Stockholm School of Economics
Department of Economics
659 Degree project in economics
Spring 2017

Gentrification in Stockholm: A study on determinants of dynamic spatial income distribution

Lilian Ivstam (23327) and Gustav Tillman (23346)

Abstract. This study employs the framework of the monocentric model of land-use to investigate causal factors of gentrification in Stockholm between 2000 and 2010. To calibrate the model to this previously untested city, we first examine if the model can explain the static income patterns in Stockholm as of year 2000. We find that the income distribution in Stockholm can be explained by the presence of amenities, which attracts high-income households, and by public transit, which attracts low-income households. Based on this, we continue to examine the two major dynamic modifications of the model that can be applied in explaining gentrification. Our key finding is that the degree of gentrification is influenced by neighborhood spillover effects, measured as the distance to the closest high-income neighborhood. This suggests that gentrification moves like ripples on the water, which has implications for future city planning. However, while filtering effects have been emphasized in previous gentrification literature, we find no significant evidence for this in Stockholm. The filtering effects imply that gentrification occurs in deteriorated neighborhoods with high dwelling ages. We suggest that the special features of Stockholm, with a rich amenity center, anchor high-income households to the city center, preventing the filtering process in central areas of the city.

Keywords: gentrification, urban economics, monocentric land-use model, Stockholm

JEL: R14, R23, R28

Supervisor: Örjan Sjöberg
Date submitted: May 14, 2017
Date examined: June 7, 2017
Discussants: Julia Näslund and Olle Kruber
Examiner: Chloé Le Coq

Acknowledgements

We would like to express our sincerest gratitude toward our supervisor Örjan Sjöberg for his enthusiasm and support, and for sharing valuable insights on urban development. Furthermore, we are grateful for the feedback received from our friends and classmates Agnes, Arthur, Olivia, and Hugo.

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1. Introduction

By the year of 2008, urban areas were for the first time more populated than rural areas. Western cities initially formed for industrial purposes are currently in the phase of restructuring to meet the needs of a post-industrial society. As such, cities are struggling to satisfy the various demands of a diverse population seeking urban living. An issue that has been observed within urban development more recently is the increasing level of segregation. It is clear that cities are not evolving in a uniform manner. While certain areas are falling deeper into poverty, others are becoming homogenous high-income areas. One mechanism related to this is *gentrification* – a process whereby a neighborhood undergoes an upgrade in terms of socioeconomic status. The presence of gentrification is highly ambiguous, and it has been a topic of research and discussion for several decades. Moreover, there are disagreements regarding whether the consequences of gentrification are desirable or not: on the one hand, displacing initial lower-income residents; on the other hand, creating new spaces for a growing middle-class. Consequently, decision-makers are confronted with adversity. While improvements in neighborhood quality can create prosperity and higher living-standards, it can also cause marginalization of low-income households.

The objective of this research paper is to investigate the potential of underlying determinants causing gentrification to occur in a neighborhood in Stockholm. Thus, through increasing the understanding of the causality factors, we aim to make a contribution toward future policy decisions in Stockholm's city development. A plethora of different theories have been used to study the causes of gentrification, in which neoclassical and marxist theories are the most prominent within the economics literature. In Stockholm, the latter approach is most frequently applied. However, these theories tend to be difficult to test empirically, and have thus received criticism for using unreliable measures. While the neoclassical approach has been successfully employed in explaining gentrification within many US cities, it has only been used to a limited extent outside of the US context. For instance, research on US cities has found that the spatial distribution of dwelling ages and proximity to high-income areas act as underlying causes for gentrification. It is therefore of interest to investigate if these explanatory factors are applicable in understanding changes in the socioeconomic status of neighborhoods in Stockholm as well.

To our knowledge, there has been no study on gentrification in Stockholm utilizing the neoclassical framework, leaving a gap in the literature which we seek to fill. Employing the monocentric land-use model – a model within this framework – the study seeks to uncover contingent patterns causing gentrification aligned with prior findings. Using an extensive set of manually compiled tract-level and parcel-level geo-coded data, detailed analysis giving reliable results can be made.

This paper begins with a review of the previous literature on gentrification in Section 2. In Section 3, the reader is given a contextual background of the characteristics of Stockholm.

Furthermore, Section 4 provides a detailed specification of the research focus. Section 5 contains the theoretical framework which we base our empirical models in Section 6 on. When presenting our models in Section 6, a detailed description of the variables is included, as well as potential issues with the models. In Section 7, specific details of the featured data is provided. Section 8 presents the result of the study, and Section 9 consists of a discussion of these results. Finally, the paper ends with a conclusion in Section 10.

2. Previous Research

This section begins with reviewing how gentrification has been defined in the literature. While there has been an extensive amount of studies on gentrification from several fields, such as urban economics, geography, sociology, and city planning, this review will focus on the causes of gentrification within the economics literature.

2.1 Defining gentrification

The term *gentrification* was coined by Ruth Glass in 1964, as she sought to define the phenomenon of inner-city neighborhoods in London undergoing rehabilitation as middle-class residents moved in, displacing working-class residents:

> One by one, many of the working class quarters have been invaded by the middle classes – upper and lower. […] Once this process of "gentrification" starts in a district it goes on rapidly until all or most of the working class occupiers are displaced and the whole social character of the district is changed. (Glass, 1964, p.xvii)

The expression originates from the word *gentry*, which is the denotation of the social class next below the nobility. In her book, Glass (1964) describes how working-class neighborhoods were undergoing elevations in terms of economic, demographic, commercial, cultural, and physical character, while accentuating the negative consequences of these changes as the initial lower-income residents were pushed out (Brown-Saracino, 2013).

Ever since, the definitions of gentrification have become more complex and diverse, and even ideologically or politically loaded (Lees, Slater, and Wyly, 2008), with the most frequently used distinction being to which extent lower-income residents are displaced (Ellen and O'Regan, 2012). In other words, some researchers imply that the act of displacement is an intrinsic feature as neighborhood change takes place (e.g. Hedin, et al., 2012). In contrast, other researchers do not necessarily view residential movement as a decisive factor, meaning that neighborhood change can take place in the light of "rapid economic and social changes" (Ellen and O'Regan, 2012, p.3). However, we have found that within the gentrification literature, the most fundamental denominator used in the definition is *an increase in a neighborhood's socioeconomic status*, which is most commonly measured as the growth of average income – either solitary, or in combination with other factors such as residential mobility, shifts in housing stocks, or reinvestments (e.g. Millard-Ball, 2002; Helms, 2003; Hedin, et al., 2012).

2.2 Causes of gentrification

Historically, the gentrification literature addressing causalities has generally been divided into production theories (supply-side explanations) and consumption theories (demand-side explanations). Whereas production theories argue that it is the flow of *capital* – controlled by structural and political mechanisms – determining whether gentrification occurs; consumption theories argue that it is the flow of *actors* – revitalizing neighborhoods due to shifts in consumption preferences – representing the underlying elements of gentrification.

We will begin by presenting demographic, social and cultural factors, which are highly related to demand-side explanations. We then proceed to present the economic factors, which are divided into marxist theories and neoclassical theories. While marxist theories are closely related to supply-side explanations, the neoclassical framework utilizes both demand-side and supply-side explanations.

2.2.1 Demographic, social, and cultural factors

Research in this area focuses on employing consumption factors to explain gentrification. Some research relates gentrification to the shift from the industrial society – with manufacturing and working-class labor located in the cities, to the post-industrial society – with middle-class white-collar workers inhabiting the cities (e.g. Bell, 1976; Lipton, 1977; Hamnett, 2003; Vigdor, 2002). Other research emphasizes the social or cultural characteristics of gentrifiers, such as Florida's (2002) theories of *the creative class* (gays, youths, bohemians, professors, scientists, artists, entrepreneurs, etc.), which is regarded as the "the key to economic growth in the contemporary city or region" (Lees, Slater, and Wyly, 2008, p.xix–xx). Ley (2003) further underlines that this creative class has a large amount of cultural capital, yet low amount of economic capital, valuing poverty neighborhoods for their "affordability and mundane, off-centre status" (p.2527). However, once these so-called pioneers have habituated the neighborhoods, the newly created cultural environment becomes appealing for middle-class residents with higher economic capital, who then move into the neighborhood, creating a gentrification process.

2.2.2 Economic factors

When examining the causal economic factors of gentrification, a distinction is usually made between marxist and neoclassical frameworks. The marxist framework is often applied by geographers and planners, and provides a limited amount of theories strongly influenced by politics, mainly focusing on production factors. The neoclassical framework is firmly established in the field of urban economics, and focuses on different factors determining how urban land will be utilized, and hence, employs both production and consumption factors.

Marxist theories

The dominating theory within this framework is the *rent gap*, established by Neil Smith (1979) and defined as "the disparity between the potential ground rent level and the actual ground rent capitalized under the present land use" (p.545). Smith explains inner-city gentrification as an effect of suburbanization, which causes downtown housing stock to depreciate as people move out to the suburbs. Subsequently, as the rent gap becomes large enough, capital is invested in the deteriorated inner-city neighborhoods, successively causing the back to the city movement of middle-class and upper-class residents. The rent gap has been empirically tested by Clark (1988), and Badcock (1989), finding evidence of the theory in Malmö, Sweden, and in Adelaide, Australia, respectively. Hamnett and Randolph (1986) have developed the theory further by defining what is called the *value gap*, meaning that when a property's value under owner-occupation is higher than that under rental housing, a tenure conversion occurs from the latter.

The rent gap theory has, however, been criticized for not providing reliable measurements for potential ground rent, and for not being able to accurately link the rent gap to gentrification per se (e.g. Bourassa, 1993; Yung and King, 1998). Moreover, Ley (1986) investigates several Canadian cities, and finds that gentrification has occurred due to urban amenities and various economic factors, rather than housing market dynamics. In addition, he implements tests on the rent gap theory, yet finds no evidence of it in the Canadian cities.

Neoclassical theories

In contrast to the marxist framework, both consumption and production theories are employed in the neoclassical framework. When utilizing this framework, focus is usually set within the broader subject of the relative position of households with different income levels. Gentrification is then identified as a change in the patterns predicted by the model (Ellen and O'Regan, 2012). An important model within this framework is the monocentric model of land-use, first formulated by Alonso (1964), and later modified by Mills (1967) and Muth (1969). In this model, cities are monocentric, that is, all employment is found in a central business district (CBD). Households choose where to locate in relation to the CBD based on the trade-off between commuting costs and the cost of housing. To study income patterns, it is usually assumed that there are two different types of households, high-income and low-income. One weakness of the monocentric model is that it has difficulties explaining where these households will live, since this depends on how the two groups value low commuting costs contra more housing consumption.

Several attempts have been made to measure empirically how the demand for housing and commuting changes when income changes (e.g. Wheaton, 1977; Glaeser, Khan, and

Rappaport, 2008), yet no clear conclusions have been made regarding which force is dominant. Furthermore, income distribution patterns differ in US and European cities (Brueckner, Thisse, and Zenou, 1999). The model has difficulties explaining why high-income households tend to locate in the suburbs in the United States, while they tend to locate close to the CBD in many European cities. Consequently, researchers have tried to find other explanations for income distribution by modifying the standard monocentric model.

Brueckner, Thisse, and Zenou (1999) present a monocentric model which incorporates amenities to explain the locations of income groups. They show that Paris has a great amount of amenities pulling high-income households to the city center, while the opposite applies for Detroit. This could help explain the differences in income patterns between US and European cities. LeRoy and Sonstelie (1983) develop a modification of the monocentric model to include the role of transport mode in income distribution patterns. Furthermore, Glaeser, Khan, and Rappaport (2008) incorporate the assumptions made by LeRoy and Sonstelie (1983) to develop a more modern approach to the impact of transport modes. They show that if high-income households use cars and low-income households use public transit, the equilibrium where the low-income households live in the inner city, is more likely to occur than if they used the same mode of transport.

Modifications with a dynamic perspective

The monocentric model, and its modifications outlined above, provide a base for analyzing the *initial structure* of cities. In the context of explaining gentrification, they act as the base model, but are inherently static in nature. This is criticized by Brueckner and Rosenthal (2009), as they argue that a static model does not help explain *changes* in the status of neighborhoods, yet only explains households' relative locations given the features of a city. Gentrification is per definition a dynamic phenomenon, and thus researchers have attempted to create dynamic models of neighborhood change.

An early approach was made by Kern (1981) who included a taste variable in the utility function of households in the monocentric model, with certain demographic groups having different preferences. For instance, he argued that unmarried adults would have a stronger preference for urban living, and that their increasing prevalence could help explain why upper-income residents prefer to move to the inner city. However, his empirical analysis is mostly descriptive, and the inclusion of a taste parameter is regarded as somewhat controversial in theoretical economics.

The influential paper by Brueckner and Rosenthal (2009) focuses on the supply-side and includes the age of housing stock as a predictor of economic status of a neighborhood. They base this argument on classical filtering models, in which high-income residents move to newly-built houses, leaving their old homes to lower-income residents. This theory goes hand in hand with the literature on redevelopment and revitalization, which argues that the older a building becomes, the more valuable is the option to redevelop it (Clapp and Salavei, 2010).

Building on this notion, Helms (2003) defined gentrification as redevelopment, and not as increases in the average income of a neighborhood. Using a parcel-level dataset on renovation activity, he tests whether neighborhood characteristics affect the likelihood of renovation. He finds support for a myriad of variables, such as natural amenities, historical architecture, public transit and dwelling age.

Another approach to the economic status of neighborhoods is the analysis of social dynamic effects. Guerrieri, et al. (2013) develop a model with the feature that high-income residents prefer to habituate next to other high-income households because of positive externalities. Employing this model, they show that when there is a positive demand-shock in a city, high-income households will expand into neighborhoods adjacent to the existing high-income areas – a result which they find strong support for empirically. This is also one of the key contributions of Kolko (2007), who finds that neighboring tract income contributes to gentrification.

Lastly, Lee and Lin (2017) provide a dynamic perspective on natural amenities, showing that natural amenities anchor neighborhoods to high income levels over time. Although their focus is mainly on cross-city variation, their results and methods are highly relevant to understanding income variation over time in neighborhoods.

3. Stockholm

This section contains a description of the context in which the study takes place. Reviewing the history of Stockholm and analyzing the changes, strategies, and characteristics of the city provides an understanding for the city's structure as of today. The main purpose of this section is to provide tools for employing the theoretical framework on the specific context of Stockholm. Furthermore, it will also facilitate in understanding and interpreting the results of the study.

3.1 Creation of the city

During the first half of the 20th century, the creation of suburbs began to cater the needs of an increasing population and a housing shortage in Stockholm. After a social housing investigation, it was decided in 1947 that the state should be responsible for the financing of new housing, whereas the municipalities had imperative responsibility for organizing, planning, and conveying preferential government loans. In 1948, Bostadsstyrelsen, an administrative authority for housing was formed by Parliament. In conjunction, rent regulations were introduced – a modern two-room apartment should not cost more than twenty percent of an industrial worker's salary. As such, housing became a political issue. Following the new regulations, almost one hundred public housing companies – owned or controlled by municipalities – were created. A reform in 1968 gave the public housing companies the role to set rental standards. (SABO, 2017a; SABO, 2017b)

In 1950, the first part of the subway system was set in traffic, stretching from Slussen to Hökarängen. As a result, additional suburbs with individual small-scaled centers were created around the subway stations in the 1940s and 1950s. Based on the idea of the subway suburbs, so-called *ABC-städer* (ABC-towns) became the ideal – such as Vällingby in the north and Farsta in the south, built in the 1950s and 1960s respectively. The ABC-town was supposed to provide work, housing, and commerce, as well as cater access to culture, healthcare, and community service. (Stockholms Stad, 2017a)

As housing was still not sufficient to reach the demand, *Miljonprogrammet* was implemented in 1965, set to create a million new accommodations in Sweden during the ten following years. Modern, efficient, and standardized housing with reasonable prices was built in subway suburbs such as Akalla, Hjulsta, Husby, Skärholmen, Rinkeby, Tensta, and Sätra. (Stockholms Stad, 2017b)

In parallel to the housing shortage, overcrowded housing and low living standards were also problems arising in the urban areas. A sanitation program of the inner city began after the Second World War, in which buildings were torn down, rebuilt, or upgraded (SABO, 2017c). In 1974, a housing sanitation law was implemented stating that apartments should satisfy "minimum acceptable standards," and the rules for state housing loans were changed to spur reconstruction and renovation of older buildings (Råberg, 1976, p.22, our translation). During the 1970s, working-class neighborhoods were upgraded and renewed, by merging smaller apartments and installing modern facilities (SABO, 2017c). Meanwhile, between 1951 and 1984 office space in the inner city increased by 118 percent (Borgegård and Murdie, 1993).

3.2 Gentrification in Stockholm

When studying gentrification in Stockholm, many researchers tend to highlight housing policy as an important factor in explaining gentrification in Stockholm. Extensive restructuring in the housing market occurred in the beginning of the 1990s. The department of housing was closed, and income taxes were reduced to give households more control over their private consumption (SABO, 2017d). Compensating for these costs, the so-called *Danellsystem* reduced interest grants and state subsidies to housing construction (Boverket, 2002). As a result, a great amount of public housing was converted into market-based cooperative housing (Andersson and Turner, 2014). Furthermore, a redistribution of national income was made as "the housing sector went from being a net burden on state finances of roughly 30 billion Swedish crowns in the late 1980s to providing a net income of roughly 31 billion crowns ten years later" (Hedin, et al., 2012, p.445). In 2011, the public housing companies lost their rent-setting role (SABO, 2017e).

The drastic increase in cooperative housing and segregation of tenure forms has been highlighted in the media. During the years 2007 to 2014, 26 000 of public housing companies' rental apartments were sold out to cooperative housing companies for tenure changes

(Hellekant and Orre, 2015). Rental housing in Stockholm has reduced drastically, especially in the inner city, which is said to contribute to segregation across the city (Tottmar, 2012). Gentrification studies on Stockholm are often circulated around tenure conversions and rent regulation. However, research results on the area are scattered. Several studies emphasize the effect of tenure conversions on gentrification as well as segregation (Hedin, et al., 2012; Andersson and Turner, 2014; Borgegård and Murdie, 1993). Millard-Ball (2000) however, finds that luxury renovations and housing allocation mechanisms provide more reliable explanations, due to difficulties to control for endogeneity when examining tenure conversions. An additional paper by Millard-Ball (2002, p.853) further states that tenure changes cause gentrification in an indirect process, through "the change and type of available housing vacancies." A study by Lind and Hellström (2006) investigates the argument that a deregulated housing market causes high market rents and therefore economic segregation. They find that a slow move toward market rents does not drastically increase economic segregation. Another paper by Lind (2015) states that current rent regulations encourage landlords to improve the quality of their apartments since it allows increased rents, which in turn spurs gentrification.

Hedin, et al. (2012) provide the most extensive mapping of gentrification in Stockholm. The study shows that gentrification is a widely-spread phenomenon. Not only *classical gentrification* (gentrification in areas among the bottom 25 percent in initial income level) is found in the city, but also *ordinary gentrification* (gentrification in areas among the middle 50 percent in initial income level), and *super gentrification* (gentrification in areas among the top 25 percent in initial income level). Moreover, Clark and Gullberg (1991) use production theories to explain how the rent gap in lower Norrmalm in Stockholm can be understood in relationship to building activity and building provision structures. In contrast, Franzén (2005) uses consumption theories to explain how new social movements have caused gentrification in Södermalm, Stockholm.

3.3 Evidence of a monocentric and centralized city

Stockholm has been built outwards from the central city, sometimes described as growth rings on a tree (Andersson, 1997). Regarding locations of work, a report by the European Commission states that the concentration of work is significantly higher than the concentration of households in the inner city (Dijkstra and Poelman, 2015). Furthermore, a recent publication by the housing sales website Hemnet (2017) shows that average housing prices per square meter along the subway stations in Stockholm in many cases are twice as high at centrally located stations, compared to stations toward the end of the subway line.

Even though earlier attempts have been made to create decentralization in Stockholm, for instance through producing the subway and ABC-towns, a report by Stockholms Stad (2014) shows that areas with a population density higher than 150 persons per hectare almost exclusively lie within the central city. As such, the city is still highly centralized around the

CBD. According to this report, the high demand and high prices on inner-city housing are due to "well-defined city qualities where the supply of shops, restaurants and cultural activities is crucial, as is the proximity of public rail and green areas" (Stockholms Stad, 2014, p.7, our translation). This can be related to the observation by Brueckner, Thisse, and Zenou (1999) that European cities tend to have rich amenities in the central city, thus attracting high-income households to the CBD. They argue that, in general, European metropolitan cities have a long history, creating, among other things, historical monuments in the inner city and a central city infrastructure.

4. Specification of research focus

The research objective of this study is to examine causes of gentrification in Stockholm. Previous studies on gentrification in Stockholm have focused on marxist economic theories to explain the phenomenon in terms of tenure changes, rent gaps, rent regulations, and neoliberal housing policies. However, many of these studies suffer from endogeneity issues, and often lack examinations of underlying causes. For instance, an understanding of why gentrification occurs in certain areas rather than others is not provided by existing literature. Furthermore, as mentioned in the literature review, criticism has been directed to the methods of measuring rent gaps, in which Clark's (1988) approach among others has been claimed to contain deficiencies. In contrast to the gap theories, Bourassa (1993, p.1731) acknowledges the neoclassical theory, stating that "the standard neoclassical concept of land-use succession is more coherent than the rent gap concept." Based on Section 3.3, we argue that the monocentric model of land-use is relevant for analysis in Stockholm, since the city shows clear tendencies of being monocentric. Research using this theoretical framework to investigate gentrification in Stockholm has, as to our knowledge, not been carried out, thus creating a gap in the literature which we seek to fill. This leads us to our research question:

> *To what extent can the monocentric land-use model be used in explaining the occurrence of gentrification in Stockholm?*

Our approach provides several contributions. Understanding how, why and where gentrification emerges in Stockholm provides direct policy implications for future decisions regarding city structure. For instance, if policymakers wish to limit the occurrence of gentrification, understanding where to put in efforts to prevent it is of crucial importance. We do not merely seek to explain gentrification by applying a new theoretical framework; we also seek to uncover underlying determinants of gentrification in the city structure. Hence, we contribute to the research on gentrification in Stockholm by examining whether there are other causal factors which can explain the occurrence of gentrification in the city's neighborhoods more thoroughly. As such, our study does not necessarily contradict previous findings in Stockholm.

Furthermore, the data which has been compiled contains detailed information of the variables we intend to study, providing opportunities for creating in-depth analysis on the chosen city, and therefore giving reliable results. As such, this study can provide a broad and cohesive empirical research by combining several of the explanatory variables put forward in the previous literature. In addition, this research also is important for understanding general causality factors of gentrification by examining whether the dominant determinants in the urban economics literature also can be found in a new and different research context. As pointed out by Rosenthal and Ross (2015), there is a lack of utilization of the neoclassical framework to study neighborhood income dynamics outside of the US. Therefore, although this is not the main purpose of our study, we will also contribute to the urban economics literature.

5. Theoretical framework

The monocentric model of land-use has numerous extensions and modifications, relating to many different issues. In this section, we present a theoretical review of the modifications that have been effective in explaining income patterns, both static and dynamic, while still providing clear, testable implications in the context of Stockholm. The main purpose of the theoretical framework is to provide a base for our empirical models in Section 6.3. Furthermore, in the discussion of our results in Section 8, these theories will also act as tools for analysis.

First, we introduce the basic mechanics of the monocentric model in Section 5.1. We then proceed to add several modifications that have provided explanations for underlying causes of gentrification. While Section 5.2 presents the static modifications of the model determining *income patterns*, Section 5.3 presents the dynamic modifications determining *income change*. We use several theories to base our research on, as we have chosen to not discriminate amongst previous findings.

5.1 The monocentric land-use model

The description that follows is mainly adapted from Brueckner (2011). The fundamental assumption of the monocentric model is that all employment is located within the central city, also known as the central business district (CBD). A second assumption is that households are identical – both in terms of preferences and income – and only consist of one person. A third assumption is that a dense and radial network of roads exists, which means households travel as the crow flies toward the CBD. A fourth assumption is that consumers only consume two goods: Housing (q) and a composite good (g), representing anything other than housing. Utility is thus defined as $u(g,q)$. Consumption of housing is denoted by pq, where q represents the square footage of a dwelling and p represents the price per square feet.

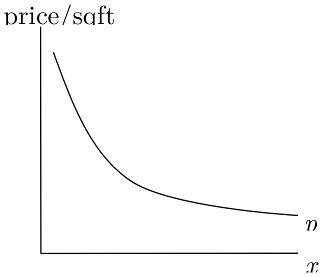
Since employment is located in the CBD, all residents must commute to work and face a linear material commuting cost c per unit distance. In the basic model, c is the same for all residents. If x represents the distance to CBD and y represents the income earned per household, disposable income is then y-cx, where cx represents the total commuting cost. The *budget constraint* of a consumer is thus:

$$g+pq=y-cx \tag{1}$$

The consumer chooses the level of g and q that maximizes utility subject to the budget constraint. Since the total cost of commuting (cx) increases with the distance from the CBD, the price of housing (p) decreases with the distance from the CBD. Utility is thus the same for all residents at all distances (x). In other words, a low price (p) can compensate for a high distance (x), and vice versa.

A key concept is the *bid-rent* – defined as the maximum price per square foot a household can pay to reside at location x and maintain some given level of utility. Bid-rent curves are constructed by showing how p changes with respect to x.

Figure 1: Bid-rent curve



The slope of p with respect to x is given by:

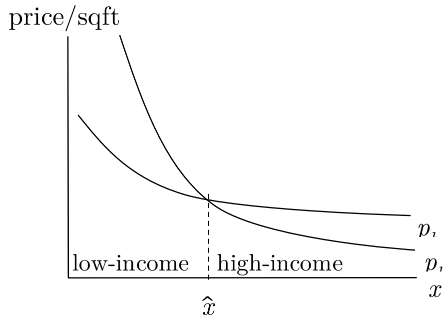
$$\frac{\partial p}{\partial x}=\frac{-c}{q} \tag{2}$$

This means that the slope is convex since q increases with x, given that c stays the same.

Introducing income distribution

To study income patterns and income dynamics within a city, two different income groups are introduced. High-income households earn income y_h and low-income households earn income y_l, giving the two groups different budget constraints and bid-rent curves. Furthermore, the bid-rent curves of high-income households (the p_h line) will be flatter than the bid-rent curves of low-income households (the p_l line), since it is assumed that high-income households have a higher demand for housing (i.e. a high value of q). There now exists a distance from CBD, $\hat{x}$, which separates the two groups. When assuming the two groups have the same cost of commuting per unit distance, the only outcome is the one in which high-income households will outbid the low-income households for locations at high x, as seen in Figure 2. This means that the high-income households will live in the suburbs, and the low-income households will live in the city center. The intuition is that since high-income households demand large dwellings, they will favor locations where price per square feet is low, found at distances far from the CBD.

Figure 2: Bid-rent curves of low-income households and high-income households



Introducing opportunity cost of time

Up to this point, we have not considered the fact that long commutes impose an opportunity cost. If the time spent commuting instead of working is t and wages per unit time is w, the opportunity cost of time is given by tw. Since $w_h > w_l$, high-income households have a higher opportunity cost of time. When we include this effect, total commuting cost is given by $(c+tw)\times x$. The slope of the bid-rent function is then as follows:

$$\frac{\partial p}{\partial x} = \frac{-(c+tw)}{q} \tag{3}$$

Now, the income group with the steepest slope will reside closer to the CBD. With this specification, the prediction of the relative location of the two income groups is *ambiguous*. There are basically two opposing forces: On the one hand, high-income households have a higher demand for housing, pulling them toward the suburbs, where housing (q) price per unit is cheaper. On the other hand, high-income households have a higher opportunity cost of time (tw), pulling them closer to the CBD in which work is located.

5.2 Static modifications of the model

In this section, we outline how extensions of the baseline model, such as the inclusion of amenities and different transit modes, can reduce ambiguity in explaining static income patterns.

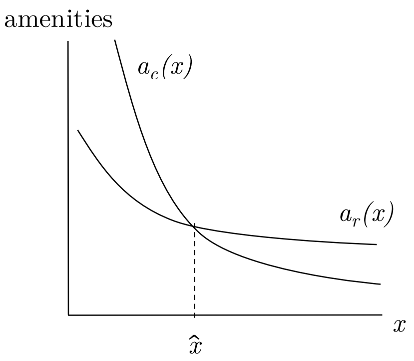
Amenities

The idea of including amenities in the monocentric land-use model is based on the theory that it is not only housing consumption and transportation costs that determine where households locate, but also the presence of amenities. Brueckner, Thisse, and Zenou (1999) show that the pull of central amenities can be strong enough to only have one equilibrium outcome with high-income residents living in the inner-cities.

More specifically, Brueckner, Thisse, and Zenou (1999) provide a framework with three different amenity classes: natural amenities, historical amenities, and modern amenities. Natural amenities are defined as topographical features, such as coastlines and beautiful scenery, while historical amenities are classified as for instance, monuments and buildings from past eras. Both of these amenity classes are mainly exogenous. Modern amenities, such as theaters, restaurants and tennis courts, are however endogenous, since they mainly depend on the current economic status of a neighborhood.

Brueckner, Thisse, and Zenou (1999) develop a model including exogenous amenities. Building on the monocentric model, an exogenous amenity level at distance x is included, denoted as $a(x)$. A key assumption is that the marginal valuation of amenities rises sharply with income. The intuition is that high-income households can afford to prefer proximity to amenities, since for a given size of housing, they have a higher disposable income to spend on amenities than low-income households. It is also reasonable to believe that a household with low income will value housing higher than amenities. The utility function is now given by $u(g,q,a)$, while the budget constraint is the same as in the basic monocentric model. The bid-rent curves of high-income households (p_h) and low-income households (p_l) are thus implemented in the same way, with $\hat{x}$ determining where a given group's bid prices are equal. Subsequently, the analysis adds a reference city with denotations $\hat{x}_r$ and $a_r(x)$, and a comparison city with denotations $\hat{x}_c$ and $a_c(x)$. A common group boundary between the two cities is found at level $\hat{x}$ and the common amenity level at this location is denoted $\hat{a}$. At $\hat{x}$, the slope of the amenity functions is the only difference between the cities – represented by $a_r'(x)$ in the reference city and $a_c'(x)$ in the comparison city.

Figure 3: Amenity curves



In the reference city with amenity function $a_r(x)$, high-income households locate in the suburbs. However, if the marginal amenity valuation rises faster than housing consumption as income increases, the location pattern will be reversed and high-income households will locate in the central city, as in the comparison city with amenity function $a_c(x)$. This is shown in Figure 3. Thus, the theoretical prediction of the model is that high-income households will locate in areas with a high amount of amenities, in which they outbid the low-income households.

Disamenities

Several authors choose to incorporate disamenities in their explanations for income distribution (e.g. Harris and Ullman, 1945; Helms, 2003; Lee and Lin, 2017). In the same way that amenities have the ability to attract high-income households, disamenities are theorized to repel high-income households. That is, the marginal tolerance of disamenities falls sharply with income.

Access to public transit

Glaeser, Kahn, and Rappaport (2008) provide a modification of the monocentric model including different modes of transportation, based on previous work by LeRoy and Sonstelie (1983). As shown in Section 5.1, when accounting for the opportunity cost of time, the slope of the bid-rent curve is given by equation 3. Now, assume households travel either by public transit or by car – whereby the time to travel distance x is shorter for cars ($t_c < t_p$). Also assume a variable material cost for both transport modes, where c_c denotes the cost per distance x for cars, and c_p denotes the cost per distance x for public transport. Furthermore, a fixed cost for both transport modes is included, which is lower for public transit. Lastly, assume that the fixed cost of travelling by car is too high for low-income households to afford, and that all high-income households use cars. Then, the low-income households will have a steeper bid-rent curve, and reside in the city center if:

$$\frac{(c_p + w_l t_p)}{q_l} > \frac{(c_c + w_h t_c)}{q_h} \tag{4}$$

This is more likely to hold than the condition in previous sections, since the low-income households will find it advantageous to locate close to the subway stations, and subway stations are more densely located closer to the CBD. In other words, the low-income households will outbid the high-income households for areas where public transit accessibility is high. The main prediction of this theory is therefore that areas with high accessibility to public transit will have lower income levels. In other words, if public transit accessibility would be the same in the entire city, low-income households would locate further out from the CBD, compared to if accessibility is higher in the center.

5.3 Dynamic modifications of the model

The only way to explain gentrification using the above modifications of the model is that the slopes of the bid-rent curves for the two income groups shift relative to each other. For example, if the opportunity cost of time of high-income households increases, they would move closer to the city center. As such, these modifications are better suited at explaining income distributions at a certain point in time. Gentrification is a dynamic phenomenon, and therefore we proceed by introducing two modifications of the monocentric model with a dynamic perspective – the inclusion of dwelling age and neighborhood spillover effects.

Dwelling age

Brueckner and Rosenthal (2009) present a model theorizing that high-income households move as a result of housing cycles, in which new housing stock is created and old housing stock becomes renovated. It is shown how dwelling ages in a neighborhood affect the occurrence of gentrification. This argument is based on the assumption that high-income residents move to newly-built houses, leaving their old homes to lower income residents. Houses are thus "filtered down" the income ladder. If the city expands outwards, the implication is that the high-income households will move further and further away from the city center, where new housing stock can be built. However, if the city center is later redeveloped, a point will occur where high-income classes will find it attractive to move to these newly built, or dramatically renovated, dwellings.

While the model developed by Brueckner and Rosenthal (2009) is grounded in the monocentric model, the key assumption that cities develop and redevelop from the center and outwards over time creates a dynamic approach. The utility function $u(g,q)$ is the same as in the basic model in Section 5.1. However, a critical assumption that housing consumption is dependent on dwelling age, $q(d)$, is added, in which d represents dwelling age. Since the model is dynamic, a time aspect is also included, denoted z. Consequently, the slopes of the bid-rent curves are similar to the ones in the monocentric model, but account for dwelling age and time, as can be seen in equation 5:

$$\frac{\partial p}{\partial x} = -tw(z) + \frac{u_q}{u_g} \times q'(d) \times \frac{\partial d}{\partial x} \tag{5}$$

Firstly, the only cost of commuting is assumed to be the time cost, given by $-tw(z)$. Secondly, the marginal rate of substitution between the utility of housing consumption and the utility of non-housing consumption, u_q/u_g, is assumed to be higher for high-income households, as they have a higher demand for housing. Thirdly, the marginal utility from housing decreases with age ($q'(d)<0$). Lastly, dwelling age is initially assumed to fall linearly with respect to distance ($\partial d/\partial x<0$), since the city has expanded outwards over time. In this case, high-income households will outbid low-income households for locations far from the CBD (i.e. they live in the suburbs).

Eventually, however, a point will be reached in which buildings in the central city start to become renovated or rebuilt. This leads to the formation of two generations of dwellings. Assuming that the renovation activity begins at the CBD and advances outwards over time, there will be a boundary between the two generations at $\hat{x}$. Just outside this point, at $\hat{x}+$, dwelling age is equal to a high number L, and just inside, at $\hat{x}-$, dwelling age is 0. For high-income households to be indifferent between locations at $\hat{x}+$ and $\hat{x}-$, the following equality must hold:

$$u\left[\widehat{w_h}(1\text{-}\hat{t}x)\text{-}p_h(\hat{x}\text{-}),\ q(0)\right]=u\left[\widehat{w_h}(1\text{-}\hat{t}x)\text{-}p_h(\hat{x}+),\ q(L)\right] \tag{6}$$

That is, the total utility from consuming both housing and non-housing should be the same, regardless of on what side of $\hat{x}$ the household is located. Since consumption of a new dwelling, *q(0)*, is larger than consumption of an old dwelling about to be replaced, $q(L)$, $p_h(\hat{x}\text{-})$ must be larger than $p_h(\hat{x}+)$. Furthermore, if we let $\hat{b}$ denote the distance to the edge of the city, we know that this point will have the same dwelling age as a dwelling at $\hat{x}$-, since the latest restructuring or building activity has taken place in both those places. If the high-income households outbid the low-income households at $\hat{b}$, they must also do so at $\hat{x}$-. This leads to the key conclusion that some high-income households will move into the most newly renovated part of the city center, just inside $\hat{x}$. As such, gentrification occurs.

In other words, since renovated housing increases housing consumption, this implies that the high-income households will find it attractive to move closer to CBD, even if this means a higher price per square feet. The intuition is that the willingness-to-pay for housing of a given age rises faster for high-income households than for low-income households when distance from the CBD decreases, since high-income households' have a higher time cost $(\widehat{w_h}t>\widehat{w}_l t)$.

To summarize, based on the assumption that high-income households prefer to live in new housing stock, the theory predicts that gentrification occurs when dwellings are renovated. Furthermore, the critical age beyond which occupancy switches from low-income to high-income is higher in dwellings closer to the city. This implies that, when controlling for dwelling ages, the association between distance and income (wage) should be weakened or reversed.

Spillover effects

Guerrieri, et al. (2013) examine neighborhood spillover effects as a part of what they call endogenous gentrification. They design a spatial equilibrium model to show that, after a positive demand shock, gentrification is more likely to occur in areas close to high-income areas. The baseline theory is that agents derive increasing utility with the income of their neighbors, as they create a positive neighborhood externality. The utility function of a household is given by $u(g,q,s)$, where s represents the spillover effect of living in a high-income area. This is based on the idea that high-income neighborhoods are associated with desired amenities such as restaurants, service industries, movie theaters, and higher school quality, through for instance peer effects. This can thus be related to the theory of endogenous amenities presented in Section 5.2. A further assumption is that high-income households have a stronger preference for living close to high-income neighbors than low-income households do. Hence, the initial setting will be total separation between the two income groups, since low-income households are outbid by high-income households in high status neighborhoods.

Given a shock in demand for housing, that is, when the existing high-income neighborhoods cannot contain all high-income residents, high-income households will then begin expanding into the adjacent low-income neighborhoods. This is a form of gentrification. Although the setting of this model is not strictly within the monocentric model, the assumptions and workings of the model are directly relevant to explaining changing income patterns in a monocentric setting, as Kolko (2007) does. For example, if the high-income households initially occupy the suburbs, a demand shock for housing – not met by an equal increase in supply – pushes the high-income households closer to the CBD, into what initially were low-income areas. The theoretical prediction is thus that gentrification is more likely in areas with high proximity to high-income areas.

6. Method

To tackle our research question, a two-stage analysis is performed using OLS multivariate regression analysis. In the first stage, we test how well the monocentric model, with its several modifications, can explain the static *income pattern* for a given year in Stockholm. In the second stage, we test how well the different modifications of the model can be used to explain the *income change* between two given years. Even though gentrification per definition is a dynamic phenomenon, the inclusion of the first stage is important to understand how the variables in the basic static model can affect the dynamic model.

In this section, we begin by introducing the time frame and spatial context of the study. This is followed by an explanation of how we operationalize the different modifications of the monocentric model into variables. Subsequently, we present the different models used in the regression analysis, and our hypotheses for these. Lastly, we discuss and address potential issues with the models.

6.1 The setting of the study

Time frame

All explanatory variables included in the study are measured as of the year 2000. It is therefore natural to study this year in the first stage of the analysis, when the static income pattern is examined. When we then proceed to analyze gentrification, we use the change in income over ten years, since this is the range most commonly used in previous studies. Furthermore, this is reasonable since it is long enough to capture consistent income changes, yet still short enough to make it relevant for policy implications. The time frame studied thus ranges from year 2000 to year 2010. There are several reasons for why the selected time frame is relevant. Firstly, it is of interest to perform further research based on different periods of time, since most research have examined the last three decades of the 20th century. Secondly, when studying recent gentrification patterns, the policy implications are more relevant.

Spatial context

The units of study are SAMS-areas (Small Areas for Market Statistics), of which there are 128 in Stockholm (see Appendix B, Figure 4). Stockholm is defined as the *municipality of Stockholm*. The surrounding municipalities which are a part of *Stockholm conurbation*, such as Lidingö, Solna, Huddinge, Nacka, and Danderyd, are not included as research objects in the study, although their presence would be of relevance. For instance, the subway system stretches out in some of these suburbs and they are recognized as integrated areas of Stockholm as a city. However, all neighboring municipalities are included in the variable calculating spillover effects. While it would be interesting to include adjacent municipalities in additional parts of the model, this is not done due to data constraints and the ability to consider previous and future policy actions within the municipality.

6.2 Model variables

Dependent variables

In the first stage of our analysis we examine *income patterns*. In these models, average income in each SAMS-area in year 2000 is used. Furthermore, in our study, gentrification is defined as the percentage change in income within an area, as it the most conventional definition used in previous literature. When studying *income changes* we calculate the average increase in income over the ten years studied in each SAMS-area, relative to the whole city. This creates a form of standardization centered around 1, meaning that SAMS-areas above 1 grew faster than the city average. This makes interpretation more intuitive.

Baseline explanatory variable

The distance to CBD is the crucial variable of the monocentric model. The contextual background of our research object shows that Stockholm can be regarded as a monocentric city, in which work is located and land value is higher in the city center. In line with the theoretical framework, CBD is defined as a point, even though this is a strong simplification. We define CBD as the central station, which is reasonable given that this point connects all the subway and commuter trains. The distance to this point is measured from the centroid, which is the midpoint of the length and height, of each SAMS-area.

Static explanatory variables

In our first static modification, we study *amenities* as a group.[1] While natural amenities can be a broad characteristic, we choose to focus on the distance from each individual building to the nearest major lake, river or sea. We construct a dummy variable, where the outcome for

[1] In our model, we will refer to both natural and historical amenities, as well as disamenities, as "amenities." This should be thought of as the net benefit of amenities.

each individual building will be set to 1 if the distance to water is under 1,300 meters, and 0 otherwise. This is done to capture the fact that water only acts as an amenity if it is accessible. Since it takes approximately fifteen minutes to walk this distance, we argue that proximity to water is accessible within 1,300 meters. To find the average value, the individual buildings are aggregated into SAMS-areas, whereby each area receives a number between 0 and 1, which is then used in the regression. Regarding historical amenities, we follow Lee and Lin (2017) and use the share of buildings built before 1940 as a proxy.

To capture the effect of disamenities, we follow Helms (2003) in considering high proximity to highways as a disamenity. In his model, a dummy variable is included, in which buildings located within one tenth of a mile of a highway are regarded as being a disamenity. Similarly, in our study, the outcome for each individual building will be set to 1 if the distance to a highway is under 300 meters, and 0 otherwise. The aggregation method is the same as for natural amenities. The distance of 300 meters represents a distance of approximately four minutes of walking. We argue that this is short enough for a dwelling to be affected by the potential negative externality caused by the highway in terms of air quality, noise and unaesthetic environment. The negative effect of living close to a highway should however not be overestimated, as it can contribute with transport communications. Thus, we argue that a cutoff-point at 300 meters is reasonable. While further disamenities could be included, for example proximities to industries, we argue that they tend to be correlated with each other.

Furthermore, we measure *access to public transit* as the distance from each individual building to the nearest subway station. A dummy variable is created with a cutoff-point at 800 meters. If a building is located within 800 meters of a subway station, it receives the value 1, and 0 otherwise. The aggregation method is the same as for natural amenities and disamenities. The distance of 800 meters represents approximately ten minutes of walking. The reason for not including a linear effect is that for a person not living within walking distance of a subway station the difference between 1000 and 2000 meters is not as important, since he or she will most likely have to take the bus anyway.

Dynamic explanatory variables

To examine the impact of *dwelling ages* on gentrification, we follow Helms (2003) and measure the median dwelling age in each SAMS-area.

The method used to measure *spillover effects* is the distance from the centroid of every SAMS-area to the centroid of the closest high-income neighborhood. A high-income neighborhood is defined as a SAMS-area within the municipality of Stockholm or a municipality adjacent to the municipality of Stockholm, which is in the top quartile with respect to average income in the year of 2000. This is the method that Guerrieri, et al. (2013) use in their model.

6.3 Model specifications

We begin our analysis by investigating the static factors' explanatory power in the monocentric model, in terms of understanding the distribution of income as of year 2000. Brueckner and Rosenthal (2009, p.726) use local amenities and public transit – "factors that previously have been emphasized in the literature as affecting location patterns" – as controls in their monocentric gentrification model. However, while control variables can usually be taken for granted, the monocentric model has mostly been applied in a US context. We will thus examine if amenities and public transit are reasonable to use as control variables in the dynamic models, in the context of Stockholm. In other words, if we find that any of the static explanatory variables are not significant in explaining income patterns, it would be inappropriate to include them as controls in our dynamic model.

Subsequently, we proceed to incorporate dynamic factors in order to explain income changes, and thus also gentrification, over the following 10 years. These models will potentially include relevant controls, if they are found to be significant in the static scenario. As the dynamic models are based on theories explaining the occurrence of gentrification, and not merely income distribution, they provide answers to our research question. To answer this question, we develop two models of special interest that examine the effect dwelling ages and neighborhood spillover effects have on gentrification, respectively.

In all models presented below, the denotation i in the models represents the data on the SAMS-areas in our study. Furthermore, in the monocentric model, the baseline variable studied is distance to CBD. Hence, it is also of interest to examine how the other variables affect distance to CBD.

Static models

Model 1 is the baseline model, which only includes distance to CBD as an explanatory variable. Based on the characteristics of Stockholm presented in Section 3.3, the high housing prices in the central city gives indications of high-income households habituating here. We therefore expect that model 1 will confirm this observation, and thus have a negative coefficient on distance to CBD. If we do not find significance for this variable, the applicability of the monocentric model in Stockholm will have to be questioned. As such, the independent variables in subsequent models will have to be interpreted with higher caution in relation to the assumptions of the monocentric model.

Model 1: $$Income_i = \beta_0 + \beta_1 Distance\ to\ CBD_i + \varepsilon_i$$

Model 2 proceeds to add amenities into the analysis. Based on the theoretical framework, we assume that high-income households prefer to live close to amenities and far from disamenities. Hence, we also assume that amenities are more present in the city center. This is further supported by the fact that the inner city has few large roads (low disamenities), a large share of old, historical buildings (high historical amenities), and high access to water (high natural amenities). Based on this, we expect the coefficients of natural and historical amenities to be positive as they attract high-income households, and the coefficient of disamenities to be negative as they repel high-income households. Furthermore, one would expect that the inclusion of amenities in the model will have an upward effect on the coefficient of distance to CBD. In other words, controlling for the attractiveness of amenities would mean that high-income households prefer to live further away from the CBD than otherwise.

Model 2:

$$Income_i = \beta_0 + \beta_1 Distance\ to\ CBD_i + \beta_2 Historical\ amenities_i + \\ + \beta_3 Disamenities_i + \beta_4 Natural\ amenities_i + \varepsilon_i$$

Model 3 includes distance to CBD and access to public transit. Given the assumption from the theoretical framework that high-income households have access to cars, and that low-income residents must use public transit, we expect income levels to be higher further away from subway stations, since the low-income residents "outbid" the high-income residents in terms of housing close to the subway. We therefore expect the coefficient on the variable to be negative. Since access to public transit is likely to be lower when distance to CBD is high, we also expect that controlling for access to public transit in the model will have a downward effect on the coefficient of distance to CBD. The intuition is that access to public transit in fact acts as a disamenity for the high-income households, given that they use cars. Therefore, without public transit, the polarization in income levels between the inner city and the suburbs would be even larger.

Model 3:

$$Income_i = \beta_0 + \beta_1 Distance\ to\ CBD_i + \beta_2 Access\ to\ public\ transit_i + \varepsilon_i$$

Dynamic models

Following the structure of model 1, model 4 includes only distance to CBD as an explanatory variable, while the dependent variable is now *change* in income.

Model 4:

$$Income\ Change_i = \beta_0 + \beta_1 Distance\ to\ CBD_i + \varepsilon_i$$

Model 5 is included if we find variables from model 2 and model 3 to be significant. In this case, distance to CBD is included along with a vector, $\boldsymbol{X}_i$, of controls based on the variables from the static models.

Model 5:

$$Income\ Change_i = \beta_0 + \beta_1 Distance\ to\ CBD_i + \delta_1 \boldsymbol{X}_i + \varepsilon_i$$

Model 6 includes the first of our two dynamic approaches, the distribution of dwelling age, along with potential controls from model 5. We expect the coefficient of the age variable to be positive, since renovation, and thus gentrification, should be more likely when the median age of buildings in year 2000 is high. Since we know from Section 3 that the city has been built outwards over time, the trend should be that dwelling age decreases with distance to CBD. Thus, we expect that controls for the dwelling age should have an upward effect on the coefficient of distance to CBD.

Model 6:

$$Income\ Change_i = \beta_0 + \beta_1 Distance\ to\ CBD_i + \\ + \beta_2 Dwelling\ age_i + \delta_1 \boldsymbol{X}_i + \varepsilon_i$$

Hypothesis 1: Gentrification occurs in SAMS-areas which have a high median dwelling age relative to other SAMS-areas.

Model 7 adds the second of our two dynamic approaches, the neighborhood spillover effect, along with potential controls from model 5. We assume that high-income households prefer to live close to other high-income households. Therefore, we expect the coefficient of the spillover variable to be negative. Furthermore, this implies that controls for the high-income neighborhoods should have an upward effect on the coefficient of distance to CBD. The intuition is that, assuming income levels are higher in the city center, any area in the city center is more likely to be close to a high-income area. Controlling for this effect, we thus have less "pull" inwards for high-income residents, and incomes should increase more further away from CBD than is otherwise the case.

Model 7:

$$Income\ Change_i = \beta_0 + \beta_1 Distance\ to\ CBD_i + \\ + \beta_2 Distance\ to\ high\text{-}income\ area_i + \delta_1 \boldsymbol{X}_i + \varepsilon_i$$

Hypothesis 2: Gentrification occurs in SAMS-areas located close to high-income SAMS-areas.

While our two main models – including the effect of dwelling ages and spillover effects respectively – are not fully comprehensive representations of the neoclassical gentrification literature, Rosenthal and Ross (2015) postulate that these two are the most relevant modifications for explaining gentrification. Thus, we argue that if neither of the theories have explanatory power, the monocentric model in its current specifications is most likely unable to explain gentrification in Stockholm. If we find significance in one of the models, we conclude that the monocentric model is applicable in Stockholm. If the results are significant but in the opposite direction to that predicted, we conclude that the monocentric model is applicable, but that the effect must be studied closer in further research.

6.4 Addressing issues with the models

In this section, we address potential issues of our approach, starting with how we define our variables of interest, and continuing with potential problems in our models.

Definitions of variables

As elaborated in the literature review, definitions of *gentrification* vary across studies. Consequently, researchers use different methods to measure gentrification. We have found that majority of researchers find common ground in using the increase of neighborhood income to determine whether gentrification has occurred. Hammel and Wyly (1996) compile a set of nine dependent variables based on previous studies to measure gentrification, and conclude that change in income has the highest explanatory power for identifying gentrified neighborhoods. What previous research has not agreed upon to the same extent is how to exactly operationalize income when measuring gentrification empirically. Some use the percentage change in neighborhood income (Kolko 2007; Glaeser, et al. 2008), while others use cutoff-points with dummy variables to determine which areas are gentrified (Hedin, et al., 2012). The latter approach means some variation in the sample is lost, which underlies our decision to use the former approach.

When measuring *natural amenities*, it would be reasonable to include other measurements than proximity to water, such as parks and forests. However, we were not able to acquire such data. Moreover, while data on proximity to water as of today can be used since this has not changed since year 2000, parks can be endogenous and therefore we would have needed data on parks from year 2000 in order to make reliable analyses. Due to several reasons our analysis only includes *exogenous amenities*. Firstly, Brueckner, Thisse, and Zenou (1999) find in their study that exogenous amenities influence the spatial distribution of income, irrespectively of whether endogenous amenities are considered in the model. Secondly, modern amenities are difficult to measure since they are endogenous, and are thus commonly proxied by neighborhood income, something we partly capture anyway in our neighborhood spillover variable.

Previous studies measuring *public transit* effects have, for instance, used self-reported commuting time to work (Kolko, 2007), and cutoff-points of the top ten percent of neighborhoods with households relying on public transit to work (Brueckner and Rosenthal, 2009). However, these methods can be problematic. Using commuting time will likely result in collinearity issues with the distance to CBD variable, and the share of households within an area may be a poor proxy for actual access. This motivates our decision to use average distance to the closest subway station.

As elaborated in the Section 5.3, the impact of *dwelling age* is the main contribution by Brueckner and Rosenthal (2009). In their study a deeply lagged measure of dwelling age is used, which is divided into several intervals (0–5 years, 5–9 years etc.). The percentage share of each interval in a tract is then used in their regression model. Helms (2003) uses another method in which median dwelling age in each neighborhood is calculated, to reflect the same mechanism. We choose to use the second method, since it is less likely to lead to collinearity issues with our proxy for historical amenities.

Another research paper measuring *spillover effects* in gentrification is Kolko (2007). Here, spillover effects are measured through weighing the average income of adjacent neighborhoods. While this might seem as a more elaborate method, it contains certain biases which are less severe in the method used by Guerrieri, et al. (2013). An endogeneity problem arises along with issues of distinguishing whether the adjacent neighborhoods are affecting the area in question or vice versa. Furthermore, in Kolko's (2007) method the Modifiable Area Unit Problem (MAUP) is more distinct. The MAUP is a bias which arises when areas are modified into district boundaries. This is however an issue concerning our entire approach, and will therefore be described in greater detail in the following section.

The Modifiable Areal Unit Problem (MAUP)

A statistical bias known as the Modifiable Areal Unit Problem (MAUP) arises when pointed-based data is aggregated into spatial areas. The bias is rendered as the data values are summarized into chosen district boundaries. Thus, the aggregated values will differ depending on how boundaries are drawn. Naturally, these boundaries can be more or less arbitrarily depicted. The implications are that more homogenous areas creates less bias when studying neighborhood effects. The MAUP was first described by Openshaw (1984), in which the phenomenon is explained to consist of a scale problem – the size of the units, and an aggregation or zoning problem – how the units are shaped.

As the purpose of this study is to analyze gentrification, which in itself is a neighborhood phenomenon, the MAUP will be inevitable. Nevertheless, what is evident in the case of Stockholm, is that the SAMS-boundaries are not entirely arbitrarily drawn. The SAMS-boundaries are defined by Statistics Sweden (SCB) as "a nationwide division into homogeneous residential/business areas" (SCB, 2012, p.69, our translation). These areas are utilized for statistics and as geographic building blocks for social planners – such as division of healthcare areas, police districts, and municipal planning areas – among other things (Stockholms Läns Landsting, 2011). The validity of the usage of SAMS is further reinforced by Section 3, in which it is described how Stockholm is built as growing rings on a tree, as areas are suggestively developed based on different strategies, functions, and objectives. However, a study by Amcoff (2012) questions both the homogeneity of SAMS and whether homogenous geographic units are relevant for understanding neighborhood effects.

While the issues of MAUP and SAMS-areas are noted, it is outside of the scope of this study to either create or receive access to additional districts. Therefore, in this study, it is of relevance to use the SAMS-classifications, as they are both designed and utilized for research purposes (Amcoff, 2012).

Multicollinearity

Multicollinearity occurs when two or several independent variables correlate with each other. While this does not cause a bias in the coefficients, it can cause standard errors to be substantially larger than otherwise. This means that one runs the risk of committing a type I error, i.e. failing to detect a relationship that is present, due to large confidence intervals. We suspect that this could be the case in our models since many of the explanatory variables are likely to be correlated with distance to CBD. Furthermore, building age acts as the base for both our measure of historical amenities and dwelling ages, which means that these might be heavily correlated. We account for this potential problem by performing a robustness check on the models including both these variables, where we test what happens if one of the two variables is excluded (Appendix C, Table 5).

Endogeneity

A common concern in much research on income patterns is that the causal effects might go in the opposite direction to what is theorized. For example, a high-income neighborhood with a high amount of shops might not have those income levels because of the presence of those shops, it could just as easily be that those shops are there just because the neighborhood has a high-income level.

In our static models, we tackle this problem by only including exogenous amenities that do not depend on neighborhood income levels. Furthermore, since the subway network has not been changed since 1994, and that change only affected a small part of the city, the access to public transit is also relatively non-dependent on income levels.

In our dynamic models, we use *change* in income as our dependent variable, and this means that the endogeneity problem is even smaller, since all independent variables are as of year 2000. It is unlikely that these independent variables depend on future income changes.

7. Data

This section explains how relevant data for operationalizing our variables was gathered. As mentioned before, the units of study are SAMS-areas. The boundaries of these areas were gathered from the GET database and is in the form of geographical information system (GIS) data (Lantmäteriet, 2017). This information is then used to combine data from several sources, which is geocoded in order to perform analysis in a GIS program (see Appendix A for further details on the methods used). To ensure that the SAMS-boundaries are consistent with those used by other sources, they were manually verified to a map over Stockholms Stad (Stockholms Läns Landsting, 2017). Accordingly, some areas had to be joined together.[2] This results in a

[2] *Flaten* (21503) and *Orhem* (51506) have been merged together with *Skrubba* (21509). *Lunda* (22404) has been merged together with *Solhem* (22406).

total number of 128 areas. The boundaries have been consistent during the entire period of our study.

Data on income was ordered directly from the Stockholm statistics department (Bodén, 2017). The income is from employment only, and includes people with no income. We have further chosen to exclude incomes from the ages 16–19 and 65–, since many of these have no income from employment and so may distort measures of average income. The data on average income was aggregated on a SAMS-level prior to delivery. Descriptive data for the income variables can be found in table format and map format in Appendix B (Table 3, and Figure 5 and Figure 6, respectively).

Data on distance to the CBD from the centroid of each SAMS-area is measured using GIS software. Data on dwelling ages is from a parcel-level census from year 2000 on all buildings in Stockholm, performed by Exploateringskontoret in Stockholm. The dataset was gathered from the Stockholm city archives, and contains information on 58,185 buildings (Exploateringskontoret, 2000). The names of the buildings are cross-referenced with a GIS-file with building locations from the GET database (Fastighetskartan), to geocode the data (Lantmäteriet, 2017). In this process, 1,660 observations are lost. This is natural, since the data from Fastighetskartan is from 2017. Thus, we assume that the observations that are not in both datasets have been built after year 2000, and that their omission therefore is correct. A visualization of the distribution of dwelling ages is provided in Appendix B (Figure 8).

Data on historical amenities would ideally be a dataset with all the historical buildings and monuments in the city. We initially intended to use such a register, provided by the Swedish National Heritage board, but when validating the data, we observed discrepancies between their GIS-files and the data provided on their website. Therefore, we use the second-best option as proxy for historical amenities: the share of buildings built before year 1940 (Exploateringskontoret, 2000). This is the method used by Lee and Lin (2017).

Data on water and highways is obtained from the GET database (Lantmäteriet, 2017). The distance from each building to the nearest respective feature is measured using GIS software. Since the coastlines in Stockholm have not been changed since year 2000, data from the GET database from 2017 is used to reflect the distribution of coastlines in 2000. Data on highways is also compiled from the GET database from 2017. This data is manually edited to remove highways built after year 2000[3]. The definition of what constitutes a highway in our study is broader than the technical definition. In addition to regular highways, we also include all roads that have a traffic barrier, which means that the two directions of driving are separated. These can be just as noisy as highways, and often contain heavy traffic. Since we use roads to measure disamenities, highways passing through tunnels are not included.

[3] The parts of *Norra Länken* built after year 2000 were removed.

Since the subway system in Stockholm was last expanded in 1994, data from locations of stations from 2017 is used to reflect the locations of year 2000. The locations of the stations have manually been coded into GIS software.

To measure spillover effects, the median income levels of all surrounding municipalities were gathered from SCB in order to make sure that the spillover effects for the SAMS-areas on the periphery are more properly estimated (SCB, 2017). The distance to the nearest upper quartile income area as of year 2000 was then measured using GIS software. While data on income levels in the municipalities were not available in average income, we argue that it is more appropriate to account for the median income in these areas, than to exclude spillover effects from adjacent municipalities. Furthermore, as these income levels also include the ages 65–, this age category is also included in the average income levels in SAMS-areas when measuring the spillover variable.

Descriptive data for all independent variables can be found in Appendix B (Table 4).

8. Results

This section will begin with presenting the results from the static models, analyzing the *income pattern* year 2000. Subsequently, the dynamic models are presented, analyzing the *income change* between year 2000 and year 2010.

8.1 Static models

Table 1: Regression of static variables on the income level year 2000

	(1)	(2a)	(2b)	(3)
VARIABLES	Income	Income	Income	Income
Distance to CBD (m)	-3.838***	5.144**	4.340**	-6.498***
	(1.377)	(1.975)	(1.834)	(1.429)
Historical amenities		124,888***	128,338***	
		(18,469)	(19,733)	
Disamenities		-61,173***	-59,929***	
		(15,148)	(14,991)	
Natural amenities		18,632		
		(11,270)		
Public transit				-67,394***
				(16,282)
Constant	266,084***	162,092***	176,760***	327,169***
	(8,595)	(21,055)	(18,111)	(18,929)
Observations	128	128	128	128
R-squared	0.040	0.456	0.445	0.199

Robust standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

Table 1 shows the static models with income year 2000 as the dependent variable. In column 1 the first model which only includes distance to CBD as independent variable is presented. Column 2a keeps distance to CBD and proceeds to add amenities. As the variable measuring natural amenities was shown to be insignificant in the model in column 2a, this variable is removed in column 2b. Finally, column 3 includes distance to CBD and public transit.

The interpretation of model 1 is that income decreases with SEK 3.838 as the distance to CBD increases with one meter, assuming there is no omitted variable bias. As predicted, high-income households tend to locate near the CBD, even though this relationship is rather weak. Interpreting the model in terms of our theoretical framework, the bid-rent curve of high-income households has a higher slope than that of low-income households, meaning that at locations close to the CBD, they outbid the low-income households. The coefficient on this variable is highly significant ($p<0.01$), but the value of R-squared is low, indicating that there are other factors which can contribute to explain the city's income pattern.

Accordingly, adding amenities in model 2a greatly increases the R-squared. As predicted, the inclusion of amenities has an upward effect on the coefficient of distance to CBD. Furthermore, the sign of the distance to CBD variable is changed, meaning that when the level of amenities is controlled away, income instead rises with an increasing distance to CBD. The intuition is that if the same levels of amenities would exist over the entire city, high-income households would instead locate in the suburbs. The signs of the coefficients of the explanatory variables are as predicted, but the coefficient for natural amenities is insignificant. The interpretation is that if a neighborhood only contains houses built before 1940, they have SEK 124,888 higher income levels per year and household than if the share was 0, for a given distance to CBD. Similarly, if all households in a neighborhood lie within 300 meters of a highway, they have SEK 61,173 lower income level than if the share was 0, for a given distance to CBD.

As noted above, the coefficient on natural amenities is statistically insignificant. A possible reason for this is its collinearity with distance to CBD (corr = -0.45), which is supported by the fact that the standard error on distance to CBD decreases when natural amenities are excluded in model 2b. Dropping the variable does not cause a major decrease in R-squared or any drastic changes in the coefficients on the other variables. We hence conclude that natural amenities merely add a slight unique explanatory power regarding income patterns.

Lastly, model 3 shows that, holding distance to CBD constant, a neighborhood that has high access to public transit will have lower income levels. In other words, for a given distance to CBD, a neighborhood where all households lie within 800 meters of a subway stations will have SEK 67,394 lower average income than a neighborhood where zero households lie within 800 meters of a subway station. The intuition is that, if public transit access were equal at all distances from CBD, the polarization between high-income households living close to CBD and low income households living in the suburbs would be even stronger.

We conclude that all static variables, except natural amenities, are relevant in explaining location patterns based on income, and thus should be added as controls in the dynamic model in the following section.

8.2 Dynamic models

Table 2: Regression of dynamic variables on income change year 2000-2010[4]

VARIABLES	(4) Income Change	(5) Income Change	(6) Income Change	(7) Income Change
Distance to CBD (km)	-0.0155***	-0.0149***	-0.0131***	-0.0144***
	(0.0033)	(0.0037)	(0.0033)	(0.0038)
Dwelling age			0.0011	
			(0.0010)	
Distance to high-income area (km)				-0.0116*
				(0.0067)
Constant	1.089***	1.103***	1.048***	1.117***
	(0.0283)	(0.0393)	(0.0504)	(0.0386)
Controls	No	Yes	Yes	Yes
Observations	128	128	128	128
R-squared	0.207	0.239	0.248	0.248

Note: Controls include historical amenities, disamenities and public transit.
Robust standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1.

Table 2 shows the dynamic gentrification models which have income change between the years 2000 and 2010 as dependent variable. Column 4 only includes distance to CBD as an independent variable, and column 5 includes controls for historical amenities, disamenities and access to public transit. Column 6 keeps distance to CBD and controls, and adds dwelling age. Lastly, column 7 includes distance to CBD, controls and the spillover variable, measured as distance to the closest high-income area.

Model 4 shows that income change decreases with 1.55 percentage points as the distance to CBD increases with one kilometer. This means that increases in income were higher closer to the CBD. After adding the controls decided upon in Section 8.1 to the regression, model 5 shows an increase in the R-squared. However, the increase in the R-squared variable is not as strong as in the static models, meaning that the controls are better at predicting income patterns than income change. Still, including controls has an upward effect on the distance to CBD, meaning that they “push” the increase in income away from the CBD. The intuition is

[4] In the dynamic model, distances are measured in kilometers for interpretive reasons, since the values of the coefficients measured in meters become very small.

similar to the one in the static models; if we control away the presence of amenities and public transit access, increases in income become smaller in the CBD and larger in the suburbs.

In model 6, the first dynamic variable, dwelling age, is added to the regression. The inclusion of median dwelling ages has an upward effect on the coefficient of distance to CBD. Now, income change decreases with 1.31 percentage points as distance to CBD increases by one kilometer. The intuition is that since dwelling age decreases as distance to CBD increases (corr = -0.71), holding age fixed further flattens out the relationship between distance to CBD and income changes. However, the coefficient of dwelling age is insignificant and can therefore not be interpreted.

In the last model presented, model 7, the second dynamic variable is included. The coefficient of distance to the closest high-income area is significant at ten percent ($p<0.1$). The interpretation of the coefficient is that when controlling for distance to CBD, the income change decreases with 1.16 percentage points as the distance to closest high-income area increases with one kilometer. This variable has an upward effect on the coefficient of the distance to CBD variable, meaning that the relationship between income change and distance to CBD is flattened in the presence of positive spillover effects across neighborhoods.

9. Discussion

9.1 Analyzing the results

In this section, we will start by analyzing the results with respect to previous literature, the context of our research area, and the theoretical framework. While the assumptions in the latter are often strict and binary, we argue that the patterns and effects that the theoretical framework provides are relevant to study in a context with continuous variables. Where it is relevant, we include a discussion regarding the appropriateness of the assumptions made.

The static models

In the first stage of our analysis, in Table 1, we find that most of the explanatory variables identified in previous literature have a significant effect on static income patterns in Stockholm. However, the variable measuring proximity to water as a proxy for natural amenities was not significant, as seen in model 2a. This does not necessarily mean that location patterns are entirely unaffected by the presence of water, but rather it implies that it does not have that much unique explanatory power in the context of Stockholm, given the other variables in the model. In other words, income patterns could better be explained by distribution of historical amenities and disamenities. Furthermore, while water is highly present in the inner city – in which we have found that high-income households tend to habituate – the whole city is located in an inland lake. This could be an explanation to why proximity to water is not found to be a determinant of income distribution. Another explanation could be that industrial harbors (i.e. disamenities), which we were not able to control for, are also located by the water.

Furthermore, while it would be relevant to include other natural amenities such as parks, forests, and elevations, we were unfortunately unable to receive access to such data. However, as natural amenities are present in a majority of areas in the city, not the least in the suburbs, they might not have a large effect on explaining income patterns. In the municipality of Stockholm, 90 percent of the inhabitants live within 300 meters to parks or other nature (Stockholms Stad, 2017d).

While the amenities were – based on previous theory and simply by observing the city – in many ways expected to affect income distribution patterns, the effect of public transit was less predictable in the context of Stockholm. The theories we use to study the effect of public transit on income patterns are based on research made on US cities (Glaeser, Khan, and Rappaport 2008; LeRoy and Sonstelie, 1983). What is puzzling is that many high-income areas in Stockholm also have high access to public transit, not the least in the central city in which a large fraction of high-income households are found. Based on this, we would have expected to see a positive coefficient on public transit in model 3. The reason for this result probably lies in the fact that, especially in the western suburbs, there is a strong negative correlation between access to public transit and income levels. Appendix B, Figure 7 demonstrates this fact. Furthermore, many low-income households are located in suburbs in connection to subway stations. As we learned from Section 3.1, low-cost, large-scale and efficient housing was built in for instance Hjulsta, Husby, and Rinkeby – low-income areas as of today. Thus, these relationships can outweigh the positive association between transit access and income on low levels of distance to CBD. This is related to the fact that we made the assumption that all high-income households use cars and low-income households use public transit. While this might not be realistic, the overall effect should still be the same, even if this assumption strictly does not hold in real life.

The results from the static models show that the monocentric land-use model is applicable in explaining static income patterns in the context of Stockholm. However, the underlying assumptions in the monocentric model could be criticized. While it is shown that work is highly located close to the CBD, this is of course not the case for all households. Suburbs such as Kista and Solna are as of today attracting many businesses in Stockholm. Although distance to CBD is conventionally used as a proxy when utilizing the monocentric model for explaining household distribution patterns or gentrification, it is a drastic simplification. For instance, in Stockholm, the topography hinders commuters to travel as the crow flies. In the optimal case, we would use the actual distance by road, rail or boat from each SAMS-area to the CBD.

The dynamic models

When proceeding to analyzing the results of the dynamic models, we start with model 5, which showed that increases in income were larger close to the CBD. This is supported by the fact that income disparities between the areas in the study have increased between 2000 and 2010, which means that the central areas have grown relatively richer in terms of income (see Appendix B, Table 3, column 4 and column 5). This would correspond to what Hedin, et al. (2012) define as super gentrification.

The only dynamic factor in our study that has a significant impact on income changes is the neighborhood spillover effects in model 7. The sign of the coefficient is in line with our hypothesis and can be interpreted as for a given distance to CBD, level of amenities, and level of public transit access, income increases will be larger closer to high-income neighborhoods. This is reflected in the pattern of high-income areas, in which – especially in the western suburbs – high-income areas are connected to each other like a string (see Appendix B, Figure 7). This result is important, since it not only explains why gentrification occurs, but also *where* it occurs. The result can further explain why gentrification has yet to come to the far-out subway suburbs, but has occurred in the suburbs just south of the city center. It predicts a pattern in which, given the initial setting of a center with high-income households, gentrification moves like the ripples on water further and further out. The theory incorporates a demand shock as a trigger of the gentrification process; a clear indication of this is found in Stockholm during the period of our study. For instance, inner-city house prices per square meter increased by 46% between 2005 and 2010 (Andersson, 2015). Moreover, our findings further support the occurrence of super gentrification in Stockholm, as it is shown that there is a strong relationship between high-income areas and gentrification.

In model 6, the coefficient on the dwelling age variable is insignificant, which means we cannot exclude the fact that dwelling age has no effect on income, controlling for distance to CBD, amenities and public transit. However, the use of the share of buildings built before 1940 as a proxy for historical amenities constitutes a possible problem because of its strong collinearity with the median dwelling age (corr = 0.82). In Appendix C, we remove the control for historical amenities and find that the coefficient of dwelling age is still insignificant. We therefore conclude that dwelling age most likely has no significant causal effect on gentrification in Stockholm.

Furthermore, model 6 shows that the dwelling age has an upward effect on the coefficient of the distance to CBD variable, as hypothesized. In Stockholm, older dwellings are located in the inner city, as we learned from Section 3. We further hypothesized that gentrification would occur in older dwellings due to the need for renovation. This means, that when controlling for dwelling ages across the city, the "pull" inwards of income increases – caused by old dwellings located in the inner city – is reduced. Hence, given the same dwelling age across the city, increases in income would occur further away from the CBD. However, this effect is rather miniscule; for every increase in distance to CBD by one kilometer, the income increase would be 0.18 percentage points higher than if dwelling age were not controlled for.

Moreover, the basic assumption of the filtering model that older dwellings become deteriorated – and thus in need of renovation – can be questioned in the context of Stockholm. Observing the buildings in Stockholm's inner city, one will rarely see any "deteriorated buildings." This is possibly a result of the housing sanitation program, in which buildings in the whole central city underwent extensive renovations and upgrades, described in Section 3.1. As such, the idea based on the welfare society, in which all households should meet certain standards, may have caused a void of low-priced households within the inner city, segregating the central neighborhoods from suburbs. Furthermore, dwellings renovated and rebuilt in the inner city during the 1950s to 1970s have probably stayed in an attractive condition because the high-income households have remained close to the CBD. We suggest that this is due to the strong attraction of amenities in central Stockholm. As Lee and Lin (2017) show, exogenous amenities can anchor high-income neighborhoods to high-income levels over time. This can cause homeowners to constantly perform minor renovations on their dwellings. Thus, our choice to use the share of buildings built before 1940 as a proxy for historical amenities might actually be perfectly suitable to capture the fact that old buildings are not considered as a negative by the high-income households in Stockholm; it actually acts as an amenity in itself. Hence, this could be an explanation for why the median dwelling age in a SAMS-area is insignificant in explaining where gentrification occurs.

Lastly, when examining the effect of dwelling characteristics on gentrification, a connection between the filtering model and the rent gap can be made. Although the rent gap merely reflects the difference between actual ground rent and potential ground rent, as mentioned in the literature review, it is often assumed that areas or buildings are left for decay to capture a maximum rent gap. Thus, in the context of modern Stockholm, both the filtering model, in the neoclassical framework, and the rent gap theory, in the marxist framework, can be questioned. When reviewing production theories, previous gentrification research in Stockholm may provide better explanations. For instance, Millard-Ball (2000) finds that luxury renovations spurs gentrification, and Lind (2015) highlights the current rent regulation which requires quality improvements to be made in apartments if landlords want to increase rents. In line with our analysis above, this means that small steps in terms of upgraded housing quality may instead be the cause of gentrification in Stockholm, rather than major renovations.

9.2 Policy implications

Throughout the modern history of Stockholm we have seen attempts to disperse the city, for instance in forms of subway suburbs and ABC-towns. However, Stockholm is still highly centralized around the CBD, and inner-city housing prices are constantly increasing. The insights we have gained can provide explanations for failed attempts to decentralize the city. Although the basic monocentric model predicts that households prefer to live near work since they want to reduce their commuting costs, merely focusing on creating business hubs outside of the CBD is not always effective. This has partly been the case in Kista, to which many tech businesses have been attracted, yet still has problems with attracting households. For instance, in 2006 only five percent of those who had their workplace in Kista also lived there (Bienkowska and Hedberg, 2006). As of year 2011, Kista-Rinkeby was the neighborhood in Stockholm with highest unemployment rate at 7.4 percent (DN, 2011). Attempts of heterogenizing household income levels have furthermore been made (Bienkowska and Hedberg, 2006). Our study has shown that amenities and public transit affect income distribution. As such, this can be taken into account when developing the city further. For instance, if city planners seek to minimize gentrification, or super gentrification more specifically, increased access to public transit might disperse the homogeneity of high-income neighborhoods. However, the study also shows that historical amenities have a significant effect on where high-income households live. Therefore, it is important to notice that the historical inner-city area has a strong advantage over other locations in Stockholm.

The causes of gentrification in Stockholm that this study has identified can be difficult to prevent, if this is city planners' objective. Positive externalities from high-income neighborhoods cannot merely be eliminated. While this may not give any clear answers to an explicit strategy, this study may contribute to the identification of potential issues with existing strategies. The general strategy for Stockholm municipality published in 1999 sought to further densify the inner city (Stockholms Stad, 2014). However, the latest comprehensive strategy established by Stockholms Stad has the objective to connect the city's different neighborhoods, through more greener spaces, among other things (Stockholms Stad, 2010). This new strategy highlights the issues of segregation, which is believed to be increased by centralizing the inner city (Stockholms Stad, 2010). However, given the results of our study, this strategy can also cause gentrification, which in many ways is closely connected to segregation. When the high-income inner city areas are linked with the inner suburbs it is likely that this will cause a spillover effect, and that gentrification will occur in these suburbs. This may further marginalize the lower-income suburbs, pushing low-income households further out to the periphery of the city. While the occurrence of gentrification has, and will be, a complicated mechanism in urban areas, it is important to recognize the causes of it in order to provide implications for future city development, and find strategies to reduce the negative consequences of gentrification.

10. Conclusion

The aim of this paper has been to investigate the potential of underlying determinants causing gentrification to occur in a neighborhood in Stockholm. Defining gentrification as the increase in average income of an area, we investigate underlying causal factors for the income changes of 128 SAMS-areas. We use the, in Stockholm, previously untested monocentric model of land-use and its different modifications to examine explanations of gentrification identified in previous theoretical and empirical work. Using a manually compiled dataset from several different sources, we first examine the model's capability of explaining static income patterns of Stockholm in year 2000. The results show that income distribution in Stockholm can be explained by the presence of amenities, which attracts high-income households, and by public transit, which attracts low-income households. However, the presence of natural amenities has no significant effect in explaining income distribution.

Based on these results, we then test two dynamic approaches to explain income changes over time, between 2000 and 2010. First, based on the assumption that neighborhoods filter down in status as they age, and thus become subject for renovation, we test whether the distribution of dwelling ages can explain the occurrence of gentrification. We find no significant evidence that this is the case. A possible explanation for this is that houses in central Stockholm never deteriorate, because the high level of amenities anchor high-income households to these neighborhoods over time. Thus, our first main result is that the distribution of dwelling age seems to be no causal factor in explaining gentrification in Stockholm. However, this phenomenon is a topic for future research, as it would be of interest to investigate how the presence of amenities in central cities affects the level of renovation and deterioration. This could be examined by looking at building permit micro data.

The second dynamic approach that we test is neighborhood spillover effects. The theory considers proximity to high-income households as a positive externality. As such, a positive demand shock for housing should cause high-income households to move into adjacent low-income neighborhoods. Hence, gentrification is more likely to occur close to high-income neighborhoods. We find evidence for this effect, and can thus conclude that gentrification of neighborhoods in Stockholm depends on their proximity to high-income neighborhoods. These results are in line with previous findings by e.g. Guerrieri, et al.

To conclude, we find that the monocentric model of land-use can be used to explain both static and dynamic income distribution effects in Stockholm. More specifically, to answer our research question, the monocentric land-use model can be used to a high extent as it can explain gentrification in terms of neighborhood spillover effects. Our results have three contributions. Firstly, our major contribution is to the understanding of gentrification in Stockholm, providing policy implications, as discussed in Section 9.2. Secondly, we contribute to the general literature on gentrification in showing that spillover effects are important determinants of not only why, but where gentrification occurs. Thirdly, we contribute to the field of urban economics, by having performed analysis with the monocentric model in a context outside the United States.

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Appendix

Appendix A: GIS analytic methods

The software used for producing the geographically based variables is ArcGIS Pro.

Distance to CBD is measured by first defining the centroid of each SAMS-area, and then using the "generate near table", where the point data of CBD is in another layer is the feature to be found. Then, this table is joined to the original table by using the command "add join", by using the FID field as a common reference. Spillover effects are measured in a similar manner, but where the near feature instead is a high-income area.

Distance to water, subways and roads is measured using the same commands. However, this is measured from the individual buildings from the GET database.

Appendix B: Descriptive statistics

Figure 4: SAMS-areas included in the study, CBD marked by circle

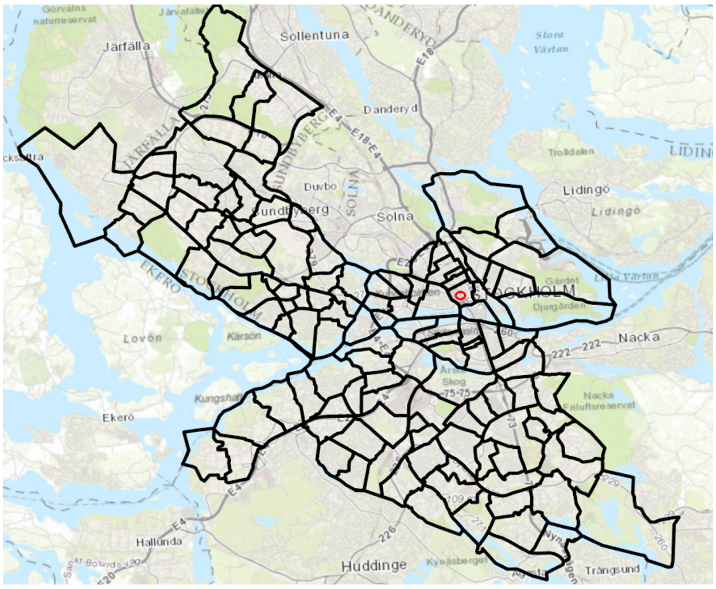


Table 3: Descriptive statistics of dependent variables

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
Income (2000)	128	242,151	65,935	103,116	461,518
Income (2010)	128	323,510	101,882	110,982	608,993
Income Change (2000-2010)	128	0.993	0.118	0.754	1.896

Table 4: Descriptive statistics of independent variables

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
Distance to CBD	128	6,235	3,455	182.2	15,509
Historical amenities	128	0.419	0.363	0	1
Access to public transit	128	0.660	0.412	0	1
Spillover effect	128	1,357	1,221	0	5,177
Disamenities	128	0.257	0.278	0	0.958
Natural amenities	128	0.613	0.422	0	1
Dwelling age	128	56.58	20.29	9	110

Figure 5: Income pattern year 2000, darker means higher income (method used to create classes is Jenks natural breaks optimization)

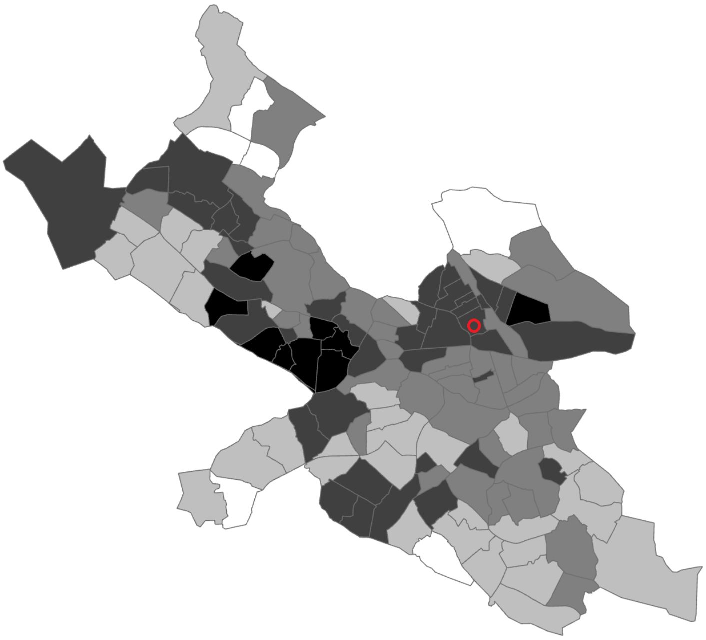


Figure 6: Income change 2000-2010, darker means higher increase (method used to create classes is Jenks natural breaks optimization)

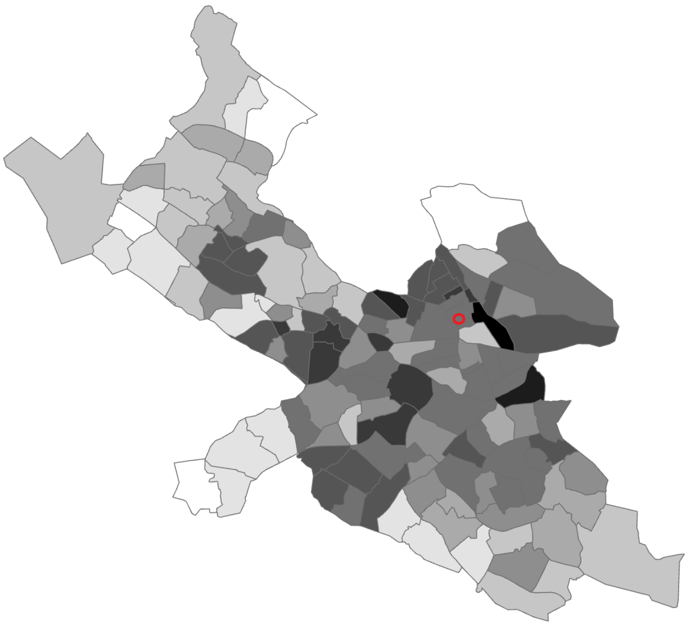


Figure 7: High income areas (upper quartile) year 2000 (dark areas) and subway stations (dots)

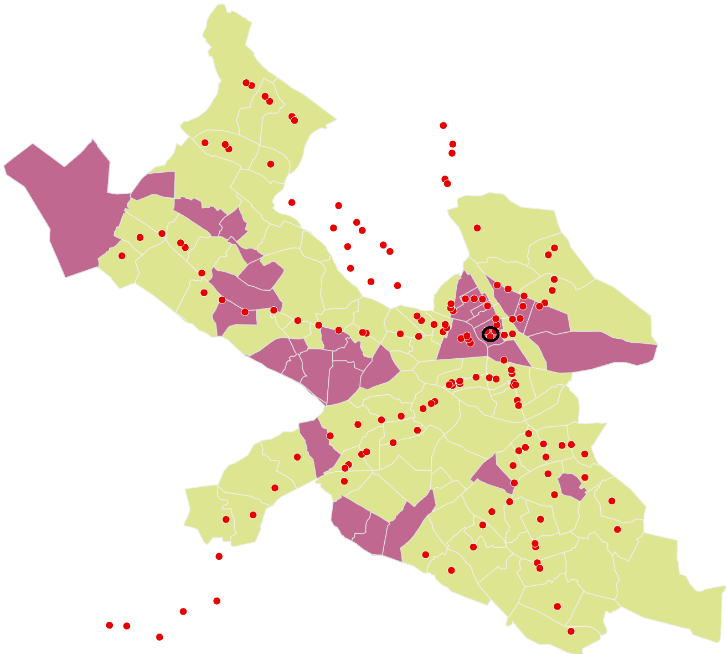
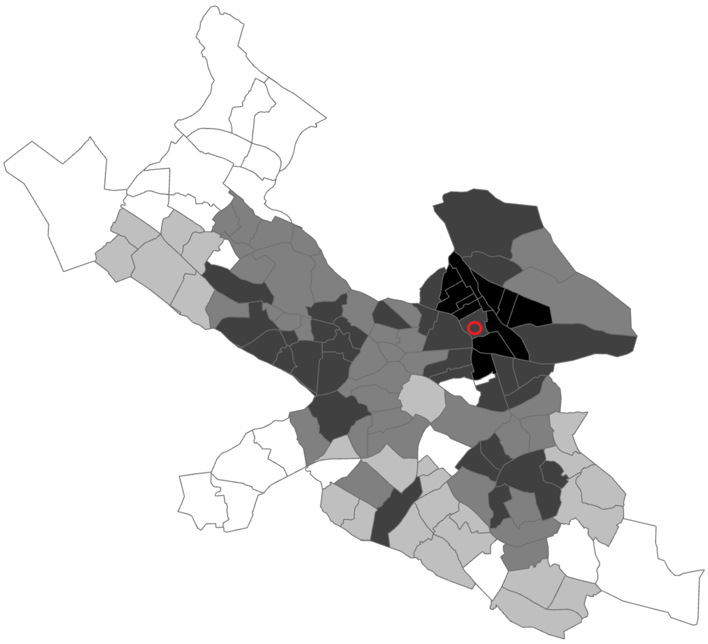


Figure 8: Dwelling age, darker means older (method used to create classes is Jenks natural breaks optimization)



Appendix C: Alternative regression

Table 5: Alternative regression

	(1)
VARIABLES	Income Change
Distance to CBD (km)	-0.0130***
	(0.00314)
Dwelling age	0.00104
	(0.000628)
Constant	1.049***
	(0.0484)
Controls	Yes
Observations	128
R-squared	0.248

Note: Controls include disamenities and public transit. Robust standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1.