (position quality sort [quality] of
patches) / count patches]
end
to sort-incomes
  set sorted-income sort [income] of turtles
end
to update-neighborhood-incomes
  let i 0
  repeat number-of-neighborhoods
  [
    ifelse count turtles with [neighborhood-index = i] > 0
    [set income-of-neighborhoods replace-item i income-of-neighborhoods mean
[income] of turtles with [neighborhood-index = i]][set income-of-neighborhoods
replace-item i income-of-neighborhoods 0]
    set i i + 1
  ]
  let j 0
  while [item j sort income-of-neighborhoods = 0]
  [set j j + 1]
  set richest-nhoods-income/poorest max income-of-neighborhoods / item j sort
income-of-neighborhoods
end
to sort-neighborhood-prices
  let i 0
  let price-of-neighborhoods []
  repeat number-of-neighborhoods
  [
    set price-of-neighborhoods lput mean [price] of patches with [neighborhood-
index = i] price-of-neighborhoods
    set i i + 1
  ]
  set sorted-prices-for-neighborhoods sort price-of-neighborhoods
end
;;;;;;;;;;;;;;;;;;;;
;INITIALIZATION ENDS
;;;;;;;;;;;;;;;;;;;;
to go
;if not parca analizi!! BEWARE!!
  choose-better-neighborhood
;  if migration?
;  [ask turtles [let dummyincome income if price > income [if count patches with
[count turtles-here = 0 AND price <= dummyincome] > 0 [move-to one-of patches
with [count turtles-here = 0 AND price <= dummyincome]]]]]
; ask turtles [maximize-SES]

  update-neighborhoods-prices
  update-neighborhoods-quality

;  ask turtles with [income-percentile < .25][]
;  ask turtles with [income-percentile >= .75][]
;  ask turtles with [income-percentile >= .25 AND income-percentile < .5][]
;  ask turtles with [income-percentile >= .5 AND income-percentile <
.75][maximize-SES]

;  if move-decision != "bounded-rational"
;  [ask turtles [set utility calculate-utility]]
;  ask turtles [set utility calculate-utility]

;  if feedback
;  [
;    ask turtles
;    [
;      ;if time-to-check-neighborhood - 1 = (ticks mod min-stay-period)
;      ;[update-income-SES]
;      update-income-SES
;    ]
;   normalize-income-SES
```

```
;   sort-incomes
;   calculate-income-percentiles
;   ask turtles [update-turtle-color]
;   update-lorenz-and-gini
;   update-ratios
;  ]
;
;  if growing-inequality
;  [
;   ask turtles with [income-percentile >= .99][set income income ^ (1 + add)
set SES SES ^ (1 + add)]
;   normalize-income-SES
;   sort-incomes
;   calculate-income-percentiles
;   ask turtles [update-turtle-color]
;   update-lorenz-and-gini
;   update-ratios
;  ]

;  update-neighborhood-incomes

;  update-D*-based-on-Moore-nhood
;  update-index-of-dissimilarity
  update-Hr
  update-patch-color

  ;some measures to be reported at the end of the simulation
  set avg-Hr lput Hr avg-Hr
;  set avg-D lput index-of-dissimilarity avg-D
;  set avg-D-Moore lput index-of-dissimilarity-based-on-Moore-nhood avg-D-Moore
;  set avg-H10 lput item 9 Hp avg-H10
;  set avg-H50 lput item 49 Hp avg-H50
;  set avg-H90 lput item 89 Hp avg-H90

  tick
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;Housing price MUST be less than income!
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;to mandatory-migration
;  if must-migrate
;  [
;   let dummyincome income
;   let dummyprice price
;;;;;;   ;move them to the rightmost poor neighborhood TOKI
;;;;;;   ;let mandatorycandidate max-one-of patches with [not any? turtles-here
AND price < dummyincome] [pxcor + pycor]
;
;   ;actually, I should move them to the poorest neighborhood possible
;   let mandatorycandidate min-one-of patches with [not any? turtles-here AND
price < dummyincome] [mean [price] of item neighborhood-index neighborhoods]
;   ifelse mandatorycandidate != nobody
;   [move-to mandatorycandidate set size 1.5]
;   ;if a proper candidate is not found, then at least a cheaper place is
searched
;   [
;    ;migrate to another city
;    ;die
;    ;OR
;    ;actually, I should move them to the poorest neighborhood possible
;    set mandatorycandidate min-one-of patches with [not any? turtles-here AND
price < dummyprice] [mean [price] of item neighborhood-index neighborhoods]
;    if mandatorycandidate != nobody
;    [move-to mandatorycandidate set size 1.5]
;    ;if even a cheaper & empty place is not found, then simply the agent does
nothing. This can be seen as a tenant who has an incresing debt to the landlord.
;   ]
;  ]
;end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;NEIGHBORHOOD CHOICE!;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;to choose-better-neighborhood
```

```
;  ifelse not endogenous-choice
;  ;Exogenous choice function
;  [
;    ask turtles
;    [
;      if time-to-check-neighborhood = (ticks mod min-stay-period)
;      [
;        ifelse price > income * max-price-over-income-ratio
;        [mandatory-migration]
;        [
;          ifelse cost-min
;          [minimize-cost]
;          [maximize-SES]
;        ]
;      ]
;    ]
;  ]
;  ;Endogenous choice function
;  [
;    ifelse choice-by-happiness
;    ;ask all if they are happy or not.
;    [
;      ask turtles
;      [
;        if time-to-check-neighborhood = (ticks mod min-stay-period)
;        [
;          ifelse price > income * max-price-over-income-ratio
;          [mandatory-migration]
;          [
;            let weight-of-income-price-tradeoff 1 - income-percentile
;            ;if you are unhappy, move
;            if utility < utility-threshold-to-move
;            [
;              ; if weighted income-price-tradeoff is worse than weighted SES-
quality-tradeoff, then move to minimize cost. Else, move to maximize SES
;              ifelse (weight-of-income-price-tradeoff * income-price-tradeoff)
< (1 - weight-of-income-price-tradeoff) * SES-quality-tradeoff
;              [minimize-cost][maximize-SES]
;            ]
;          ]
;        ]
;      ]
;    ]
;    ;ask all each min-stay-period ticks
;    [
;      ask turtles
;      [
;        if time-to-check-neighborhood = (ticks mod min-stay-period)
;        [
;          ifelse price > income * max-price-over-income-ratio
;          [mandatory-migration]
;          [
;            ;           ifelse random-float 1 <= income-percentile
;            ;           [maximize-SES][minimize-cost]
;            let weight-of-income-price-tradeoff 1 - income-percentile
;            ; if weighted income-price-tradeoff is worse than weighted SES-
quality-tradeoff, then move to minimize cost. Else, move to maximize SES
;            ifelse (weight-of-income-price-tradeoff * income-price-tradeoff) <
(1 - weight-of-income-price-tradeoff) * SES-quality-tradeoff
;            [minimize-cost][maximize-SES]
;          ]
;        ]
;      ]
;    ]
;  ]
;end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;
to choose-better-neighborhood
  if move-decision = "positional"
  [
    ask turtles
    [
```

```
      if time-to-check-neighborhood = (ticks mod min-stay-period)
      [
         ifelse happiness-matters?
         [
          ifelse income * avg-price-over-income-ratio * (1 + price-tolerance) >=
price AND quality >= SES * (1 - quality-tolerance)
          []
          [
            ifelse random-float 1 <= income-percentile
            [maximize-SES][minimize-cost]
          ]
         ]
         [
           ifelse random-float 1 <= income-percentile
           [maximize-SES][minimize-cost]
         ]
      ]
    ]
  ]
  if move-decision = "bounded-rational"
  [
    ask turtles
    [
      if time-to-check-neighborhood = (ticks mod min-stay-period)
      [
         ifelse happiness-matters?
         [
          ifelse income * avg-price-over-income-ratio * (1 + price-tolerance) >=
price AND quality >= SES * (1 - quality-tolerance)
          []
          [
          if income * avg-price-over-income-ratio * (1 + price-tolerance) -
price > 0
          [maximize-SES stop]

          if quality - SES * (1 - quality-tolerance) > 0
          [minimize-cost stop]

;          ifelse random-float 1 <= (income * avg-price-over-income-ratio * (1 +
price-tolerance) - price)  / (income * avg-price-over-income-ratio * (1 + price-
tolerance) - price + quality - SES * (1 - quality-tolerance))
          ifelse random-float 1 <= ((income * avg-price-over-income-ratio * (1 +
price-tolerance) - price) / (income * avg-price-over-income-ratio * (1 + price-
tolerance))) / ((income * avg-price-over-income-ratio * (1 + price-tolerance) -
price) / (income * avg-price-over-income-ratio * (1 + price-tolerance))+
(quality - SES * (1 - quality-tolerance))/(SES * (1 - quality-tolerance)))
          [minimize-cost][maximize-SES]
          ]
         ]
         [
          ifelse income * avg-price-over-income-ratio * (1 + price-tolerance) >=
price AND quality >= SES * (1 - quality-tolerance)
          [
;           ifelse random-float 1 <= income * avg-price-over-income-ratio * (1 +
price-tolerance) - price  / (income * avg-price-over-income-ratio * (1 + price-
tolerance) - price + quality - SES * (1 - quality-tolerance))
           ifelse random-float 1 <= ((income * avg-price-over-income-ratio * (1
+ price-tolerance) - price) / (income * avg-price-over-income-ratio * (1 +
price-tolerance))) / ((income * avg-price-over-income-ratio * (1 + price-
tolerance) - price) / (income * avg-price-over-income-ratio * (1 + price-
tolerance))+ (quality - SES * (1 - quality-tolerance))/(SES * (1 - quality-
tolerance)))
           [maximize-SES][minimize-cost]
          ]
          [
           if income * avg-price-over-income-ratio * (1 + price-tolerance) -
price > 0
           [maximize-SES stop]

           if quality - SES * (1 - quality-tolerance) > 0
           [minimize-cost stop]
```

```
 ;          ifelse random-float 1 <= income * avg-price-over-income-ratio * (1 +
price-tolerance) - price  / (income * avg-price-over-income-ratio * (1 + price-
tolerance) - price + quality - SES * (1 - quality-tolerance))
           ifelse random-float 1 <= ((income * avg-price-over-income-ratio * (1
+ price-tolerance) - price) / (income * avg-price-over-income-ratio * (1 +
price-tolerance))) / ((income * avg-price-over-income-ratio * (1 + price-
tolerance) - price) / (income * avg-price-over-income-ratio * (1 + price-
tolerance))+ (quality - SES * (1 - quality-tolerance))/(SES * (1 - quality-
tolerance)))
           [minimize-cost][maximize-SES]
          ]
         ]
      ]
    ]
  ]
  if move-decision = "more-bounded-rational"
  [
    ask turtles
    [
      if time-to-check-neighborhood = (ticks mod min-stay-period)
      [
         ifelse happiness-matters?
         [
          ifelse utility >= (utility-threshold-to-move - max-tolerance)
          []
          [
          if income-price-tradeoff > 0
          [maximize-SES stop]

          if SES-quality-tradeoff > 0
          [minimize-cost stop]

          ifelse random-float 1 <= (income-price-tradeoff) / (utility)
          [minimize-cost][maximize-SES]
          ]
         ]
         [
;           ifelse random-float 1 <= income-percentile
;           [maximize-SES][minimize-cost]
         ]
      ]
    ]
  ]
  if move-decision = "rational"
  ;ask all if they are happy or not.
  [
    ask turtles
    [
      if time-to-check-neighborhood = (ticks mod min-stay-period)
      [
        ifelse happiness-matters?
        [
         ;if you are unhappy, move
         if utility < utility-threshold-to-move
         [
           ;maximize the utility
           maximize-utility
         ]
        ]
        [
          maximize-utility
        ]
      ]
    ]
  ]
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;
to-report calculate-utility
  if utility-type = "first"
  [    set income-price-tradeoff 2 / (1 + exp ((- income * fraction-of-price-
upperbound-to-be-happy + price)/ (income * fraction-of-price-upperbound-to-be-
happy))) - 1
```

```
    set SES-quality-tradeoff 2 / (1 + exp ((- quality + SES * fraction-of-
quality-lowerbound-to-be-happy)/ (SES * fraction-of-quality-lowerbound-to-be-
happy))) - 1


    let weight-of-income-price-tradeoff 1 - income-percentile
    report weight-of-income-price-tradeoff * income-price-tradeoff + (1 -
weight-of-income-price-tradeoff) * SES-quality-tradeoff
  ]
  if utility-type = "second"
  [
    set income-price-tradeoff 2 / (1 + exp ((- income * avg-price-over-income-
ratio * (1 + income-percentile) + price)/ (income * avg-price-over-income-ratio
* (1 + income-percentile)))) - 1
    set SES-quality-tradeoff 2 / (1 + exp ((- quality + SES * (income-percentile
+ 1 / population))/ (SES * (income-percentile + 1 / population)))) - 1
    let weight-of-income-price-tradeoff 1 - income-percentile
    report weight-of-income-price-tradeoff * income-price-tradeoff + (1 -
weight-of-income-price-tradeoff) * SES-quality-tradeoff
  ]
  if utility-type = "third"
  [
    set income-price-tradeoff 2 / (1 + exp ((- income * avg-price-over-income-
ratio + price)/ (income * avg-price-over-income-ratio))) - 1
    set SES-quality-tradeoff 2 / (1 + exp ((- quality + SES * fraction-of-
quality-lowerbound-to-be-happy)/ (SES * fraction-of-quality-lowerbound-to-be-
happy))) - 1
    report income-price-tradeoff + SES-quality-tradeoff
  ]
  if utility-type = "fourth"
  [
    let weight-of-income-price-tradeoff (1 - income-percentile)
    set income-price-tradeoff weight-of-income-price-tradeoff * (2 / (1 + exp
((- income * avg-price-over-income-ratio + price)/ (income * avg-price-over-
income-ratio))) - 1)
    set SES-quality-tradeoff (1 - weight-of-income-price-tradeoff) * (2 / (1 +
exp ((- quality + SES * fraction-of-quality-lowerbound-to-be-happy)/ (SES *
fraction-of-quality-lowerbound-to-be-happy))) - 1)
    report income-price-tradeoff + SES-quality-tradeoff
  ]
  if utility-type = "fifth"
  [
    set income-price-tradeoff (income * avg-price-over-income-ratio -
price)/(income * avg-price-over-income-ratio)
    set SES-quality-tradeoff (quality - SES * fraction-of-quality-lowerbound-to-
be-happy)/(SES * fraction-of-quality-lowerbound-to-be-happy)
    let weight-of-income-price-tradeoff 1 - income-percentile
    report weight-of-income-price-tradeoff * income-price-tradeoff + (1 -
weight-of-income-price-tradeoff) * SES-quality-tradeoff
  ]
end
to-report calculate-candidate-utility [candidate-price candidate-quality income-
percentile-of-the-seeker candidate-income candidate-SES]
  if utility-type = "first"
  [
    let candidate-income-price-tradeoff 2 / (1 + exp ((- candidate-income *
fraction-of-price-upperbound-to-be-happy + candidate-price)/ (candidate-income *
fraction-of-price-upperbound-to-be-happy))) - 1
    let candidate-SES-quality-tradeoff 2 / (1 + exp ((- candidate-quality +
candidate-SES * fraction-of-quality-lowerbound-to-be-happy)/ (candidate-SES *
fraction-of-quality-lowerbound-to-be-happy))) - 1
    let weight-of-income-price-tradeoff 1 - income-percentile-of-the-seeker
    report weight-of-income-price-tradeoff * candidate-income-price-tradeoff +
(1 - weight-of-income-price-tradeoff) * candidate-SES-quality-tradeoff
  ]
  if utility-type = "second"
  [
    let candidate-income-price-tradeoff 2 / (1 + exp ((- candidate-income * avg-
price-over-income-ratio * (1 + income-percentile-of-the-seeker) + candidate-
price)/ (candidate-income * avg-price-over-income-ratio * (1 + income-
percentile-of-the-seeker)))) - 1
```

```
    let candidate-SES-quality-tradeoff 2 / (1 + exp ((- candidate-quality +
candidate-SES * (income-percentile-of-the-seeker + 1 / population))/ (candidate-
SES * (income-percentile-of-the-seeker + 1 / population)))) - 1
    let weight-of-income-price-tradeoff 1 - income-percentile-of-the-seeker
    report weight-of-income-price-tradeoff * candidate-income-price-tradeoff +
(1 - weight-of-income-price-tradeoff) * candidate-SES-quality-tradeoff
  ]
  if utility-type = "third"
  [
    let candidate-income-price-tradeoff 2 / (1 + exp ((- candidate-income * avg-
price-over-income-ratio + candidate-price)/ (candidate-income * avg-price-over-
income-ratio))) - 1
    let candidate-SES-quality-tradeoff 2 / (1 + exp ((- candidate-quality +
candidate-SES * fraction-of-quality-lowerbound-to-be-happy)/ (candidate-SES *
fraction-of-quality-lowerbound-to-be-happy))) - 1
    report candidate-income-price-tradeoff + candidate-SES-quality-tradeoff
  ]
  if utility-type = "fourth"
  [
    let candidate-income-price-tradeoff 2 / (1 + exp ((- candidate-income * avg-
price-over-income-ratio + candidate-price)/ (candidate-income * avg-price-over-
income-ratio))) - 1
    let candidate-SES-quality-tradeoff 2 / (1 + exp ((- candidate-quality +
candidate-SES * fraction-of-quality-lowerbound-to-be-happy)/ (candidate-SES *
fraction-of-quality-lowerbound-to-be-happy))) - 1
    let weight-of-income-price-tradeoff 1 - income-percentile-of-the-seeker
    report weight-of-income-price-tradeoff * candidate-income-price-tradeoff +
(1 - weight-of-income-price-tradeoff) * candidate-SES-quality-tradeoff
  ]
  if utility-type = "fifth"
  [
    let candidate-income-price-tradeoff (candidate-income * avg-price-over-
income-ratio - candidate-price)/ (candidate-income * avg-price-over-income-
ratio)
    let candidate-SES-quality-tradeoff (candidate-quality - candidate-SES *
fraction-of-quality-lowerbound-to-be-happy)/ (candidate-SES * fraction-of-
quality-lowerbound-to-be-happy)
    let weight-of-income-price-tradeoff 1 - income-percentile-of-the-seeker
    report weight-of-income-price-tradeoff * candidate-income-price-tradeoff +
(1 - weight-of-income-price-tradeoff) * candidate-SES-quality-tradeoff
  ]
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;CHOICE FUNCTIONS;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;COST-MINIZING CHOICE
to minimize-cost
   set min-cost-counter min-cost-counter + 1
   let dummyprice price
   let prospective-house nobody
   let income-percentile-of-the-seeker income-percentile
   let dummy-utility utility
   let dummy-income income
   let dummy-SES SES
   let price-tolerance-of-the-seeker price-tolerance
   let quality-tolerance-of-the-seeker quality-tolerance

   ifelse nhood-search?
   [
    let i 0
    let candidates []
    let candidate-neighborhood nobody
    repeat number-of-neighborhoods
    [
      if mean [price] of item i neighborhoods <= dummyprice * (1 + price-
tolerance)
      [set candidates lput i candidates]
      set i i + 1
    ]
    ifelse length candidates > 0
    [set candidate-neighborhood one-of candidates]
    [set unsuccessful-cost-min-nhood-search unsuccessful-cost-min-nhood-search +
1 stop]
```

```
    let prospective-houses item candidate-neighborhood neighborhoods
    ;move to a cheaper house which makes her utility discrepancy with happiness
(non-negative utility) at least threshold-to-move % much less or if it is
positive make it threshold-to-move % higher

    if count prospective-houses with [count turtles-here = 0] = 0
    [set min-cost-not-found-since-full min-cost-not-found-since-full + 1 stop]

    ifelse utility-based-decision?
    [
      ifelse dummy-utility < 0
      [
        ifelse means-test-at-min-cost?
        [set prospective-house one-of prospective-houses with [not any? turtles-
here AND price <= dummyprice AND price <= (dummy-income * (1 + price-tolerance-
of-the-seeker)) AND ((utility-threshold-to-move - dummy-utility) * (1 -
threshold-to-move)) > (utility-threshold-to-move - (calculate-candidate-utility
price quality income-percentile-of-the-seeker dummy-income dummy-SES))]]
        [set prospective-house one-of prospective-houses with [not any? turtles-
here AND price <= dummyprice AND ((utility-threshold-to-move - dummy-utility) *
(1 - threshold-to-move)) > (utility-threshold-to-move - (calculate-candidate-
utility price quality income-percentile-of-the-seeker dummy-income dummy-SES))]]
      ]
      [
        ifelse means-test-at-min-cost?
        [set prospective-house one-of prospective-houses with [not any? turtles-
here AND price <= dummyprice AND price <= (dummy-income * (1 + price-tolerance-
of-the-seeker))  AND ((utility-threshold-to-move - dummy-utility) * (1 +
threshold-to-move)) > (utility-threshold-to-move - (calculate-candidate-utility
price quality income-percentile-of-the-seeker dummy-income dummy-SES))]]
        [set prospective-house one-of prospective-houses with [not any? turtles-
here AND price <= dummyprice AND ((utility-threshold-to-move - dummy-utility) *
(1 + threshold-to-move)) > (utility-threshold-to-move - (calculate-candidate-
utility price quality income-percentile-of-the-seeker dummy-income dummy-SES))]]
      ]

    ]
    [
      ifelse better?
      [
        ifelse means-test-at-min-cost?
        [set prospective-house one-of prospective-houses with [not any? turtles-
here AND price <= dummyprice AND price <= (dummy-income * (1 + price-tolerance-
of-the-seeker))]]
        [set prospective-house one-of prospective-houses with [not any? turtles-
here AND price <= dummyprice]]
        ;[set prospective-house one-of prospective-houses with [not any?
turtles-here AND price <= dummyprice AND quality >= dummy-SES * (1 - quality-
tolerance-of-the-seeker)]]
      ]
      [
        ifelse means-test-at-min-cost?
        [set prospective-house min-one-of prospective-houses with [not any?
turtles-here AND price <= dummyprice AND price <= (dummy-income * (1 + price-
tolerance-of-the-seeker))][price]]
        [set prospective-house min-one-of prospective-houses with [not any?
turtles-here AND price <= dummyprice][price]]
      ]
    ]
   ]
   [
    ifelse utility-based-decision?
    [
      ifelse dummy-utility < 0
      [
        ifelse means-test-at-min-cost?
        [set prospective-house one-of patches with [not any? turtles-here AND
price <= dummyprice AND price <= (dummy-income * (1 + price-tolerance-of-the-
seeker)) AND ((utility-threshold-to-move - dummy-utility) * (1 - threshold-to-
move)) > (utility-threshold-to-move - (calculate-candidate-utility price quality
income-percentile-of-the-seeker dummy-income dummy-SES))]]
```

```
        [set prospective-house one-of patches with [not any? turtles-here AND
price <= dummyprice AND ((utility-threshold-to-move - dummy-utility) * (1 -
threshold-to-move)) > (utility-threshold-to-move - (calculate-candidate-utility
price quality income-percentile-of-the-seeker dummy-income dummy-SES))]]
      ]
      [
        ifelse means-test-at-min-cost?
        [set prospective-house one-of patches with [not any? turtles-here AND
price <= dummyprice AND price <= (dummy-income * (1 + price-tolerance-of-the-
seeker))  AND ((utility-threshold-to-move - dummy-utility) * (1 + threshold-to-
move)) > (utility-threshold-to-move - (calculate-candidate-utility price quality
income-percentile-of-the-seeker dummy-income dummy-SES))]]
        [set prospective-house one-of patches with [not any? turtles-here AND
price <= dummyprice AND ((utility-threshold-to-move - dummy-utility) * (1 +
threshold-to-move)) > (utility-threshold-to-move - (calculate-candidate-utility
price quality income-percentile-of-the-seeker dummy-income dummy-SES))]]
      ]
    ]
    [
      ifelse better?
      [
        ifelse means-test-at-min-cost?
        [set prospective-house one-of patches with [not any? turtles-here AND
price <= dummyprice AND price <= (dummy-income * (1 + price-tolerance-of-the-
seeker))]]
        [set prospective-house one-of patches with [not any? turtles-here AND
price <= dummyprice]]
      ]
      [
        ifelse means-test-at-min-cost?
        [set prospective-house min-one-of patches with [not any? turtles-here
AND price <= dummyprice AND price <= (dummy-income * (1 + price-tolerance-of-
the-seeker))][price]]
        [set prospective-house min-one-of patches with [not any? turtles-here
AND price <= dummyprice][price]]
      ]
    ]
   ]

   if prospective-house != nobody
   [move-to prospective-house set min-cost-moves min-cost-moves + 1]
end
;UTILITY-MAXIMIZING CHOICE
to maximize-utility
   let dummyquality quality
   let dummy-income income
   let prospective-house nobody

   let income-percentile-of-the-seeker income-percentile
   let dummy-utility utility
   let dummy-SES SES

   ifelse dummy-utility < 0
   [
    ifelse better?
    [set prospective-house one-of patches with [not any? turtles-here AND price
<= dummy-income AND ((utility-threshold-to-move - dummy-utility) * (1 -
threshold-to-move)) > (utility-threshold-to-move - (calculate-candidate-utility
price quality income-percentile-of-the-seeker dummy-income dummy-SES))]]
    [set prospective-house max-one-of patches with [not any? turtles-here AND
price <= dummy-income AND ((utility-threshold-to-move - dummy-utility) * (1 -
threshold-to-move)) > (utility-threshold-to-move - (calculate-candidate-utility
price quality income-percentile-of-the-seeker dummy-income dummy-
SES))][(calculate-candidate-utility price quality income-percentile-of-the-
seeker dummy-income dummy-SES)]]
   ]
   [
    ifelse better?
    [set prospective-house one-of patches with [not any? turtles-here AND price
<= dummy-income AND ((utility-threshold-to-move - dummy-utility) * (1 +
threshold-to-move)) > (utility-threshold-to-move - (calculate-candidate-utility
price quality income-percentile-of-the-seeker dummy-income dummy-SES))]]
```

```
    [set prospective-house max-one-of patches with [not any? turtles-here AND
price <= dummy-income AND ((utility-threshold-to-move - dummy-utility) * (1 +
threshold-to-move)) > (utility-threshold-to-move - (calculate-candidate-utility
price quality income-percentile-of-the-seeker dummy-income dummy-
SES))][(calculate-candidate-utility price quality income-percentile-of-the-
seeker dummy-income dummy-SES)]]
   ]

   if prospective-house != nobody
   [move-to prospective-house]
end

;STATUS MAXIMIZING CHOICE
to maximize-SES
   set max-SES-counter max-SES-counter + 1
   let dummyquality quality
   let dummy-income income
   let income-percentile-of-the-seeker income-percentile
   let price-tolerance-of-the-seeker price-tolerance
   let dummy-utility utility
   let dummy-SES SES
   let prospective-house nobody

   ifelse nhood-search?
   [
    let i 0
    let candidates []
    let candidate-neighborhood nobody
    repeat number-of-neighborhoods
    [
     if mean [quality] of item i neighborhoods >= dummyquality * (1 - quality-
tolerance)
     [set candidates lput i candidates]
     set i i + 1
    ]
    ifelse length candidates > 0
    [set candidate-neighborhood one-of candidates]
    [set unsuccessful-max-SES-nhood-search unsuccessful-max-SES-nhood-search + 1
stop]

    let prospective-houses item candidate-neighborhood neighborhoods
    ;move to a higher quality house which makes her utility discrepancy with
happiness (non-negative utility) at least threshold-to-move % much less or if it
is positive make it threshold-to-move % higher

    if count prospective-houses with [count turtles-here = 0] = 0
    [set max-SES-not-found-since-full max-SES-not-found-since-full + 1 stop]

    ifelse utility-based-decision?
    [
      ifelse dummy-utility < 0
      [set prospective-house one-of prospective-houses with [not any? turtles-
here AND price <= (dummy-income * (1 + price-tolerance-of-the-seeker)) AND
quality >= dummyquality AND ((utility-threshold-to-move - dummy-utility) * (1 -
threshold-to-move)) > (utility-threshold-to-move - (calculate-candidate-utility
price quality income-percentile-of-the-seeker dummy-income dummy-SES))]]
      [set prospective-house one-of prospective-houses with [not any? turtles-
here AND price <= (dummy-income * (1 + price-tolerance-of-the-seeker)) AND
quality >= dummyquality AND ((utility-threshold-to-move - dummy-utility) * (1 +
threshold-to-move)) > (utility-threshold-to-move - (calculate-candidate-utility
price quality income-percentile-of-the-seeker dummy-income dummy-SES))]]
    ]
    [
      ifelse better?
      [set prospective-house one-of prospective-houses with [not any? turtles-
here AND price <= (dummy-income * (1 + price-tolerance-of-the-seeker)) AND
quality >= dummyquality]]
      [set prospective-house max-one-of prospective-houses with [not any?
turtles-here AND price <= (dummy-income * (1 + price-tolerance-of-the-seeker))
AND quality >= dummyquality][quality]]
    ]
   ]
   [
```

```
    ifelse utility-based-decision?
    [
      ifelse dummy-utility < 0
      [set prospective-house one-of patches with [not any? turtles-here AND
price <= (dummy-income * (1 + price-tolerance-of-the-seeker)) AND quality >=
dummyquality AND ((utility-threshold-to-move - dummy-utility) * (1 - threshold-
to-move)) > (utility-threshold-to-move - (calculate-candidate-utility price
quality income-percentile-of-the-seeker dummy-income dummy-SES))]]
      [set prospective-house one-of patches with [not any? turtles-here AND
price <= (dummy-income * (1 + price-tolerance-of-the-seeker)) AND quality >=
dummyquality AND ((utility-threshold-to-move - dummy-utility) * (1 + threshold-
to-move)) > (utility-threshold-to-move - (calculate-candidate-utility price
quality income-percentile-of-the-seeker dummy-income dummy-SES))]]
    ]
    [
      ifelse better?
      [set prospective-house one-of patches with [not any? turtles-here AND
price <= (dummy-income * (1 + price-tolerance-of-the-seeker)) AND quality >=
dummyquality]]
      [set prospective-house max-one-of patches with [not any? turtles-here AND
price <= (dummy-income * (1 + price-tolerance-of-the-seeker)) AND quality >=
dummyquality][quality]]
    ]
   ]
   if prospective-house != nobody
   [move-to prospective-house set max-SES-moves max-SES-moves + 1]
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;UPDATE FUNCTIONS;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
to update-neighborhoods-prices
  let i 0
  repeat number-of-neighborhoods
  [
    ask item i neighborhoods
    [
      let average-income-in-neighborhood-i 0
      if count turtles-on item i neighborhoods != 0
      [set average-income-in-neighborhood-i mean [income] of turtles-on item i
neighborhoods]

      let average-price-in-neighborhood-i mean [price] of item i neighborhoods

      let neighborhood-income-component-of-price avg-price-over-income-ratio *
average-income-in-neighborhood-i
      let neighborhood-price-component-of-price average-price-in-neighborhood-i
      let immediate-neighbors-price-component-of-price mean [price] of neighbors
      let price-change-anchor 0

      ifelse count neighbors with [count turtles-here != 0 ] != 0
      ;if there is someone around you in the Moore neighborhood!
      ;update the prices according to both neighborhood and immediate
neighborhoods subject to rent-control
      [
        let immediate-neighbors-income-component-of-price avg-price-over-income-
ratio * mean [income] of turtles-on neighbors

        set price-change-anchor
        (moore-neighborhood-weight * (1 - weight-of-income-in-price-adjustment))
* immediate-neighbors-price-component-of-price +
        (moore-neighborhood-weight * weight-of-income-in-price-adjustment) *
immediate-neighbors-income-component-of-price +
        ((1 - moore-neighborhood-weight) * weight-of-income-in-price-adjustment)
* neighborhood-income-component-of-price +
        ((1 - moore-neighborhood-weight) * (1 - weight-of-income-in-price-
adjustment)) * neighborhood-price-component-of-price
      ]
      ;if there is noone around in the Moore neighborhood, distribute the weight
of impact of moore neighborhood's income to others equally
      [
        set price-change-anchor
```

```
        ((moore-neighborhood-weight * weight-of-income-in-price-adjustment) / 3
+ moore-neighborhood-weight * (1 - weight-of-income-in-price-adjustment)) *
immediate-neighbors-price-component-of-price +
        ((moore-neighborhood-weight * weight-of-income-in-price-adjustment) / 3
+ (1 - moore-neighborhood-weight) * weight-of-income-in-price-adjustment) *
neighborhood-income-component-of-price +
        ((moore-neighborhood-weight * weight-of-income-in-price-adjustment) / 3
+ (1 - moore-neighborhood-weight) * (1 - weight-of-income-in-price-adjustment))
* neighborhood-price-component-of-price
      ]

      let price-change (price-change-anchor - price) / housing-price-adjustment-
time
      ifelse count turtles-here != 0
      [
        ifelse (price * rent-control-variable) > price-change
        [set price price + price-change]
        [set price price + price * rent-control-variable set rent-control-
counter rent-control-counter + 1]
      ]
      ;if a house is empty, then its price should also fall, independent of the
neighborhood, so .95% of price
      [
        ;the equation that Yaman hoca criticized!
        ;set price (price + price-change) * empty-house-multiplier

        set price price * empty-house-multiplier + price-change
      ]
    ]
    set i i + 1
   ]
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
to update-neighborhoods-quality
  let i 0
  repeat number-of-neighborhoods
  [
    let average-quality-in-neighborhood-i 0
    if count turtles-on item i neighborhoods != 0
    [set average-quality-in-neighborhood-i mean [SES] of turtles-on item i
neighborhoods]
    ask item i neighborhoods
    [
      ifelse count neighbors with [count turtles-here != 0 ] != 0
      ;if there is someone around!
      ;update the quality according to both neighborhood and immediate
neighborhoods
      [
        let quality-component-of-immediate-neighbors mean [SES] of turtles-on
neighbors
        set quality quality + ((moore-neighborhood-weight * quality-component-
of-immediate-neighbors + (1 - moore-neighborhood-weight) * average-quality-in-
neighborhood-i) - quality) / housing-quality-adjustment-time
      ]
      ;if there is noone around in the Moore neighborhood
      [
        set quality quality + ( average-quality-in-neighborhood-i  - quality ) /
housing-quality-adjustment-time
      ]
    ]
    set i i + 1
  ]
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
to update-income-SES
  let dummy-neighborhood-index neighborhood-index
;  set income income * coeff + (1 - coeff) * mean [income] of turtles-on patches
with [neighborhood-index = dummy-neighborhood-index]
```

```
;  set SES SES * coeff + (1 - coeff) * mean [SES] of turtles-on patches with
[neighborhood-index = dummy-neighborhood-index]
;  if count turtles-on neighbors4 != 0
;  [
;    set income income ^ (mean [income] of turtles-on neighbors / income)
;    set SES  SES ^ (mean [income] of turtles-on neighbors / SES)
;  ]
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;UPDATE INDICES;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
to update-ratios
  set eightieth/twentieth (mean[income] of max-n-of (population * .20) turtles
[income]) / (mean[income] of min-n-of (population * .20) turtles [income])
  set ninetieth/tenth (mean[income] of max-n-of (population * .10) turtles
[income]) / (mean[income] of min-n-of (population * .10) turtles [income])
  set fiftieth/tenth (mean[income] of max-n-of (population * .50) turtles
[income]) / (mean[income] of min-n-of (population * .10) turtles [income])
end
to update-patch-color
   let sorted-prices sort [price] of patches
   ;higher the price, the lighter the patch
   ask patches [set pcolor (position price sorted-prices / ((max-pxcor + 1) ^
2)) * 10]
end
to update-turtle-color

   if income-percentile <= .25 [set color red]
   if income-percentile >= .75 [set color blue]
   if income-percentile < .75 AND income-percentile >= .5 [set color sky]
   if income-percentile < .5 AND income-percentile > .25 [set color orange]
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;From (Benard & Will 2007) & (Winship, 1977)!!!!!;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
to update-index-of-dissimilarity
  let median-income median [income] of turtles
  let Q count turtles with [income < median-income] / population
  let P 1 - Q
  let dummy-index-of-dissimilarity  0
  let i 0
  repeat number-of-neighborhoods
  [
    let members-of-neighborhood-i turtles-on patches with [neighborhood-index =
i]
    if count members-of-neighborhood-i > 0
    [set dummy-index-of-dissimilarity  dummy-index-of-dissimilarity  + count
members-of-neighborhood-i * abs ((count members-of-neighborhood-i with [income <
median-income] / count members-of-neighborhood-i) - Q)]
    set i i + 1
  ]
  set index-of-dissimilarity (1 / (2 * population * P * Q)) * dummy-index-of-
dissimilarity

  set i 0
  let expected-index-of-dissimilarity 0
  repeat number-of-neighborhoods
  [
    let members-of-neighborhood-i turtles-on patches with [neighborhood-index =
i]
    let j 0
    let dummy-expected-index-of-dissimilarity 0
    let Ti count members-of-neighborhood-i
    if Ti > 0
    [
     repeat (Ti + 1)
     [
       set dummy-expected-index-of-dissimilarity
       dummy-expected-index-of-dissimilarity +  (factorial Ti / (factorial j *
factorial (Ti - j))) * (Q ^ j) * (P ^ (Ti - j)) * abs ((j / Ti) - Q)
       set j j + 1
     ]
    ]
```

```
    set expected-index-of-dissimilarity expected-index-of-dissimilarity + Ti *
dummy-expected-index-of-dissimilarity
    set i i + 1
  ]
  set expected-index-of-dissimilarity expected-index-of-dissimilarity / (2 *
population * P * Q)

  set index-of-dissimilarity 100 * (index-of-dissimilarity - expected-index-of-
dissimilarity) / (1 - expected-index-of-dissimilarity)
end
to update-D*-based-on-Moore-nhood
  let median-income median [income] of turtles
  let Q count turtles with [income < median-income] / population
  let P 1 - Q
  let dummy-index-of-dissimilarity-based-on-Moore-nhood  0
  ask turtles
  [
    let members-of-neighborhood-i turtles-on neighbors
    ifelse count members-of-neighborhood-i != 0
    [set dummy-index-of-dissimilarity-based-on-Moore-nhood  dummy-index-of-
dissimilarity-based-on-Moore-nhood  +  abs ((count members-of-neighborhood-i
with [income < median-income] / count members-of-neighborhood-i) - Q)]
    []
  ]
  set index-of-dissimilarity-based-on-Moore-nhood (1 / (2 * population * P * Q))
* dummy-index-of-dissimilarity-based-on-Moore-nhood

  let expected-index-of-dissimilarity-based-on-Moore-nhood 0
  ask turtles
  [
    let members-of-neighborhood-i turtles-on neighbors
    let j 0
    let dummy-expected-index-of-dissimilarity-based-on-Moore-nhood 0
    let Ti count members-of-neighborhood-i
    if Ti > 0
    [
     repeat (Ti + 1)
     [
       set dummy-expected-index-of-dissimilarity-based-on-Moore-nhood
       dummy-expected-index-of-dissimilarity-based-on-Moore-nhood +  (factorial
Ti / (factorial j * factorial (Ti - j))) * (Q ^ j) * (P ^ (Ti - j)) * abs ((j /
Ti) - Q)
       set j j + 1
     ]
    ]
    set expected-index-of-dissimilarity-based-on-Moore-nhood expected-index-of-
dissimilarity-based-on-Moore-nhood + dummy-expected-index-of-dissimilarity-
based-on-Moore-nhood
  ]
  set expected-index-of-dissimilarity-based-on-Moore-nhood expected-index-of-
dissimilarity-based-on-Moore-nhood / (2 * population * P * Q)

  set index-of-dissimilarity-based-on-Moore-nhood 100 * (index-of-dissimilarity-
based-on-Moore-nhood - expected-index-of-dissimilarity-based-on-Moore-nhood) /
(1 - expected-index-of-dissimilarity-based-on-Moore-nhood)
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;
; from A New Approach to Measuring Socio-Spatial Economic Segregation, (Reardon
2006), pg 23
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;
to update-Hr
  let p 1
  let dummyHr 0
  ;We approximate the integral with a Riemann Sum approach by letting dt=(1 /
Hr-precision-level)
  repeat (Hr-precision-level - 1)
  [
    let j 0
    let dummyHp 0
    repeat number-of-neighborhoods
    [
```

```
      let Ejp 0
      let turtles-on-neighborhood-j turtles-on item j neighborhoods
      let number-in-neighborhood-j count turtles-on-neighborhood-j
      ;if noone is in there, then just skip that neighborhood
      if number-in-neighborhood-j = 0 [stop]
      let proportion-of-p-income-below count turtles-on-neighborhood-j with
[income <= item round ((1 / Hr-precision-level) * p * population - 1) sorted-
income] / number-in-neighborhood-j
      ifelse proportion-of-p-income-below = 0 OR proportion-of-p-income-below =
1
      ;0 * log number=0 base=2 is defined as 0 via taking the limit of it as p
approach to zero! see reardon 2011, pg 19
      [][set Ejp (proportion-of-p-income-below * (log (1 / proportion-of-p-
income-below) 2) + (1 - proportion-of-p-income-below) * (log (1 / (1 -
proportion-of-p-income-below)) 2))]
      set dummyHp dummyHp + (Ejp / (item (p - 1) Ep)) * (number-in-neighborhood-
j / population)
      set j j + 1
    ]
    set Hp replace-item (p - 1) Hp (1 - dummyHp)
    set dummyHr dummyHr + (item (p - 1) Hp) * (item (p - 1) Ep) * (1 / Hr-
precision-level)
    set p  (p + 1)
  ]
  set Hr 2 * ln 2 * dummyHr
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;
; Moore neighborhood based Hr calculation.. Note that it gives negative results
becuase,
; by using Moore neighborhoods, we count certain turtles more than once!!
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;
to update-Hr-Moore
  let p 1
  let dummyHr 0
  ;We approximate the integral with a Riemann Sum approach by letting dt=(1 /
Hr-precision-level)
  repeat (Hr-precision-level - 1)
  [
    let j 0
    let dummyHp 0
    ask turtles
    [
      let Ejp 0
      let turtles-on-neighborhood-j turtles-on neighbors
      let number-in-neighborhood-j count turtles-on-neighborhood-j
      ;if noone is in there, then just skip that neighborhood
      if number-in-neighborhood-j = 0 [stop]
      let proportion-of-p-income-below count turtles-on-neighborhood-j with
[income <= item round ((1 / Hr-precision-level) * p * population - 1) sorted-
income] / number-in-neighborhood-j
      ifelse proportion-of-p-income-below = 0 OR proportion-of-p-income-below =
1
      ;0 * log number=0 base=2 is defined as 0 via taking the limit of it as p
approach to zero! see reardon 2011, pg 19
      [][set Ejp (proportion-of-p-income-below * (log (1 / proportion-of-p-
income-below) 2) + (1 - proportion-of-p-income-below) * (log (1 / (1 -
proportion-of-p-income-below)) 2))]
      set dummyHp dummyHp + (Ejp / (item (p - 1) Ep)) * (number-in-neighborhood-
j / population)
      set j j + 1
    ]
    set Hp-Moore replace-item (p - 1) Hp-Moore (1 - dummyHp)
    set dummyHr dummyHr + (item (p - 1) Hp-Moore) * (item (p - 1) Ep) * (1 / Hr-
precision-level)
    set p  (p + 1)
  ]
  set Hr-Moore 2 * ln 2 * dummyHr
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;; from Wealth Distribution model in Models Library
;; this procedure recomputes the value of gini-index-reserve
```

```
;; and the points in lorenz-points for the Lorenz and Gini-Index plots
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
to update-lorenz-and-gini
  let total-income sum sorted-income
  let income-sum-so-far 0
  let index 0
  set gini-index-reserve 0
  set lorenz-points []
  ;; now actually plot the Lorenz curve -- along the way, we also
  ;; calculate the Gini index.
  ;; (see the Info tab for a description of the curve and measure)
  repeat population [
    set income-sum-so-far (income-sum-so-far + item index sorted-income)
    set lorenz-points lput ((income-sum-so-far / total-income) * 100) lorenz-
points
    set index (index + 1)
    set gini-index-reserve
    gini-index-reserve +
    (index / population) -
    (income-sum-so-far / total-income)
  ]
end
to-report factorial [number]
  ifelse number = 0 OR number = 1
  [report 1]
  [
   let dummy number
   let result 1
   repeat (number - 1)
   [set result result * dummy set dummy dummy - 1]
   report  result
  ]
end
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```

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