DEMOGRAPHIC CHANGE AND HOUSING MARKETS IN AN AGING SOCIETY

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Urban and Regional Planning – Master in Urban and Regional Planning

2019

ABSTRACT

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Population aging in the United States (U.S.) has reached an inflection point. The population who are aged 65 and above increased by 19.7 percent between 2010 and 2016, compared with a 4.8 percent increase among the total population. There is a lack of research about how population aging impacts local housing markets at the county level in the United States. My thesis aims to address this research gap. I use fixed effects models to study the causal relationship between the increasing size of the elderly population and housing prices from 1990 to 2010. The results suggest that population aging has no effect on housing prices in general nor any effect on the price of smaller homes (those with two bedrooms or less). However, there is modest evidence that the increase of the elderly population may contribute significant declines in the price of larger houses (with three bedrooms or more). The findings potentially have important implications for urban planning and housing policy. Identifying the need of housing units inhabited by the elderly population helps planners facilitate the appropriate allocation of permitted newly built housing units (for example, smaller homes for the elderly). It will benefit the well-being of the elderly as population aging becomes an imperative issue.

This thesis is dedicated to my parents and my loving grandfather.
Thanks to my mom and my father for the bread and milk they provided.
Thanks to my parents for believing that
pursuing knowledge is worthy of their daughter's time and efforts.
I appreciate that my mom always accompanies me through all of life's ups and downs.
My grandfather passed away in the second year of my masters' program.
At this moment, when I complete my thesis, I would like to dedicate my work
in memory of my loving grandfather.
All the happiness of childhood with you and the great love from you are
the most precious memories in my life and will be with me forever.

ACKNOWLEDGEMENTS

First, I would like to express my sincere appreciation to my advisor Dr. Noah Durst in the Urban and Regional Planning (URP) program at the School of Planning, Design and Construction (SPDC). The door to Dr. Durst's office was always open whenever I had a question. Every time we discussed my thesis or the various projects that I worked on with him, Dr. Durst was always motivated, thoughtful, and helpful. He has consistently allowed me to conduct my research independently and encouraged me to be patient with unexpected problems in the course of research. His guidance and support have helped me throughout this thesis and my academic work.

My sincere appreciation also goes to my committee members: Dr. Zeenat Kotval-K in the Urban and Regional Planning (URP) program at SPDC, and Dr. Suk-Kyung Kim in the Interior Design (ID) program at SPDC. Dr. Zeenat Kotval-K is continually helpful and supportive. She has offered me great opportunities to work on her various projects, which has enhanced my research ability significantly. Dr. Zeenat Kotval-K always provides prompt responses and thoughtful comments at the times when I got stuck. I am also grateful for Dr. Suk-Kyung Kim's prompt help and encouragement. At the beginning of my thesis when I needed help with my thesis proposal, Dr. Suk-Kyung Kim answered my email late at night, and she always provided me helpful advice to revise my thesis work.

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KEY TO ABBREVIATIONS

IPUMS Integrated Public Use Microdata Series

FHFA Federal Housing Finance Agency

HPI House Price Index

ACS American Community Survey

CHAPTER 1. INTRODUCTION

1.1. Study Motivation

Many countries across the world have witnessed a shift in their demographic structure due to the unprecedented increase in its elderly population (i.e., the population aged 65 years old and above). After World War II, the world experienced high birth rates between 1946 and 1964, and the population born during this time period are named baby boomers (Hogan, Perez, & Bell, 2008). Baby boomers started reaching retirement age at the beginning of the current decade: the population born in 1946 turned 65 years old in 2011; the population born in 1964 will turn 65 years old in 2029. Similarly, in the U.S., the population aged 65 years old and above has continued to increase in the last three decades, with a more dramatic growth after 2010: the population aged 65 years and older in the country increased by 7.4 million over two decades between 1990 and 2010, reaching 38.6 million in 2010, or 12.7 percent of the total population; six years later (2016) this number reached 46.2 million, or 14.5 percent of the total population (U.S., Census, 2017). Also, compared to the total population, both the size and the share of the elderly population have increased at a rapid pace. The data obtained from the World Population Prospect by the United Nations (2017) shows that the total population in the U.S increased by 4.8 percent between 2010 and 2016, while the population aged 65 and above increased by 19.7 percent. This increasing rate in the size and proportion of the population 65 years and older, which is referred to as Population Aging in this study, brings new challenges to social systems and housing markets.

Scholarly literature suggests that this demographic shift in the elderly population is closely related to housing market dynamics (Chiuri & Jappelli, 2008; Mankiw & Weil, 1988; Takats, 2012). Specifically, an increase in the working age population drives a rise in housing demands. Conversely, a rapid rise in the elderly population is more likely to reduce the need for newly built units. Starting with the ground-breaking work conducted by Mankiw and Weil (1988), scholars have put forth a great effort to examine the effects of demographic changes caused by baby boomers on housing prices in the United States (Chiuri & Jappelli, 2008; Green & Hendershott, 1993; Green &. Hendershott, 1996; Martin, 2005; Myers & Ryu, 2008; Saita, Shimizu, & Watanabe, 2016; Takats, 2012), and across the world (Chiuri & Jappelli, 2008; Fortin & Leclerc, 2000; Levin, Montagnoli & Wright, 2009; Martin, 2005; Myers & Ryu, 2008; Ohtake & Shintani, 1996; Takáts, 2012; Saita, Shimizu, & Watanabe, 2016). Traditional studies assume that people tend to buy homes during their working ages and sell their homes after they reach retirement age (Hiller & Lerbs, 2016; Nishimura & Takáts, 2012; Saita, Shimizu, & Watanabe, 2016; Takáts, 2012). Selling their homes due to financial needs or deaths as people ascend into retirement age, this increase in the elderly population may depress housing demand significantly. Even these influential prior studies conducted by previous authors, the findings about how population aging affects housing prices are still debatable.

This thesis aims to further examine the relationship between demographic transitions and the housing market at the county level, which is lacking in previous research due to the limitations of data availability. Previous literature on the topic has been conducted at the national level (Chiuri & Jappelli, 2010; Engelhardt & Poterba; 1991; Green & Hendershott, 1996; Hendershott, 1991; Martin, 2005; Nishimura & Takats, 2012), while a limited number of studies have examined the changes in housing prices at the state level (Myers & Ryu, 2008; Saita, Shimizu, & Watanabe, 2016). Even fewer studies have been conducted at the city level (Hiller & Lerbs, 2016). In the United States, the research scale has been switched from the country level (Chiuri & Jappelli, 2010; Engelhardt & Poterba; 1991; Green & Hendershott, 1996; Hendershott, 1991; Mankiw & Weil, 1988; Martin, 2005; Nishimura & Takats, 2012) to the state level (Myers & Ryu, 2008; Saita, Shimizu, & Watanabe, 2016). As illustrated below, prior findings on the relationship between population aging and the housing market are debatable among the studies at different geographical levels (e.g., international, county, region, and city) and various study areas, which suggests that further examination and exploration on the topic are needed. This study about how demographics affect the housing market in U.S. counties will help local municipalities and planners better understand the housing market trajectories in an aging society (Bogin, Doerner, & Larson, 2018).

1.2. Study Purpose

This study aims to investigate the effects of demographic transitions on the local housing market in U.S. counties. With the house price index published by the Federal Housing Finance Agency available at the county level (Bogin, Doerner, & Larson, 2018), the project proposes to conduct a county level study to investigate how demographic changes affect the local housing market in the United States. Conducting quantitative research to study the impact of demographic structural shifts on the housing market at the county level is pressing and meaningful for several reasons. First, counties are one of the primary forms of local government in the United States, and each county typically has the authority and capacity to distribute local resources and provide public facilities (Bardhan, 2002). Second, counties have relatively fixed boundaries over time, which provides an opportunity to study changes in housing prices over multiple time periods as proposed in this study. Third, counties are small enough to capture local housing market differences but large enough to hold constant variations across neighborhoods (Nau & Bishai, 2018).

Inspired by the increase in the population aged 65 years and older and housing downsizing among the elderly population, I framed two research questions throughout my thesis: 1) How do housing prices in counties within the U.S. respond to changes in the number of individuals aged 65 years old and above? 2) Does the impact of population aging on the housing market differ by housing size? The structure of this thesis is organized in five chapters. Chapter 1 introduces the study motivation and study purpose that inspired me to frame my thesis and then clearly describes the two research questions. Chapter 2 summarizes prior studies and the main findings by previous authors. Chapter 3 provides the methodology used in my thesis, which refers to the data sources, the data management, the measures and model, as well as the limitations that exist in my thesis, which are expected to be addressed in future research. Chapter 4 provides an interpretation and discussion of the regression outcomes from the fixed effects model. Chapter 5, the last chapter, is a summary of the findings in this thesis, a comparison of these results to prior literature, and the study's contributions and implications.

CHAPTER 2. LITERATURE REVIEW

Previous literature on examining the housing market has identified a series of factors that may contribute to the housing price dynamics, such as population size and economic status. Specifically, total population and economic conditions are principal drivers of housing demand and consequently increased housing prices (Hiller & Lerbs, 2016; Mason, Lee, Tung, Lai, & Miller, 2006; Takats, 2012); increases in the working age population increases housing demands, while increases in the elderly population decreases housing demands (Fortin & Leclerc, 2000; Green & Hendershott, 1996; Mason, Lee, Tung, Lai, & Miller, 2006). Scholarly literature suggests that the increase in the total population or the working age population is positively related to the rise in housing demand as well as housing prices (Mason, Lee, Tung, Lai, & Miller, 2006; Takats, 2012). Specifically, the working age population has higher income compared to those 65 years and older. Also, the increasing share of the young population drives the demand of newly built housing units as they reach the age of marriage, and the growth of married couples has a significant and positive influence on housing consumption (Ermisch, 1996; Paciorek, 2016). However, the increasing share of the elderly may cause the excessive supply of housing stocks due to limited income or death as people reach retirement age (Fortin & Leclerc, 2000; Hiller & Lerbs, 2016; Mankiw & Weil, 1988; Martin, 2005; Saita, Shimizu, & Watanabe, 2016; Takáts, 2012). Building off prior literature, here I group these factors into three categories: demographics, economics, and neighborhood characteristics. For each category, I begin with an introduction of the findings concluded by previous authors. I then turn to the research approaches used in prior studies.

2.1. Demographics

One of the research questions in my thesis is to examine the effects of the elderly population on the local housing market. Prior literature suggests that population size and age structure are the main drivers of housing demands and consequently affect the housing market significantly (Hiller & Lerbs, 2016). In this section, I start with an introduction of the main findings on the causal association between the increase in the population aged 65 years old and above and the housing market mentioned in prior studies. I also provide evidence for how population size impacts housing prices, as discussed in scholarly literature.

Prior findings on investigating the causal association between the increase in the elderly population and housing price dynamics are debatable. One school of thought claims that population aging has significant and negative effects on housing prices (Levin, Montagnoli, & Wright, 2009; Saita, Shimizu, & Watanabe, 2016; Takats, 2012). In this aging society, the sharp rise in the share of the population aged 65 years old and above may significantly decrease the proportion of the population in labor markets. Mankiw and Weil (1988) predicted that the increasing elderly population would cause housing prices to decline by 47 percent from 1987 to 2007 in the United States, which suggested a meltdown in the housing market due to the increase in the elderly. The work by Mankiw and Weil (1988) has inspired a plethora of statistical analyses that examined the relationship between population aging and housing prices in the last three decades. Investigating how demographic transitions impact the housing prices has become even more imperative in the current decade. Among the studies conducted across the world, Martin (2005) conducted an international comparison examining the relationship between population aging and the housing market, and the study areas included the United States, Japan, the United Kingdom, and Ireland. The research results suggest a negative relationship between the increase in the elderly population and housing prices. In addition, Chiuri and Jappelli (2008) surveyed almost 3,000,000 individuals over 15 countries that belong to the Organization for Economic Co-operation and Development (OECD): Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Sweden, UK, and US. Analyzing a cross-sectional dataset, Chiuri and Jappelli (2008) found that the increase in the elderly population has negative effects on the housing market because of declining homeownership rates among the population aged 70 years and older. Recently, Takats (2012) used a national level data collected for over 22 OECD countries, including the United States. The study suggests a one percent increase in the elderly-dependency ratio decreases housing prices by a 0.6818 percent. With regard to the findings conducted at the region and city levels, Saita, Shimizu, and Watanabe (2016) conducted an international comparison between the U.S. and Japan at the regional level and found that the old-age dependency ratio has negative effects on real estate prices in both countries. Specifically, a one percent increase in the elderly-dependency ratio is associated with a 1.3167 percent decrease in housing prices throughout the 47 prefectures in Japan and a 0.9067 percent decrease throughout the 50 states across the U.S. country. Hiller and Lerbs (2016) conducted a city-level study in Germany and found that a one percent increase in the old-age dependency ratio causes a 0.7856 percent decrease for real condominium prices, a 0.5155 percent decrease for real single-family house prices, and a 0.2218 percent decrease for real apartment rents in 81 cities.

Even though a number of prior studies have found a significant and negative association between the increase in the elderly population and housing prices across the world, other scholars hold a different thought. A study by Green and Hendershott (1993) suggests that housing prices are either flat or increase as the size of the elderly population increases because the increasing elderly population raised housing demand by 3 percent from 1990 to 2010. Also, Engelhardt and

Poterba (1991) found a minimal impact of an aging population on housing prices in Canada. Additionally, the third school of thought on the topic argues that even though the negative impacts of population aging on housing prices exist, factors such as economic conditions or household formations work to counterbalance these negative effects (Chen, Gibb Leishman, & Wright, 2012; Hendershott, 1991).

Next, I turn to the effects of population size on the housing market; that is, the aggregated housing demand increases as the total population or the working age population increases. Prior literature suggests that people tend to buy homes during their working ages and are likely to sell their homes as they reach retirement age, due to financial need or death (Hiller & Lerbs, 2016; Nishimura & Takáts, 2012; Saita, Shimizu, & Watanabe, 2016; Takáts, 2012). One good example is that the sharp rise in the total population and the working age population due to high birth rates after World War II increased housing demands and housing prices significantly (Hilber, 2009; Levin, Montagnoli, & Wright, 2009; Mankiw & Weil, 1988; Martin, 2005; McFadden, 1994; Saita, Shimizu, & Watanabe, 2016; Takáts, 2012).

Additionally, prior research suggests that age-related characteristics such as income and homeownership vary by age groups: young people are less likely to have stable jobs and become homeowners; middle-aged people are more likely to have a higher income and be able to live in larger homes with their children; and elderly people are more likely to have limited income and prefer to achieve housing downsizing by moving from owner-occupied units to rental-occupied units or from large homes to small homes (Chiuri & Jappelli, 2008; Davidoff, 2006; Ermisch, 1996; Green & Hendershott, 1996; Gabriel & Rosenthal, 2015). The study by Takats (2012) suggests that even though population aging has a negative impact on the housing market, the continued increase in individual income among the elderly might be sufficient enough to counterbalance this negative impact. Chen, Gibb Leishman, and Wright (2012) found that the decline of housing prices in Scotland might be the result of the decreased rates of household formation, not population aging. Controlling for other demographic and socio-economic factors, including income, marital status, and education among different age groups, Green and Hendershott (1996) found that the increase of elderly population is negatively associated with housing prices; however, the real cause of declining housing prices may be decreases in income and lower education levels among the elderly population compared to their young counterparts.

Meanwhile, as the economic condition among the elderly population increases compared with their previous generations, many homeowners aged 65 years and older tend to retain their homeownership rate later in life (Chiuri & Jappelli, 2008). The homeownership rate among the population aged 65 and above was 76.3 percent in 1990 and reached 80.5 percent in 2010, with a drastic growth after the baby boomers born in 1946 turned retirement age (*Table 17. Quarterly Homeownership Rates by Family Income: 1994 to Present,* Housing Vacancies and Homeownership, U.S. Census Bureau); this population group (i.e., people aged 65 years old and above) has held the highest homeownership rate since 2010 (*Table 17. Quarterly Homeownership Rates by Family Income: 1994 to Present,* Housing Vacancies and Homeownership, U.S. Census Bureau). As a result, a higher percentage of the people reaching retirement age maintain homeownership in comparison with past decades. Thus, the increase in homeownership among the elderly may also increase housing demands as well as housing prices in this aging society. Overall, previous studies suggest that age-related characteristics may confound the estimate of the impact of demographic shifts on housing prices, which has been ignored in previous research.

These discrepancies of age-related factors such as income and homeownership rate between different age groups may contribute to heterogeneous effects of population aging on housing submarkets such as small homes or large homes. A study conducted in Germany by Hiller and Lerbs (2016) suggests that housing demands of the elderly population in market segments are different from the working-age population, and different housing market segments might be heterogeneously affected by the increasing population who are aged 65 years old and above. Their regression results show that a one percent increase in the elderly-dependency ratio is associated with a 0.7856 percent decrease in real condominium prices, a 0.5155 percent decrease in real single-family house prices, and a 0.2218 percent decrease in real apartment rents in cities. The work by Hiller and Lerbs (2016) suggests that further research about how population aging impacts the housing submarkets segmented by housing size or housing types needs more attention from scholars. This thesis will address this question: "Does the impact of population aging on the housing market differ by housing size?"

2.2. Economic Factors

Housing transactions are largely determined by broader economic conditions (i.e., worldwide, nationally, and regionally), including credit systems, monetary policy, financial activity, and unemployment rate. One example is that as the economic depression followed the financial crises in 2008, housing prices in the U.S. experienced a downfall. Likewise, prior to the financial crisis, flourishing economic activities drove housing demands, and housing prices increased as well (Adams & Füss, 2010). Housing also represents a majority of individual assets and therefore comprises a significant part of people's investment portfolios during their lifetime (Doling, Elsinga, & Dol, 2013; Poterba & Samwick, 1997). Correspondingly, the consumption ability of the housing market is closely related to the purchasing capacity at the household and at the individual level, indicated by household income or per capita income (Chen, Gibb Leishman, & Wright, 2012; Hiller & Lerbs, 2016; Meen, 2011). In addition, the cost for maintaining homeownership also has an influence on the housing market from an economic perspective (Chen, Gibb Leishman, & Wright, 2012; Hiller & Lerbs, 2016). This section provides the main findings about how broader economic conditions and economic status at the individual or household level impact the housing price dynamics and to what extent.

Broad economic environments are measured and indicated in various ways according to prior literature: Real Gross Domestic Product (GDP), Gross National Product (GNP), and the unemployment rate (Mankiw & Weil, 1988; Engelhardt & Poterba, 1991; Takats, 2012; Saita, Shimizu, & Watanabe, 2016; Paciorek, 2013; Sussman, et al., 2014; Nau & Bishai, 2018). Mankiw and Weil (1988) found that in the United States, a one percent change in real GNP is associated with a 0.234 percent change in housing prices. The study by Engelhardt and Poterba (1991) suggets that a one percent change in real GNP is associated with a 0.27 percent change in housing prices in the U.S. and a 0.35 percent change in Canada. In an international study examining the heterogeneous effects of economic factors on the housing market in 22 countries, Takats (2012) found that a one percent increase in real GDP is related to a 0.8842 percent increase in housing prices. In a regional level study, Saita, Shimizu, and Watanabe (2016) found that a one percent change in per capita GDP caused a 0.288 percent change in housing prices in prefectures in Japan and a 0.4515 in U.S. states.

In addition to broad economic environments, scholars have used the household income or per capita income to indicate the effects of economic conditions at the individual or household levels and found statistically significant effects of the household income or per capita income on the housing market (Chen, Gibb Leishman, & Wright, 2012; Hiller & Lerbs, 2016; Meen, 2011). Chen, Gibb Leishman, and Wright (2012) used the natural logarithm of the ratio of median housing prices to twice the median household income (same with the approach used by Meen) to measure the relationship between housing prices and household incomes. Also, the study by Hiller and Lerbs (2016) suggests that a one percent increase in real income per capita causes a 0.8648 percent increase in real condominium prices and a 0.6334 percent increase in real single-family house prices.

The cost for maintaining homeownership is another consideration to evaluate how economic factors affect the performance of the housing market. User costs (Chen, Gibb Leishman, & Wright, 2012) and real mortgage interest rates (Hiller & Lerbs, 2016) are used to indicate the cost to maintain homeownership. Prior literature suggests a negative association between user costs or interest rates and housing prices (Chen, Gibb Leishman, & Wright, 2012; Hiller & Lerbs, 2016). Chen, Gibb Leishman, and Wright (2012) found that a one percent change in user costs is inversely related to a 0.886 percent change in housing prices estimated in Scotland, and Hiller and Lerbs (2016) found that a one percent increase in real mortgage interest rate causes a 0.9041 percent decrease in real condominium prices and a 0.8000 percent decrease in apartment rent in Germany. Overall, prior literature suggests that economic conditions increase housing prices, and the costs for maintaining homeownership decrease housing prices.

2.3. Neighborhood Characteristics

Turning to neighborhood characteristics, housing prices are also dependent on the urban form, the geographical location, the supply of existing housing units, the housing type (e.g., single-family home, multi-family home, or apartment), and the housing size (e.g., small or large home).

The urban form of the neighborhoods in which the housing is located plays an important role in determining housing prices. Housing units located in the Central Business District (CBD) areas may be more valuable than their counterparts in suburban or rural areas because of more competitive employment opportunities, sound amenities/services, and/or healthcare facilities

(Green & Hendershott, 1996; Nau & Bishai, 2018). Housing units in neighborhoods with convenient access to facilities such as schools, entertainment centers, and transportation hubs may have higher prices (Li, 2017). Housing prices in low-density neighborhoods (e.g., single-family homes) are higher than high-density neighborhoods (e.g., multi-family homes, apartments) (Glaeser, Gyourko, & Saks, 2005; Kulish, Richards, & Gillitzer, 2012). The availability of developable land influences housing prices by restricting the supply of newly built housing units (Hilber, 2009; Paciorek, 2013). Coastal areas, inland water, and hillsides limit the amount of land available for development and thereby contribute to higher housing prices (Saiz, 2010). These put restraints on the supply-side of newly built housing units, which may cause significant increases in housing prices.

The existing housing stock and the provision of newly built housing units are important indicators of the housing market from the supply side (Hiller & Lerbs, 2016). Planners and local municipalities utilize planning or housing policies to regulate the supply of newly built housing units. Housing policies such as land use regulations and zoning ordinances affect the housing market by adjusting the provision of newly built housing units. Prior studies used the number of regional total housing units, or units per capita, to indicate historical housing stock (Fortin & Leclerc, 2000; Holly & Jones, 1997; Mankiw & Weil, 1989). The permitting of newly built housing units is another indicator of the supply of the housing market: single-family homes, multi-family homes, or apartments (Glaeser, Gyourko, & Saiz, 2008; Hilber, 2009; Paciorek, 2013; Saita, Shimizu, & Watanable, 2015). Regarding the housing type built in various neighborhoods, previous research used the permitted newly built housing units published by the Building Permits Survey to monitor the supply of different segments of the housing market, such as single-family homes, or apartments (Glaeser, Gyourko, & Saiz, 2008; Hilber, 2009; Hiller & Lerbs, 2016; Mayer

& Somerville, 2000; Paciorek, 2013; Saita, Shimizu, & Watanabe, 2016). In addition, housing size indicated by the number of rooms or the number of bedrooms is a criterion that can be used to estimate the price of a housing unit (Green & Hendershott, 1996; Goodman, 1988).

2.4. Previous Study Approaches

Previous studies began with the Ordinary Least Square (OLS) and the unit root test to establish their research models. Mankiw and Weil (1988) used a time-series dataset and applied the simple first-difference regression model to identify the relationship between demographic structural changes and housing prices in the United States, which establishes a fundamental research approach for subsequent studies on the topic. The following studies repeat Mankiw and Weil's research approach by adding and changing control variables to investigate the relationship between population aging and the housing market in other countries or regions (Engelhardt & Poterba, 1991; Hendershott, 1991). Levin, Montagnoli, and Wright (2009) employed difference-in-differences models to compare regression results in Scotland and England between 1968 and 2004, two countries with different demographic shifts but similar economic conditions, such as interest rate, and inflation. The research model I utilize in my thesis builds off the work by Takáts (2012) and Saita, Shimizu, and Watanabe (2016). The panel regression analysis used by Takáts (2012) is described as follows,

$$\Delta lnP_{it} = \beta_0 + \beta_1 \Delta lnGDPPC_{it} + \beta_2 \Delta lnOLDDEP_{it} + \beta_3 \Delta lnTPOP_{it} + u_i + e_{it}$$

where P denotes housing prices, $GDPPC$ denotes real GDP per capita, $OLDDEP$ denotes the elderly-dependency ratio, $TPOP$ denotes total population, ln is the national logarithm, and subscripts i and u denote country and year. β_0, β_1, β_2, and β_3 are intercepts. u_i is used to control the time-invariant effects. e_{it} is the error term.

Saita, Shimizu, and Watanabe (2016) improved the panel regression model based on Takáts' work by adding an error correction term to investigate the effects of demographic factors on the housing market in the U.S. and in Japan. However, the research model used by Takáts (2012) and Saita, Shimizu, and Watanabe (2016) at large geographical scales are deficient that the time-invariant individual effects, such as the geographic location of the housing units or land-use regulations over countries or regions, cannot be controlled in their models. In addition, Hiller and Lerbs (2016) mentioned the "*aggregation bias*" in their work regarding the research model used by Takáts (2012) and Saita, Shimizu, and Watanabe (2016). This term is used to explain that local housing market variations are closely associated with transit modes, or land use types (Meen, 2011). Nau and Bishai (2018) used fixed and random effects models to measure the relationship between population health and housing prices in Metropolitan Statistical Areas (MSAs) in the United States. Their findings suggest that housing prices vary substantially in smaller spatial scales such as census tracts and counties, which illustrates the innovations of this thesis work conducted at the county level.

To indicate the fluctuations of the housing market, the House Price Index (HPI) published by the Office of Federal Housing Finance Agency (FHFA) was used to measure housing prices at the level of Metropolitan Statistical Areas (MSAs) (Nau & Bishai, 2018) and at the state level (Saita, Shimizu, & Watanabe, 2016). At the city level, Paciorek (2013) employed repeat-sales indices published by FHFA, deflated the indices using the Consumer Price Index (CPI), and pegged the indices to the mean house price. This calculation provides a dollar-valued measure of prices that controls for changes of housing transactions by house types in given study periods. Another measurement of the housing market change is indicated by the house value in contemporary dollars with the data drawn from the Integrated Public Use Microdata Series

(IPUMS). Sussman, et al. (2014) used the house value measurement in the natural logarithm transformation to study the relationship between housing prices and climate changes.

In terms of measuring the issue of population aging, several approaches are used in previous literature: the number of population aged 65 years old and above, the growth rate of population aged 65 years and above (Fortin & Leclerc, 2000), the average age of population aged 20 years old and above (Bakshi & Chen, 1994), the total dependency ratio (McFadden, 1994), the elderly-dependency ratio (Bakshi & Chen, 1994; McFadden, 1994; Saita, Shimizu, & Watanabe, 2016; Takáts, 2012), and the inverse of the total dependency ratio (Nishimura, 2011). The simplest approach is to use the logarithm to calculate the population aged 65 years old and above. The total dependency ratio measurement is the ratio of the population not in the labor market to the total population (McFadden, 1994), and the elderly-dependency ratio measurement is the ratio of the population aged 65 years and above to the population aged 20 to 64 years old (Bakshi & Chen, 1994; McFadden, 1994; Saita, Shimizu, & Watanabe, 2016; Takáts, 2012). In addition, the inverse of the total dependency ratio measurement is the ratio of the population aged between 0 and 19 years old and the population aged 65 years old and above to the population aged between 20 and 64 years old (Nishimura, 2011).

Overall, with the research scale shifting from the national to regional levels, and even the city level across the world, investigating the effects of population aging on the local housing market in the U.S. is a meaningful innovation. Demographic shifts may occur predominantly at the local level (i.e., counties or cities) rather than regionally or nationally and such trends may have influences on the local housing market that are not captured by studies that rely on data aggregated at the national or state level. Previous research shows that studies on this topic at the county level in the U.S. are lacking, and my thesis proposes to bridge this research gap in the first research question: “How do housing prices in counties within the U.S. respond to changes in the number of individuals aged 65 years old and above?” In terms of the regression model, building off the work by Takáts (2012), Saita, Shimizu, and Watanabe (2016), and Nau and Bishai (2018), I utilize the county fixed effects model in this thesis to contribute to current literature. A county level study in the U.S. helps to capture variations in the housing market over neighborhoods compared to previous research conducted at the country and the state level. In terms of measures, informed by prior studies, I utilize the house price index published by the Federal Housing Finance Agency (FHFA) and the house value published by the Integrated Public Use Microdata Series (IPUMS) to capture changes in the local housing market and the elderly-population ratio to indicate the shift of the elderly population size. Chapter 3 provides the research methodology in detail.

CHAPTER 3. METHODOLOGY

Motivated and inspired by prior research examining the association between population aging and the housing market, my thesis further investigates how the increase of the population aged 65 years old and above affects the local housing market in the United States. This thesis is designed to measure changes in housing prices (i.e., the dependent variable) as a function of the elderly-dependency ratio (the ratio of the population who are aged 65 and older to the working age population – i.e., those 20 to 64 years old) and a series of physical and socio-economic factors (e.g., the independent variables). To capture variation in the effect of population aging on the housing market across neighborhoods, this thesis is conducted at the county level in the U.S., which fills a gap in prior research. The study period in my thesis covers the three decades between 1990 and 2010 with a 10-year interval.

This chapter describes the methodology used in this thesis. I start with an introduction to the four data sources. I then turn to a detailed explanation of how I converted the raw data obtained from public data sources, which are only available at the individual or housing-unit levels, into a county level dataset. I also provide the measurement of each variable incorporated in my regression model. Lastly, I describe how the fixed effect is suitable for the research design of my thesis.

3.1. Data Sources

Four public data sources are used throughout this thesis: the Integrated Public Use Microdata Series (IPUMS), the House Price Index (HPI) from the Federal Housing Finance Agency (FHFA), the American Community Survey (ACS), and the Building Permits Survey published by the U.S. Census.

Integrated Public Use Microdata Series (IPUMS) USA

The Integrated Public Use Microdata Series (IPUMS) "provides census and survey data from around the world integrated across time and space"[1]. IPUMS USA "collects, preserves and harmonizes U.S. census microdata and provides easy access to this data with enhanced documentation. Data includes decennial censuses from 1790 to 2010 and American Community Surveys (ACS) from 2000 to the present"[2]. IPUMS USA provides the data source for measuring changes in the housing market, and a series of physical and demographic factors. The raw data published by IPUMS USA is available at the individual and housing-unit levels.

The analysis presented here covers three periods from 1990 to 2010. I used one-year 5% data (a 1-in-20) sample of the population for 1990 and 2000 (1990 5% State sample, and 2000 5% sample). The following provides detailed information for the data sample that I obtained. For the data in 1990, the one-year 5% state sample is a "1-in-20 national random sample of the population. This is a weighted sample. No place smaller than 100,000 population can be identified with any geographic variable."[3]

Turning to the data in 2000, the one-year 5% sample is a "1-in-20 national random sample of the population. This is a weighted sample." [4] However, for the data in 2010, IPUMS released a 1-in-100 national sample of the population instead of a 5% sample. In order to have the same sample size for each decade, I used the American Community Survey 2008-2012 5-year estimates with a 5% (1-in-20) sample of the population for the last wave of the study. Specifically, the American Community Survey 2008-2012 5-Year sample in 2012 is a "5-in-100 national random sample of the population. Contains all households and persons from the 1% ACS samples for 2008,

[1] Sources: IPUMS USA. https://usa.ipums.org/usa/index.shtml
[2] Sources: IPUMS USA. https://usa.ipums.org/usa/index.shtml
[3] Sources: IPUMS, USA. https://usa.ipums.org/usa/sampdesc.shtml#us1990a
[4] Sources: IPUMS, USA. https://usa.ipums.org/usa/sampdesc.shtml#us1990a

2009, 2010, 2011 and 2012, identifiable by year. The data include persons in group quarters. This is a weighted sample."[5]

House Price Index (HPI), Federal Housing Finance Agency (FHFA)

The House Price Index (HPI) published by the Federal Housing Finance Agency (FHFA) is "a weighted, repeat-sales index, meaning that it measures average price changes in repeat sales or re-financings on the same properties."[6] The raw data for HPI published by the Federal Housing Finance Agency (FHFA) is "obtained by reviewing repeat mortgage transactions on single-family properties whose mortgages have been purchased or securitized by Fannie Mae or Freddie Mac since January 1975"[7]. From the Federal Housing Finance Agency (FHFA), HPI is aggregated over and available at different geographical levels in the U.S., including the nation as a whole, states, metropolitan areas, and counties. This county level housing price data used in my thesis is obtained from the file titled "*Counties (Developmental Index; Not Seasonally Adjusted), Annual House Price Indexes*" which was updated on February 27, 2018. Specifically, the "*Counties (Developmental Index; Not Seasonally Adjusted), Annual House Price Indexes*" provides data for the house price index in three different types: "the index value with a base of 100 when first recorded, the index value with a base of 100 in 1990, and the index value with a base of 100 in 2000"[8]. I chose the index value with a base of 100 in 2000 as the indicator of the housing price in my thesis, because it provides the data for most counties compared to the house price index value in the other two types.

Building Permits Survey, U.S. Census

[5] Sources: IPUMS, USA. https://usa.ipums.org/usa/sampdesc.shtml#us1990a
[6] Sources: House Price Index, Federal Housing Financial Agency. https://www.fhfa.gov/DataTools/Downloads/Pages/House-Price-Index.aspx
[7] Sources: House Price Index, Federal Housing Financial Agency. https://www.fhfa.gov/DataTools/Downloads/Pages/House-Price-Index.aspx
[8] Sources: House Price Index, Federal Housing Financial Agency. https://www.fhfa.gov/DataTools/Downloads/Pages/House-Price-Index.aspx

To control for neighborhood characteristics, I also used the data from the Building Permits Survey available from the U.S. Census to calculate permits for single-family housing units. The Building Permits Survey publishes data on newly permitted buildings categorized by the number of units. The raw data is available in the file titled "*Permits by County or Place*"[9] at the country level. I calculated the number of newly permitted buildings with one unit to measure single-family home construction.

3.2. Constructing a County Level Dataset

The unit of analysis in this study is at the county level; however, a series of variables obtained from IPUMS are not currently published at the same unit (i.e. the county level). To clarify, the Integrated Public Use Microdata Series (IPUMS) provides data for the variables such as house value, housing units, and housing user costs at the housing-unit level, and for the variables such as the elderly-dependency ratio, the total population, per capita income, unemployment rate, homeownership rate for the elderly, and per capita income for the elderly at the individual level. This issue of the data availability in the public data sources requires an appropriate process of data management and data treatment to construct a new dataset. I believe that this data availability at the county level is an important issue in prior studies and can explain the lack of a county level study on the topic by previous authors. One of the innovations in this study is that I address this issue by converting the raw data, which is available either at the individual level or at the housing-unit level, into a new county level dataset. I conducted data processing and data treatment as follows.

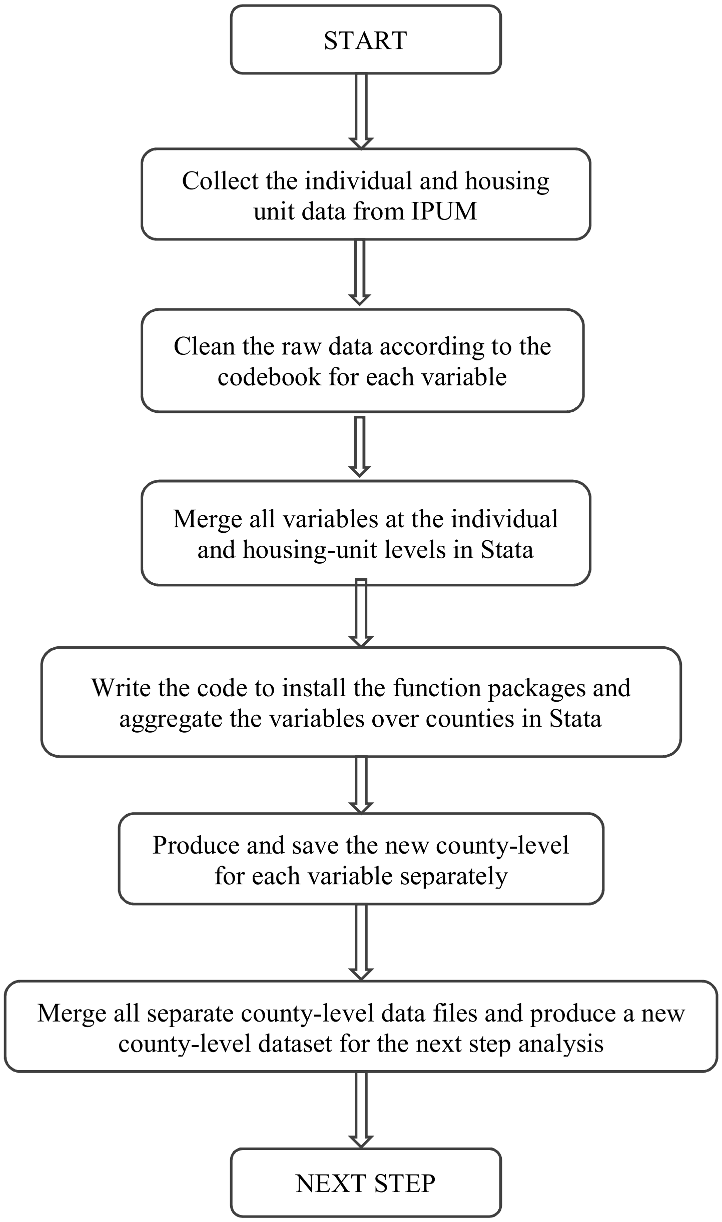
[9] Sources: Building Permits Survey, U.S. Census.

3.2.1. Data Processing

Data processing was conducted and converted between a few software programs, including StataSE 14 (64-bit), Microsoft Office Excel, and the Geographic Information System software ArcGIS. This section focuses on explaining how I aggregated individual level and housing-unit level data over counties. Figure 3.1 shows the broader conceptual steps for constructing a new county level dataset. I started by downloading the raw data in each decade as I described above, cleaning the missing data, and coding each variable according to the codebooks published by IPUMS USA.

The data collection and cleaning process were completed in Excel and Stata. I then imported the Excel files into Stata and merged all individual level and housing-unit level variables into one dataset. The next step was to install and run functional packages in Stata to aggregate the individual level and housing-unit level data over counties, which were identified by the column named “CountyCode” in the dataset. In the Appendix, I list the selected commands and functional packages that I frequently used to construct the final dataset in Appendix 2, and detailed interpretations are also provided following each command and functional package.

Figure 3.1. Flowchart for Data Processing.



Notes: See Appendix 2 for selected Stata commands/codes.

3.2.2. Data Treatment

After the county level dataset was constructed, I then moved to the process of data treatment. In this section, I provide the statistical test results to justify the variables and the types of variables (e.g. the logarithm type) that I include in the regression outcomes. To clarity, the study period covers 1990 to 2000, which means the dataset is specifically a panel/longitudinal dataset. For this panel data, I tested the normality for the mean center values instead of the actual observations (see Table 3.1). The mean center value is calculated as the difference between the mean value of three time periods and the actual value in each time period (Allison, 2009). The normality test results for the mean centered values show that the variables in the natural logarithm types have the values of skewness and kurtosis that are within or close to the normal ranges (i.e., $- 1 < \text{skewness} < +1$; $- 2 < \text{kurtosis} < + 2$). Therefore, I utilized the variables in the natural logarithm types to run the regression outcomes as follows. Also, Table 3.2 shows the Pearson's correlation coefficients for all independent variables. The coefficients between the main independent variable (i.e., elderly-dependency ratio) and the other variables range from - 0.26 to 0.2092. It shows that the independent variables incorporated in my thesis are not highly correlated and thus not likely subject to high multicollinearity.

Table 3.1. Normality Test for Mean Center Values of Variables.

Dependent Variables	**Skewness**	**Kurtosis**	**Dependent Variables in Natural Log**	**Skewness**	**Kurtosis**
House Price Index	0.3530739	2.465308	Logarithm of House Price Index	0.0146047	2.135211
House Value	0.1627333	5.43422	Logarithm of House Value	0.0025688	2.742794
House Value for Units with Two Bedrooms or Less	0.366409	6.470001	Logarithm of House Value for Units with Two Bedrooms or less	-0.1675279	3.30785
House Value for Units with Three Bedrooms	0.0315633	6.677471	Logarithm of House Value for Units with Three Bedrooms	-0.0696406	3.021543
House Value for Units with Four Bedrooms or More	0.0569673	6.027665	Logarithm of House Value for Units with Four Bedrooms or more	-0.0576045	3.137525
Independent Variables	**Skewness**	**Kurtosis**	**Independent Variables in Log**	**Skewness**	**Kurtosis**
Elderly-dependency Ratio	0.095179	15.29455	Logarithm of Elderly-dependency Ratio	0.15887	5.374289
Total Population	-0.2271148	38.13571	Logarithm of Total Population	-0.153942	5.631382
Housing Units	0.7492315	38.50464	Logarithm of Housing Units	-0.0253104	4.604805
Per Capita Income	0.0956255	2.918284	Logarithm of Per Capita Income	0.0334931	2.583159
Housing User Costs	0.105111	2.84345	Logarithm of Housing User Costs	0.067106	2.67046
Single-family Housing Units	0.895605	49.77573	Logarithm of Single-family Housing Units	-0.4724039	3.308318
Per Capita Income for the Elderly	-0.4148034	3.093567	Logarithm of Per Capita Income for the Elderly	-0.556105	3.442057

Table 3.2. Pearson's Correlations Coefficients Matrix for Independent Variables.

	Logarithm of Elderly-dependency Ratio	Logarithm of Total Population	Logarithm of Housing Units	Logarithm of Per Capita Income	Logarithm of Housing User Costs	Unemployment Rate	Logarithm of Single-family Housing Units	Ownership Rate among the Elderly	Logarithm of Per Capita Income for the Elderly
Logarithm of Elderly-dependency Ratio	1								
Logarithm of Total Population	-0.0872	1							
Logarithm of Housing Units	-0.008	0.9903	1						
Logarithm of Per Capita Income	-0.26	0.2657	0.2475	1					
Logarithm of Housing User Costs	-0.0718	-0.0127	-0.0256	0.258	1				
Unemployment Rate	0.2092	0.0971	0.114	-0.5544	-0.0555	1			
Logarithm of Single-family Housing Units	-0.1795	0.4852	0.4717	0.3424	-0.0698	-0.3897	1		
Ownership Rate among the Elderly	0.1727	-0.3511	-0.3386	-0.0215	0.1218	-0.0987	0.1848	1	
Logarithm of Per Capita Income for the Elderly	-0.0498	0.1705	0.1896	0.6266	-0.0125	-0.2605	0.1846	0.1598	1

3.3. Measures

3.3.1. Dependent Variables (DVs)

In my thesis, I measured changes in housing prices (i.e., the dependent variable) during 1990 to 2010 using two indicators: the house price index and the house value. The county level house price index is published by the Federal Housing Finance Agency (FHFA). I used the file titled *Annual House Price Indexed Housing Price Index (HPI)* to obtain the raw data for the housing price index, which was updated on February 27 in 2018. Turning to the house value, the raw data was collected at the housing-unit level from IPUMS USA. First, I applied sample weights supplied by IPUMS USA for households to calculate the median house values. Second, I adjusted the house value based on the 1990 constant dollars using the Consumer Price Index adjustment factors for each decade. Then, I used a statistical tool Stata to aggregate the housing-unit level median house value over counties. It is noteworthy that IPUMS USA only publishes the house value data for the owner-occupied housing units, while the house value data for the rental-occupied housing units is currently not available.

In addition, as mentioned in Chapter 2. Literature Review, previous research suggests that the influence of population aging on the housing market differs by housing types which is termed as “heterogeneous effects” by previous authors. For example, Hiller and Lerbs (2016) found that the increase in the elderly population is negatively associated with condominium prices and single-family house prices to varying degrees, but positively associated with apartment rent. Their work suggests that the increase in the elderly population has heterogeneous effects on the housing market. Also, inspired by prior findings that the elderly population are more likely to downsize (i.e., move from large homes to small homes, or move from owner-occupied units to rental-occupied units) as they reach retirement age, I am also interested in examining if the effects of the increase in the elderly population on the housing market differ between smaller homes and larger homes, and to what extent. To do so, my thesis further statistically investigates the heterogeneous effects of population aging on the housing market categorized by housing size. I constructed the house value data for housing submarkets categorized by the number of bedrooms: the house value for housing units with two bedrooms or less, the house value for housing units with three bedrooms, and the house value for housing units with four bedrooms or more. As mentioned above, to obtain a dataset in which the variables are normally distributed (see Table 3.1), I used the natural logarithm type to indicate the local housing market dynamics. Table 3.3 shows the measurement of each dependent variable, the data source, and the unit of measurement.

Table 3.3. Measurement of Dependent Variables.

Variables	**Measurements**	**Data Sources**	**Units of Raw Data**
House Price Index	Logarithm of House Price Index	FHFA	County
House Value	Logarithm of Median House Value	IPUMS	Housing Units
House Value for Units with Two Bedrooms or Less	Logarithm of Median House Value for Units with Two Bedrooms or less	IPUMS	Housing Units
House Value for Units with Three Bedrooms	Logarithm of Median House Value for Units with Three Bedrooms	IPUMS	Housing Units
House Value for Units with Four Bedrooms or More	Logarithm of Median House Value for Units with Four Bedrooms or more	IPUMS	Housing Units

3.3.2. Independent Variables (IDVs)

This section introduces the measurement of the independent variables. Population aging is indicated by the elderly-dependency ratio (i.e., the main independent variable). Building on prior studies (Saita, Shimizu, & Watanabe, 2016; Takáts, 2012), I calculated the elderly-dependency ratio as the population aged 65 years old and above to the population aged 20 to 64 years old. Then I transformed the elderly-dependency ratio to the natural logarithm type. For the control variable, the population size is measured by the total population in counties; the housing user cost is calculated by the total amount of the annual electricity cost, the annual gas cost, the annual waste cost, and the annual home heating fuel cost for each housing unit. I then aggregated the housing user cost over counties. I also collected data for permits for one-unit buildings published by the Building Permit Survey, U.S. Census to indicate the number of permitted single-family housing units. The per capita income is calculated to capture the individual purchasing ability, and the unemployment rate is included to indicate how broader economic conditions impact the local housing market, and to what extent. To ensure normality of the data (see Table 3.1), I transformed the total population, the housing user cost, the single-family housing units, and the per capita income to the natural logarithm types as shown in Table 3.4.

Turning to age-related characteristics among the elderly population, I suspected that a series of demographic and socio-economic characteristics among the elderly population may influence the local housing market. Specifically, the increasing share of the population aged 65 years old and above may have negative effects on the housing market due to limited income as their working hours decrease; the elderly population may prefer to downsize their homes by moving from owner-occupied units to rental-occupied units. These considerations suggest that further explorations on how aged-related factors affect the local housing market are needed. To address this question, I improve the regression model by including additional age-related variables among the elderly: the per capita income among the elderly, and the homeownership rate among the elderly population. For the same data normality reason (see Table 3.1), I transformed the per capita income among the elderly to the natural logarithm type. Table 3.4 lists the measurement of each independent variable: the elderly-dependency ratio, the total population, the total housing units, the per capita income, the housing user costs, the unemployment rate, the number of single-family permits, the per capita income among the population aged 65 years old and above, and the homeownership rate among the population aged 65 years old and above. The data sources and the units of the raw data for each variable are also provided in Table 3.4.

Table 3.4. Measurement of Independent Variables.

Variables	**Measurements**	**Data Sources**	**Units of Raw Data**
Elderly-dependency Ratio (in Natural Log)	Ratio of the Population Aged 65 Years Old and above to the Population Aged 20 to 64 multiplying by 100 (in natural logarithm type)	IPUMS-NHGIS	Individual
Total Population (in Natural Log)	Total Population (in natural logarithm type)	IPUMS-NHGIS	Individual
Housing Units (in Natural Log)	Total Housing Units (in natural logarithm type)	IPUMS-NHGIS	Housing Unit
Per Capita Income (in Natural Log)	Per Capita Income (in natural logarithm type)	IPUMS	Individual
Housing User Costs (in Natural Log)	Sum of the costs for electricity, gas, water, and fuel (in natural logarithm type)	IPUMS	Housing Unit
Unemployment Rate	Unemployment Rate	IPUMS	Individual
Single-family Housing Units (in Natural Log)	Logarithm of Single-family Housing Units (in natural logarithm type)	Building Permits Survey, U.S. Census	Housing Unit
Homeownership Rate for the Elderly (in Natural Log)	Homeownership Rate for People Aged 65 Years old and above (in natural logarithm type)	IPUMS	Individual
Per Capita Income for the Elderly (in Natural Log)	Logarithm of Per Capita Income for People Aged 65 Years old and above (in natural logarithm type)	IPUMS	Individual

3.4. Fixed Effects Model

Building on previous research (Takáts, 2012; Yumi Saita, Chihiro Shimizu, & Tsutomu Watanabe, 2016; Nau & Bishai, 2018), I utilized fixed effects models to examine the association between the increase in the elderly population and the local housing market in this study. With the county-level panel dataset that I constructed, which covers three time periods (i.e., from 1990 to 2010), the fixed effects model is helpful to control for time-invariant characteristics of counties. These characteristics may refer to geographic locations, urban areas and rural areas, or land use regulations implemented at localities, when one of these factors or all of them do not change over time. The following is the simple equation for the fixed effects model used in this study:

$$\ln(HousingPrices)_{it} = \beta_0 + \beta_1 ElderlydependencyRatio_{it} + \beta_2 X_{it} + \beta_3 Time_t + u_i + e_{it},$$

where the dependent variable is the housing prices in the natural logarithm type (i.e., $\ln(HousingPrices)_{it}$) for each county i at time *t*; the elderly-dependency ratio (i.e., $ElderlydependencyRatio_{it}$) is the indicator of the increase of the population aged 65 years old and above for each county i at time *t*; $Time_t$ indicates the effects of time on the housing prices from 1990 to 2000 and from 2000 to 2010. β_0 is the intercept item; β_1 and β_2 are the parameters of the main independent variable and the control variables; u_i is a group-specific fixed effects used to control for the time-invariant characteristics in each county *i*; and e_{it} is the error term for each county *i* at time *t*.

3.5. Limitations

The research design of my thesis presented here has certain limitations. First, if the neighborhoods characteristics in counties do change over time, which is likely to be the case, these changes need to be included as control variables in the regression models in order to control for their potential to confound estimates of the effect of population aging on housing prices. The fixed effects model used here cannot control for this temporal variation within counties. Second, housing values do not measure changes in prices for specific housing units – they measure changes in the median (resident-reported) value for all housing units. They may therefore fail to capture actual housing price changes due to demographic shifts. To clarify, as introduced in the data sources section, the house price index is "a weighted, repeat-sales index, meaning that it measures average price changes in repeat sales or re-financings on the same properties."[10] The house price index is therefore a better indicator to measure the local housing market price dynamics, because it is a repeat-sales index which measures actual house price changes. Housing values as reported by the census bureau, however, are a less reliable indicator of housing price changes over time. Third, this thesis only addresses the heterogeneity of the relationship between population aging and the housing submarkets indicated by the housing size. However, the heterogeneous effects of population aging may also exist over the housing submarkets categorized by the housing types (e.g., single-family units, condominium, multi-family units, and apartments), as the population in different age groups have their own preferences, tastes, and living habits. It merits further exploration in future research.

[10] Sources: House Price Index, Federal Housing Financial Agency. https://www.fhfa.gov/DataTools/Downloads/Pages/House-Price-Index.aspx

CHAPTER 4. REGRESSION RESULTS

To investigate the effects of population aging on the local housing market at the county level in the United States, I constructed a series of demographic and socio-economic variables that are aggregated over counties. Overall, the county level dataset used here includes 1224 observations (the unit of the observations is at the county level) over three time periods (i.e., 1990, 2000, and 2010), which provides a sample of 408 counties. The sample size accounts for more than one-tenth of counties (400 counties in each decade divided by 3142 counties and county equivalents) across the country (U.S. Census, 2018). I mapped the spatial distribution of these counties included in my regression models in Appendix 1. Before the discussion of the regression results, I provide detailed summary statistics for all variables included in the following regression models. Table 4.1 shows the number of observations, the mean value, the standard deviation, the minimum value, and the maximum value.

Then, I turn to an interpretation of the regression results in each model. To investigate the statistical association between the increase in the population aged 65 years old and above and the local housing market, I first begin with regression models that include the elderly-dependency ratio as the only independent variable. Next, I add a variety of demographic and socio-economic variables in the full regression model to control for other factors that may impact the estimate of the effects of the elderly population on the housing market. To investigate whether age-related factors among the elderly population affect the estimate of the association between population aging and the local housing market, I also develop an improved model by controlling for age-related characteristics specifically calculated for the elderly population. Building off the detailed regression outcomes (see Table 4.1- Table 4.3), I will interpret the regression outcomes in the following three consecutive models: 1) the basic model with only the elderly-dependency ratio, 2) the full model with a series of physical, demographic, and socio-economic control variables, and 3) the improved model with the additional age-related variables only calculated for the elderly population. In addition, this chapter concludes by exploring the heterogeneous effects of population aging on the housing submarkets categorized by urban structures (see Table 4.5- 4.8).

Table 4.1. Detailed Summary Statistics for Included Variables.

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Logarithm of House Price Index	1,224	4.606549	0.2665087	3.742183	5.320226
Logarithm of House Value	1,224	11.69661	0.4357402	10.68465	13.34551
Logarithm of House Value for Units with Two Bedrooms or less	1,224	11.28203	0.4838959	10.06561	13.06452
Logarithm of House Value for Units with Three Bedrooms	1,224	11.65048	0.4093377	10.71442	13.24041
Logarithm of House Value for Units with Four Bedrooms or more	1,224	11.99758	0.4092694	11.06414	13.44401
Logarithm of Elderly-dependency Ratio	1,224	3.011629	0.3076058	1.920926	4.278799
Logarithm of Total Population	1,224	12.5354	0.8276706	11.48233	16.10197
Logarithm of Housing Units	1,224	11.64776	0.8206897	10.33667	15.05139
Logarithm of Per Capita Income	1,224	9.91623	0.2079921	9.260345	10.60663
Logarithm of Housing User Costs	1,224	7.616723	0.1657805	6.952193	8.20098
Unemployment Rate	1,224	0.070079	0.0279299	0.0208339	0.181569
Logarithm of Single-family Housing Units	1,224	6.506731	1.140683	1.609438	10.37502
Ownership Rate among the Elderly	1,224	0.8193759	0.0645784	0.2977582	0.949228
Logarithm of Per Capita Income for the Elderly	1,224	9.60715	0.1894907	8.86785	10.32558

4.1. Model with only Elderly-dependency Ratio

The original research question described at the beginning of my thesis is "How do housing prices respond to changes in the number of individuals aged 65 years old and above?" To investigate a causal association between the increase in the population aged 65 years-old and above and the changes of housing prices, I begin with an interpretation of the regression outcomes for the basic model which only includes the elderly-dependency ratio as the independent variable. Table 4.2 shows the regression outcomes for the basic regression model.

Overall, the regression results in Table 4.2 suggest that the elderly-dependency ratio is highly associated with the local housing market. The coefficients of four out of five specifications for the elderly-dependency ratio are statistically significant, which suggests that increases in the elderly-dependency ratio are associated with decreases in housing prices/values. Specifically, the coefficient for the elderly-dependency ratio in the model with the house price index as the dependent variable is equal to - 0.1405 and is statistically significant at the 1% level ($p < .01$). It indicates that every one percent increase in the elderly-dependency ratio is associated with a 0.1405 percent decrease in housing prices, holding time-invariant characteristics of counties constant. In the models with the dependent variables that are indicated by the median house value, the increase in the elderly population shows significant influences on the whole housing market, particularly for larger houses. Specifically, the coefficient for the elderly-dependency ratio in the model with the dependent variable measuring the whole housing market is equal to - 0.1790 and is statistically significant at the 0.1% level ($p < .001$). It suggests that every one percent increase in the elderly-dependency ratio is associated with a 0.1790 percent decrease in the median value for owner-occupied housing units, holding time-invariant characteristics of counties constant. The coefficient for the elderly-dependency ratio in the model with the house value for units with three bedrooms as the dependent variable is equal to - 0.1279 and is statistically significant at the 1% level ($p < .01$). It suggests that every one percent increase in the elderly-dependency ratio is associated with a 0.1279 percent decrease in the median value for owner-occupied housing units with three bedrooms, holding time-invariant characteristics of counties constant. The coefficient for the elderly-dependency ratio in the model with the house value for units with four bedrooms or more as the dependent variable is equal to - 0.1755 and is statistically significant at the 0.1% level ($p < .001$). It suggests that every one percent increase in the elderly-dependency ratio is associated with a 0.1755 percent decrease in the median value for owner-occupied housing units with four bedrooms, holding other variables constant. However, the coefficient of elderly-dependency ratio for the small homes indicated by units with two bedrooms or less is substantively small (= - 0.0037) and not statistically significant.

I then move to interpret the time dummies and R-squared values. In general, the coefficients of time dummies in 2000 and 2010 are all positive values and statistically significant, which suggests that housing prices had increased over time from 1990 to 2000 and from 1990 to 2010. Specifically, housing prices indicated by the house price index increased by 30.42 percent from 1990 to 2000 and by 57.46 percent from 1990 to 2010, holding time-invariant characteristics of counties constant. Compared to the indicator of the house price index, housing prices indicated by the house value show a limited increase over time. Taking the model with the house value for the whole market as the dependent variable as an example, housing prices increased by only 5.91 percent from 1990 to 2000 and by 22.57 percent from 1990 to 2010, holding time-invariant characteristics of counties constant. Before interpreting the R-squared values for each model in Table 4.2, I begin with introducing what the R-squared value in the fixed effects model represents. The R-squared in the fixed effects model indicates that how much of the within-county variation in the dependent variables (i.e., the house price index or the median house value), can be explained by within-county variation in the independent variable (i.e., the elderly-dependency ratio in this thesis) and the national time trends (i.e., time dummies in 2000 and 2010 shown in this thesis). The R-squared values in Table 4.2 show that overall, the values for the models with the house value as the dependent variables are relatively small (ranging between 0.258 and 0.441), compared to the value in the model with the house price index as the dependent variable (= 86.4). Specifically, the R-squared value in the model with the house value as the dependent variable is 0.441, which suggests that 44.1 percent of the within-county variation in the value for owner-occupied housing units can be explained by within-county variation in the elderly-dependency ratio and the national time trends. The R-squared value in the model with the house price index as the dependent variable is 0.864, which suggests that 86.4 percent of the within-county variation in the house price index is explained by within-county variation in the elderly-dependency ratio and the national time trends.

Now, I turn to an analysis to examine whether the effects of population aging persist in the housing market after controlling for a series of physical, demographic, and socio-economic factors. Table 4.3 shows the regression outcomes by controlling for the total population, the total housing units, the per capita income, the housing user costs, the unemployment rate, and the number of single-family housing units.

Table 4.2. Regression Outcomes without Control Variables.

	(1)	(2)	(3)	(4)	(5)
	Logarithm of House Price Index	Logarithm of House Value	Logarithm of House Value for Units with Two Bedrooms or less	Logarithm of House Value for Units with Three Bedrooms	Logarithm of House Value for Units with Four Bedrooms or more
Logarithm of Elderly-dependency Ratio	-0.1405**	-0.1790***	-0.0037	-0.1279**	-0.1755***
	(-0.047)	(-0.0474)	(-0.0708)	(-0.0457)	(-0.0529)
2000.year	0.3042***	0.0591***	0.0987***	0.0291*	0.0591***
	(-0.0079)	(-0.0115)	(-0.0138)	(-0.0115)	(-0.0115)
2010.year	0.5746***	0.2257***	0.2220***	0.1476***	0.1860***
	(-0.0096)	(-0.0097)	(-0.0128)	(-0.0098)	(-0.0107)
_cons	4.7155***	12.1306***	11.1776***	11.9699***	12.4363***
	(-0.1394)	(-0.1407)	(-0.2111)	(-0.1355)	(-0.1569)
N	1224	1224	1224	1224	1224
R-sq	0.864	0.441	0.334	0.258	0.328
*Standard errors in parentheses; * p<.05, ** p<.01, *** p<.001*					

4.2. Model with Physical, Demographic, and Socio-economic Control Variables

After including the control variables in Table 4.3, the regression results show that the coefficient of the elderly-dependency ratio in the model with the housing price index as the dependent variable becomes much smaller and is no longer statistically significant, while the coefficients of the elderly-dependency ratio in the models with the house value as the dependent variables remain more or less unchanged. Specifically, the coefficient of the elderly-dependency ratio in the model with the house price index as the dependent variable significantly decreases from - 0.1405 to - 0.0011, and the coefficient becomes not statistically significant.

In terms of the effects of control variables in the model with the house price index as the dependent variable, both the total population and the per capita income are positively related with the performance of the housing market as predicted. The coefficient of the total population is equal to 0.6753 and is statistically significant at the 0.1% level ($p < .001$), which suggests that a one percent increase in the total population results in a 0.6753 percent increase in housing prices over counties, holding the other variables constant. The coefficient of the per capita income is equal to 1.0654 and is statistically significant at the 0.1% level ($p < .001$), which suggests that a one percent increase in the per capita income results in a 1.0654 percent increase in housing prices over counties, holding the other variables constant. The regression results also show that the total housing units and the unemployment rate are negatively associated with housing prices, which suggests that increases in the size of the housing stock and the higher the unemployment rate are associated with decreases in housing prices. Specifically, the coefficient of the total housing units is equal to - 0.8786 and is statistically significant at the 0.1% level ($p < .001$), which suggests that a one percent increase in the total housing units is associated with a 0.8786 percent decrease in housing prices over counties, holding the other variables constant. The coefficient of the unemployment rate is equal to - 1.1209 and is statistically significant at the 1% level ($p < .01$), which suggests that a one percent unit increase in the unemployment rate is associated with a 1.1209 percent decrease in housing prices, holding the other variables constant. In addition, the coefficients for the housing user costs and the single-family units are not statistically significant in the model with the house price index as the dependent variable.

In the models with the house value as the dependent variables, the regression results show that the effects of population aging vary over the housing submarkets categorized by housing size. In particular, the increase in the elderly population has negative effects on housing values for the whole market and the value of larger homes but shows no association with the value of smaller homes. Specifically, the coefficient for the elderly-dependency ratio in the model with housing value for the whole market is equal to - 0.1893 and is statistically significant at the 0.1% level ($p < .001$), which suggests that a one percent increase in the elderly-dependency ratio is associated with a 0.1893 percent decrease in housing values, holding other variables constant. The coefficient of the elderly-dependency ratio in the model with the house value for units with three bedrooms is - 0.1088 and is statistically significant at the 5% level ($p < .05$), which suggests that a one percent increase in the elderly-dependency ratio is associated with a 0.1088 percent decrease in house value for units with three bedrooms, holding the other variables constant. The coefficient of the elderly-dependency ratio in the model with the house value for units with four bedrooms or more is - 0.1368 and is statistically significant at the 1% level ($p < .01$), suggesting that a one percent increase in the elderly-dependency ratio is associated with a 0.1368 percent decrease in the median house value for units with four bedrooms or more, holding the other variables constant. However, the coefficient of the elderly-dependency ratio in the model with the house value for units with two bedrooms or less is not statistically significant.

The regression results for the elderly-dependency ratio in Table 4.3 suggest that population aging has heterogeneous effects across the housing market segments indicated by housing size. The same conclusion applies to the control variables. Contrary to the model with the house price index as the dependent variable, the total population shows negative effects on the house value for units with two bedrooms or less and units with four bedrooms or more, but no statistically significant association with housing values for the whole housing market and units with three bedrooms. Specifically, the coefficient of the total population in the model with the house value for units with two bedrooms is equal to - 0.6767 and is statistically significant at the 0.1% level ($p < .001$), which suggests that a one percent increase in the total population is associated with a 0.6767 percent decrease in the house value for units with two bedrooms or less, holding the other variables constant.

Table 4.3. Regression Outcomes with Physical, Demographic, and Socio-economic Variables.

	(1)	(2)	(3)	(4)	(5)
	Logarithm of House Price Index	Logarithm of House Value	Logarithm of House Value for Units with Two Bedrooms or less	Logarithm of House Value for Units with Three Bedrooms	Logarithm of House Value for Units with Four Bedrooms or more
Logarithm of Elderly-dependency Ratio	-0.0011	-0.1893***	-0.032	-0.1088*	-0.1368**
	(-0.0427)	(-0.0485)	(-0.0669)	(-0.046)	(-0.0511)
Logarithm of Total Population	0.6753***	-0.1984	-0.6767***	-0.2258	-0.3568**
	(-0.122)	(-0.1399)	(-0.1987)	(-0.1328)	(-0.1349)
Logarithm of Housing Units	-0.8786***	0.3410*	0.7747***	0.2541	0.2978
	(-0.1361)	(-0.1572)	(-0.2211)	(-0.1491)	(-0.1529)
Logarithm of Per Capita Income	1.0654***	1.2404***	1.3296***	1.3143***	1.3411***
	(-0.0854)	(-0.1017)	(-0.1336)	(-0.0984)	(-0.1034)
Logarithm of Housing User Costs	-0.1011	-0.0932	-0.2344**	-0.0973	-0.0572
	(-0.0532)	(-0.0581)	(-0.0767)	(-0.0624)	(-0.0654)
Unemployment Rate	-1.1209**	-0.1393	-0.487	-0.1319	0.0065
	(-0.3644)	(-0.3795)	(-0.5302)	(-0.3801)	(-0.4217)
Logarithm of Single-family Housing Units	0.0063	-0.0200*	-0.008	-0.0222*	-0.0133
	(-0.0099)	(-0.0097)	(-0.0154)	(-0.0094)	(-0.0117)
2000.year	0.2251***	-0.0751***	-0.0606***	-0.0961***	-0.0559***
	(-0.0118)	(-0.0141)	(-0.018)	(-0.014)	(-0.0154)
2010.year	0.7174***	0.1975***	0.2085***	0.1490***	0.2078***
	(-0.0148)	(-0.017)	(-0.0224)	(-0.017)	(-0.0192)
_cons	-3.7245***	-0.7214	-0.5384	-0.3165	0.5726
	(-0.9437)	(-1.1487)	(-1.518)	(-1.1449)	(-1.1914)
N	1224	1224	1224	1224	1224
R-sq	0.915	0.589	0.501	0.457	0.516
*Standard errors in parentheses; * p<.05, ** p<.01, *** p<.001*					

The coefficient of the total population in the model with the house value for units with four bedrooms or more is equal to - 0.3568 and is statistically significant at the 1% level ($p < .01$). This suggests that a one percent increase in the total population is associated with a 0.3568 percent decrease in the house value for units with four bedrooms or more, holding the other variables constant. Also, the current housing stock is positively associated with the house value, but still in heterogeneous ways. The regression results in Table 4.3 show that the total housing units show positive effects on the house value for the whole market and units with two bedrooms or less, but no statistically significant association with house values for units with three bedrooms or more. Specifically, the coefficient of the total housing units in the model with the house value for the whole market is equal to 0.3410 and is statistically significant at 5% level ($p < .05$), suggesting that a one percent increase in the total housing units is associated with a 0.3410 percent increase in the median house value for the whole market, holding the other variables constant. The coefficient of the total housing units in the model with the house value for units with two bedrooms or less is equal to 0.7747 and is statistically significant at 0.1% level ($p < .001$), which suggests that a one percent increase in the total housing units is associated with a 0.7747 percent increase in the house value for units with two bedrooms or less, holding other variables constant. In addition, the results also suggest that the housing user costs only show negative effects on the house value for units with two bedrooms or less, but no statistically significant impact on the house value for the whole market or for units with three bedrooms or more. Specifically, the coefficient of the user costs in the model with the house value for units with two bedrooms or less is equal to - 0.2344 and is statistically significant at 1% level ($p < .01$), which suggests that a one percent increase in the total user costs in a housing unit is associated with 0.2344 percent decrease in the house value for units with two or less bedrooms.

In brief, after incorporating additional control variables, the coefficient of the elderly-dependency ratio is not statistically significant in the model with the house price index as the dependent variable, while the elderly-dependency ratio shows negative effects on the house value for the whole market and units with three bedrooms or more, but no statistically significant impact on small homes, as indicated by units with two bedrooms or less. Turning to the R-square values, as the control variables are included, these values increase to nearly 50 percent in the models with the house value as the dependent variable. Also, the R-square value increases from 86.4 percent to 91.5 percent in the model with the house price index as the dependent variable, which means 91.5 percent of the within-county variation in the house price index can be explained by within-county variation in the elderly-dependency ratio and the other control variables.

4.3. Model with Age-related Variables only Calculated for the Elderly Population

As prior studies suggest that the negative effects of population aging on the housing market are attributable to decreasing and limited income among the elderly population as they reach retirement age, I suspected that age-related factors among the elderly population may contribute to the impact of population aging on the local housing market. In this section, I develop an improved regression model by adding age-related factors specifically calculated for the elderly population. Table 4.4 shows the regression outcomes after adding the per capita income among the elderly and the homeownership rate among the elderly.

In general, the regression results in Table 4.4 show that, compared to the regression results shown in the full regression model (see Table 4.3), the coefficients of the elderly-dependency ratio do not change significantly in the improved model. The coefficient of the elderly-dependency ratio decreases from - 0.1893 to - 0.1918 in the model with the house value for the whole market variable and remains statistically significant at the 0.1% level ($p < .001$). The coefficient of the elderly-dependency ratio increases from - 0.1088 to - 0.0990 in the model with the house value for units with three bedrooms as the dependent variable and remains statistically significant at the 5% level ($p < .05$). The coefficient of the elderly-dependency ratio increases from - 0.1368 to - 0.1348 in the model with the house value for units with four bedrooms or more as the dependent variable and is statistically significant at the 1% level ($p < .01$). As with the regression results shown in the full model, the coefficients of the elderly-dependency ratio in the models with the house price index and the house value for units with two bedrooms or less are still not statistically significant.

Turning to the age-related variables specifically calculated for the elderly population, overall, the regression results in Table 4.4 show that the homeownership rate among the elderly have significant negative effects on the housing prices indicated by the house value for the whole market, and the per capita income specifically calculated for the elderly have positive effects on the housing prices, as indicated by the house value for the whole market and units with two bedrooms or less. However, both the homeownership rate and the per capita income among the elderly show no statistically significant effects on the housing prices indicated by the house price index. Specifically, the coefficient of the homeownership rate among the elderly is equal to -0.5848 in the model with the house value for the whole market and is statistically significant at the 5% level ($p < .05$), which suggests that a one percent unit increase in the homeownership rate among the elderly is associated with a 0.5848 percent decrease in the house value for the whole market, holding the other variables constant. The coefficient of the per capita income among the elderly is equal to 0.1770 in the model with the house value for the whole market and is statistically significant at the 5% level ($p < .05$), which suggests that a one percent increase in the per capita income among the elderly is associated with a 0.1770 percent increase in the house value, holding the other variables constant.

Table 4.4. Regression Outcomes with Age-related Variables only Calculated for the Elderly.

	(1)	(2)	(3)	(4)	(5)
	Logarithm of House Price Index	Logarithm of House Value	Logarithm of House Value for Units with Two Bedrooms or less	Logarithm of House Value for Units with Three Bedrooms	Logarithm of House Value for Units with Four Bedrooms or more
Logarithm of Elderly-dependency Ratio	-0.0019	-0.1918***	-0.0561	-0.0990*	-0.1348**
	(-0.0436)	(-0.0503)	(-0.0685)	(-0.0473)	(-0.052)
Logarithm of Total Population	0.6741***	-0.2139	-0.6725**	-0.2491	-0.3692**
	(-0.1224)	(-0.1433)	(-0.2057)	(-0.1355)	(-0.137)
Logarithm of Housing Units	-0.8807***	0.3300*	0.7340**	0.2612	0.2961
	(-0.1367)	(-0.1602)	(-0.226)	(-0.1515)	(-0.1548)
Logarithm of Per Capita Income	1.0565***	1.1816***	1.2007***	1.3046***	1.3175***
	(-0.0898)	(-0.1074)	(-0.1344)	(-0.1042)	(-0.1081)
Logarithm of Housing User Costs	-0.1007	-0.0906	-0.2295**	-0.0963	-0.0559
	(-0.0532)	(-0.0577)	(-0.0748)	(-0.0627)	(-0.0656)
Unemployment Rate	-1.1435**	-0.3024	-0.7746	-0.1966	-0.0704
	(-0.3679)	(-0.3947)	(-0.529)	(-0.3936)	(-0.4296)
Logarithm of Single-family Housing Units	0.0057	-0.0237*	-0.0159	-0.0229*	-0.0148
	(-0.0101)	(-0.01)	(-0.0159)	(-0.0097)	(-0.012)
Ownership Rate among the Elderly	-0.0691	-0.5848*	-0.5965	-0.469	-0.3466
	(-0.2318)	(-0.2421)	(-0.3306)	(-0.2497)	(-0.2738)
Logarithm of Per Capita Income among the Elderly	0.0253	0.1770*	0.3406***	0.0549	0.0788
	(-0.0635)	(-0.0767)	(-0.1022)	(-0.0725)	(-0.0822)
2000.year	0.2236***	-0.0840***	-0.0856***	-0.0947***	-0.0587**
	(-0.0134)	(-0.0166)	(-0.0223)	(-0.0162)	(-0.0179)
2010.year	0.7164***	0.1932***	0.1865***	0.1551***	0.2081***
	(-0.0166)	(-0.0194)	(-0.0254)	(-0.019)	(-0.0222)
_cons	-3.7768***	-1.01	-1.4988	-0.1856	0.5101
	(-0.964)	(-1.2038)	(-1.5829)	(-1.1953)	(-1.2407)
N	1224	1224	1224	1224	1224
R-sq	0.915	0.595	0.511	0.46	0.518

Standard errors in parentheses;
** p<.05, ** p<.01, *** p<.001*

The coefficient of the per capita income among the elderly is equal to 0.3406 in the model with the house value calculated for units with two bedrooms or less and is statistically significant at the 0.1% level ($p < .001$), which suggests that a one percent increase in the per capita income among the elderly is associated with a 0.3406 percent increase in the house value for units with two bedrooms or less, holding other variables constant. However, the coefficients of the homeownership rate among the elderly are not statistically significant in the model with the house value for units with two bedrooms or more, and the coefficients of the per capita income among the elderly are not statistically significant in the model with the house value calculated for units with three bedrooms or more. These results suggest that the economic status among the elderly population is positively related to housing prices of small homes, which is consistent with the statement that the elderly population are more likely to live in small housing units mentioned in prior studies.

4.4. Models by Percentage of Population inside Urbanized Areas

Since the housing market is closely related to urban structure, this section further explores whether the effects of population aging on the local housing market vary by urban areas. To so do, I used the percentage of the population who live in urbanized areas to indicate whether the housing units are located in rural areas, suburban areas, urban areas, or inner cities. Specifically, I obtained data for the percentage of the population who live in urbanized areas at the county level from IPUMS USA. I then categorized the county-level dataset into four housing submarkets by the percentage of the population who live in urbanized areas: 1) the percentage of the population who live in urbanized areas is equal to zero, 2) the percentage is greater than zero, and is less than and equal to 50 percent, 3) the percentage is greater than 50 percent and less than 100 percent, 4) the percentage is equal to 100 percent. For each housing submarket, I estimated fixed effects model to investigate if the association between the elderly-dependency ratio and housing prices differed across areas with varying degrees of urbanization. Table 4.5- 4.8 show the regression outcomes for each model to capture the four different housing submarkets categorized by urban area. Overall, from Table 4.5- 4.8, the regression results show that the sample size is much larger in the areas in which the percentage of the population who live in urbanized areas is greater than 50 percent and less than 100 percent (i.e., almost 286 counties) than the other three housing submarkets. In total, there were only 34 counties in which no residents live in urbanized areas; 69 counties in which the percentage of the population who live in urbanized areas is greater than zero and equal to or less than 50 percent; and 20 counties in which all people live in urbanized areas.

To interpret the regression results in Table 4.5- 4.8, in general, the effects of population aging on housing prices appear to vary somewhat by urban area. Table 4.5 shows that the increase in the population aged 65 years old and above appears to have no statistically significant impact on housing prices in rural areas as indicated by both the house price index and the house value. It may suggest that the issue of population aging have little or no effects on the housing market in rural areas, however, the sample size of 34 counties may be too small to identify a statistically significant relationship.

Table 4.5. Percentage of Population inside Urbanized Areas = 0.

	(1)	(2)	(3)	(4)	(5)
	Logarithm of House Price Index	Logarithm of House Value	Logarithm of House Value for Units with Two Bedrooms or less	Logarithm of House Value for Units with Three Bedrooms	Logarithm of House Value for Units with Four Bedrooms or more
Logarithm of Elderly-dependency Ratio	-0.0259	0.0222	0.1465	-0.0795	-0.0704
	(-0.2012)	(-0.2287)	(-0.2723)	(-0.2524)	(-0.238)
Logarithm of Total Population	0.5547	-0.0093	-0.1231	0.3212	-0.0583
	(-0.377)	(-0.5879)	(-0.7396)	(-0.665)	(-0.5382)
Logarithm of Housing Units	-0.5298	0.2704	0.3294	-0.099	0.2442
	(-0.3683)	(-0.6211)	(-0.7287)	(-0.7017)	(-0.5168)
Logarithm of Per Capita Income	0.2933	0.8944	1.2565	0.7826	0.7592
	(-0.334)	(-0.4709)	(-0.6398)	(-0.4395)	(-0.4106)
Logarithm of Housing User Costs	-0.0341	0.0836	-0.213	0.055	0.0054
	(-0.1393)	(-0.1666)	(-0.1887)	(-0.1908)	(-0.1949)
Unemployment Rate	-1.9393	-1.3858	-2.6184	-0.7465	-1.3229
	(-1.1787)	(-1.4191)	(-1.8263)	(-1.4156)	(-1.4035)
Logarithm of Single-family Housing Units	0.0415	-0.0073	0.0125	0.0157	-0.0129
	(-0.0406)	(-0.0465)	(-0.0586)	(-0.0424)	(-0.0471)
Ownership Rate among the Elderly	0.9075	-1.7278	-1.6624	-0.8205	0.2726
	(-0.9731)	(-1.1152)	(-1.4531)	(-1.2895)	(-1.3617)
Logarithm of Per Capita Income among the Elderly	-0.0825	-0.0878	-0.2631	-0.3923	-0.1186
	(-0.1839)	(-0.264)	(-0.3851)	(-0.2396)	(-0.2417)
2000.year	0.2865***	0.0054	0.0106	0.0578	0.043
	(-0.0593)	(-0.0849)	(-0.1071)	(-0.0816)	(-0.0739)
2010.year	0.6929***	0.2471	0.3573*	0.2628*	0.2123
	(-0.0977)	(-0.1335)	(-0.1522)	(-0.124)	(-0.11)
_cons	0.8501	1.5951	1.7412	5.2539	3.5659
	(-4.1273)	(-5.4252)	(-6.5268)	(-5.1472)	(-4.7072)
N	101	101	101	101	101
R-sq	0.91	0.681	0.623	0.528	0.569

Standard errors in parentheses;
** p<.05, ** p<.01, *** p<.001*

The regression results in Table 4.6 estimate the relationship between the elderly-dependency ratio and housing prices/values for counties in which between zero percent and 50 percent of the population live in urbanized areas. The results show that the increase in the population aged 65 years old and above has negative effects on the house value but no statistically significant impact on the house price index. Specifically, the coefficient of the elderly-dependency ratio in the model with the house value is equal to - 0.4991 and is statistically significant at the 1% level ($p < 0.01$), which suggests that a one percent increase in the elderly-dependency ratio is associated with a 0.4991 percent decrease in the house value for the whole market, holding the other variables constant. The coefficient of the elderly-dependency ratio in the model with the house value for units with three bedrooms is equal to - 0.2885 and is statistically significant at the 5% level ($p < 0.05$), which suggests that a one percent increase in the elderly-dependency ratio is associated with a 0.2885 percent decrease in the house value for units with three bedrooms, holding the other variables constant. The coefficient of the elderly-dependency ratio in the model with the house value for units with four bedrooms or more as the dependent variable is equal to - 0.4002 and statistically significant at the 1% level ($p < 0.01$), which suggests that a one percent increase in the elderly-dependency ratio is associated with a 0.4002 percent decrease in the house value for units with four bedrooms or more, holding the other variables constant. However, the coefficient of the elder-dependency ratio in the model with the house value for units with two bedrooms as the dependent variable is not statistically significant.

Table 4.6. Percentage of Population inside Urbanized Areas > 0 & <= 50.

	(1)	(2)	(3)	(4)	(5)
	Logarithm of House Price Index	Logarithm of House Value	Logarithm of House Value for Units with Two Bedrooms or less	Logarithm of House Value for Units with Three Bedrooms	Logarithm of House Value for Units with Four Bedrooms or more
Logarithm of Elderly-dependency Ratio	-0.1773	-0.4991**	-0.2429	-0.2885*	-0.4002**
	(-0.1076)	(-0.1474)	(-0.1972)	(-0.136)	(-0.1266)
Logarithm of Total Population	-0.6272	-1.2568**	-1.5280**	-1.4691**	-0.9736**
	(-0.3736)	(-0.4607)	(-0.5528)	(-0.4392)	(-0.3633)
Logarithm of Housing Units	0.4768	1.4081**	1.7004**	1.5138**	1.0152*
	(-0.4345)	(-0.5266)	(-0.635)	(-0.5155)	(-0.4243)
Logarithm of Per Capita Income	1.1991***	1.1263***	1.4907***	1.1812***	1.1874***
	(-0.1878)	(-0.2723)	(-0.3401)	(-0.2828)	(-0.2429)
Logarithm of Housing User Costs	0.1011	0.0228	-0.0247	0.0582	0.1053
	(-0.1221)	(-0.1787)	(-0.221)	(-0.171)	(-0.1567)
Unemployment Rate	0.0692	0.8722	1.3498	0.6879	0.2459
	(-0.6143)	(-0.9398)	(-1.1212)	(-0.949)	(-0.7499)
Logarithm of Single-family Housing Units	0.0333	0.0067	-0.0294	0.0128	0.0062
	(-0.0201)	(-0.0213)	(-0.0353)	(-0.0228)	(-0.0199)
Ownership Rate among the Elderly	-0.4458	-0.7182	-0.362	-1.0479	-0.1077
	(-0.4133)	(-0.6054)	(-0.8024)	(-0.5647)	(-0.4915)
Logarithm of Per Capita Income among the Elderly	0.0739	0.2175	0.3919	0.1154	-0.0665
	(-0.1753)	(-0.2307)	(-0.2837)	(-0.2329)	(-0.2046)
2000.year	0.1845***	-0.0866	-0.0643	-0.0866	-0.0144
	(-0.0293)	(-0.0502)	(-0.0564)	(-0.0449)	(-0.0463)
2010.year	0.5954***	0.1164	0.0411	0.081	0.1796**
	(-0.0476)	(-0.0708)	(-0.0893)	(-0.0682)	(-0.0627)
_cons	-6.1321**	-0.2896	-6.4907	0.8205	1.6251
	(-1.8642)	(-3.0491)	(-3.696)	(-3.0445)	(-2.631)
N	207	207	207	207	207
R-sq	0.915	0.569	0.573	0.46	0.518
Standard errors in parentheses; * p<.05, ** p<.01, *** p<.001					

Turning to the housing submarkets in highly urbanized areas (i.e., those in which between 50 and 99 percent of the population reside in urbanized areas), the regression results are shown in Table 4.7- 4.8. The regression results in Table 4.7 show that the increase in the population aged 65 years old and above has positive effects on the house price index. Specifically, the coefficient of the elderly-dependency ratio in the model with the house price index as the dependent variable is equal to - 0.1175 and is statistically significant at the 1% level ($p < 0.01$), which suggests that a one percent increase in the elderly-dependency ratio is associated with a 0.1175 percent increase in the house price index, holding other variables constant. Also, the coefficients of the elderly-dependency ratio in the model with the house value for units with two bedrooms or less and units with three bedrooms become positive, even though the coefficients are not statistically significant. I also notice that in Table 4.7, the coefficient of the per capita income for the elderly population in the model with the house value for units with two bedrooms or less is much larger and is statistically significant, compared to the coefficients in other models. Specifically, the coefficient of the per capita income calculated for the elderly in the model with the house value for units with two bedrooms or less is equal to 0.3731 and is statistically significant at the 1% level ($p < 0.01$), which suggests that a one percent increase in the per capita income among the elderly is associated with a 0.3731 percent increase in the house value for units with two bedrooms or less, holding the other variables constant. This result may suggest that compared to rural areas, the elderly population are more likely to live in largely urbanized areas but not fully urbanized areas/inner cities.

Table 4.7. Percentage of Population inside Urbanized Areas > 50 & < 100.

	(1)	(2)	(3)	(4)	(5)
	Logarithm of House Price Index	Logarithm of House Value	Logarithm of House Value for Units with Two Bedrooms or less	Logarithm of House Value for Units with Three Bedrooms	Logarithm of House Value for Units with Four Bedrooms or more
Logarithm of Elderly-dependency Ratio	0.1175**	-0.0913	0.0591	0.0119	-0.0141
	(-0.0439)	(-0.0504)	(-0.0703)	(-0.0456)	(-0.0481)
Logarithm of Total Population	0.9198***	-0.0078	-0.4933	0.0034	-0.1416
	(-0.1394)	(-0.1618)	(-0.2545)	(-0.1417)	(-0.1534)
Logarithm of Housing Units	-1.1213***	0.1311	0.5706*	0.0157	0.0626
	(-0.1563)	(-0.1763)	(-0.2782)	(-0.1566)	(-0.1724)
Logarithm of Per Capita Income	1.2124***	1.3416***	1.2065***	1.4684***	1.5319***
	(-0.101)	(-0.1171)	(-0.1473)	(-0.1107)	(-0.1239)
Logarithm of Housing User Costs	-0.1519**	-0.1489*	-0.2739**	-0.1475*	-0.1319
	(-0.0579)	(-0.0634)	(-0.084)	(-0.0716)	(-0.0706)
Unemployment Rate	-0.7544*	0.1158	-0.3035	0.1177	0.53
	(-0.3649)	(-0.422)	(-0.5871)	(-0.4432)	(-0.4843)
Logarithm of Single-family Housing Units	0.0049	-0.0225	-0.0033	-0.0261*	-0.012
	(-0.0097)	(-0.0117)	(-0.0177)	(-0.0121)	(-0.0128)
Ownership Rate among the Elderly	-0.2923	-0.4755	-0.6124	-0.3554	-0.2162
	(-0.2552)	(-0.2735)	(-0.3918)	(-0.2894)	(-0.3217)
Logarithm of Per Capita Income among the Elderly	0.0572	0.1386	0.3731**	0.032	0.081
	(-0.0745)	(-0.0897)	(-0.1222)	(-0.083)	(-0.0996)
2000.year	0.2017***	-0.1028***	-0.1109***	-0.1150***	-0.0927***
	(-0.0152)	(-0.0206)	(-0.0277)	(-0.0198)	(-0.0219)
2010.year	0.7018***	0.1833***	0.1557***	0.1421***	0.1897***
	(-0.0172)	(-0.0205)	(-0.0278)	(-0.0195)	(-0.0227)
_cons	-5.6864***	-2.5077	-2.3446	-1.9445	-1.6956
	(-1.1359)	(-1.44)	(-1.861)	(-1.3422)	(-1.3764)
N	857	857	857	857	857
R-sq	0.924	0.6	0.502	0.457	0.532

Standard errors in parentheses;
** p<.05, ** p<.01, *** p<.001*

In Table 4.8, overall, the regression results show the effects of population aging on the housing submarket in fully urbanized areas/inner cities. Table 4.8 suggests that increases in the population aged 65 years old and above has negative effects on the house value for the whole market and units with three bedrooms, but no statistically significant impact on the house price index, and housing values for units with two bedrooms or less, and values for units with four bedrooms or more. Specifically, the coefficient of the elderly-dependency ratio in the model with house values for the whole market as the dependent variable is equal to - 0.4735 and is statistically significant at the 1% level ($p < 0.01$), which suggests that a one percent increase in the elderly-dependency ratio is associated with a 0.4735 percent decrease in the house value for the whole market, holding the other variables constant. The coefficient of the elderly-dependency ratio in the model with the house value for units with three bedrooms is equal to - 0.3244 and is statistically significant at the 5% level ($p < 0.05$), which suggests that a one percent increase in the elderly-dependency ratio is associated with a 0.3244 percent decrease in the house value for units with three bedrooms, holding the other variables constant.

Table 4.8. Percentage of Population inside Urbanized Areas = 100.

	(1)	(2)	(3)	(4)	(5)
	Logarithm of House Price Index	Logarithm of House Value	Logarithm of House Value for Units with Two Bedrooms or less	Logarithm of House Value for Units with Three Bedrooms	Logarithm of House Value for Units with Four Bedrooms or more
Logarithm of Elderly-dependency Ratio	-0.0236	-0.4735**	-0.3413	-0.3244*	-0.2564
	(-0.1147)	(-0.1631)	(-0.1641)	(-0.1314)	(-0.2271)
Logarithm of Total Population	0.3336	-0.4944	-0.4181	-0.5686	-0.2816
	(-0.4755)	(-0.6429)	(-0.7204)	(-0.5054)	(-0.8632)
Logarithm of Housing Units	-0.5801	0.4194	0.528	0.1087	-0.3253
	(-0.56)	(-0.8679)	(-0.8228)	(-0.7354)	(-1.1346)
Logarithm of Per Capita Income	0.4299*	0.2779	0.3137	0.4891	0.6229
	(-0.1963)	(-0.2721)	(-0.304)	(-0.2678)	(-0.3158)
Logarithm of Housing User Costs	-0.0824	0.0502	-0.2201	-0.127	0.4539
	(-0.1937)	(-0.2513)	(-0.2405)	(-0.2515)	(-0.4198)
Unemployment Rate	-4.8657*	-5.3632*	-2.9133	-3.9915	-1.5564
	(-2.288)	(-2.4941)	(-2.3233)	(-1.9352)	(-2.7546)
Logarithm of Single-family Housing Units	-0.0029	-0.0327	-0.049	-0.0344	-0.0238
	(-0.0232)	(-0.0201)	(-0.0283)	(-0.0208)	(-0.0337)
Ownership Rate among the Elderly	-0.7262	-1.7078	-2.1034	-0.4915	-2.7048
	(-0.8098)	(-1.1319)	(-1.3591)	(-0.9112)	(-1.6084)
Logarithm of Per Capita Income among the Elderly	0.0001	0.8882**	0.7239*	0.5884*	0.4195
	(-0.2147)	(-0.2641)	(-0.2696)	(-0.2267)	(-0.3548)
2000.year	0.2570***	-0.1500**	-0.1656**	-0.2145***	-0.0287
	(-0.0353)	(-0.0413)	(-0.05)	(-0.0401)	(-0.0792)
2010.year	0.9614***	0.3369**	0.3339**	0.2832**	0.4194**
	(-0.0865)	(-0.0954)	(-0.0949)	(-0.0826)	(-0.1388)
_cons	4.3365	4.7847	5.2044	10.3793	8.925
	(-6.0006)	(-7.249)	(-7.2526)	(-7.3915)	(-9.1927)
N	59	59	59	59	59
R-sq	0.974	0.87	0.861	0.896	0.817

Standard errors in parentheses;
** p<.05, ** p<.01, *** p<.001*

CHAPTER 5. DISCUSSION AND CONCLUSION

5.1. Discussion

This study aimed to examine two research questions: 1) How do housing prices in counties within the U.S. respond to changes in the number of individuals aged 65 years old and above; 2) Do the impacts of population aging on the housing market differ by housing size. To investigate the first research question, I used the house price index and house value to capture the fluctuations of the housing market over two decades from 1990 to 2010, and the elderly-dependency ratio was used to indicate the increase in the elderly population aged 65 years old and above. Turning to the second research question, I constructed three additional dependent variables (i.e., the house value for units with two bedrooms or less, the house value for units with three bedrooms, and the house value for units with four bedrooms or more) to measure changes in housing prices in different housing submarkets categorized by the number of bedrooms. These three house values calculated for the housing submarkets by housing size are used to investigate if the effects of the increase in the population aged 65 years old and above are the same for houses of different sizes. This expands research on the potential "heterogeneous effects" of population aging examined by previous authors (Hiller & Lerbs, 2016).

The main findings in my thesis include the following: 1) the increase in the population aged 65 years old and above do appear to show negative effects on the local housing market, but these effects are less likely to cause dramatic changes in the housing market; 2) the effects of population aging on the housing market differ by housing size: the increasing share of the elderly population has significant and negative effects on the overall housing market as well as on larger homes (with three bedrooms or more), but has no statistically significant impact on small homes (with two bedrooms or less); 3) my analysis also shows that population aging has heterogeneous effects on housing submarkets categorized by the percentage of the population who live in urbanized areas. Specifically, the increase in the population aged 65 years old and above decreases housing prices for units located in largely urbanized areas but not units located in rural areas; 4) in the largely urbanized areas in which the percentage of the population who live in urbanized areas is greater than 50 percent, population aging increases the house price index but shows no statistically significant impact on house value. Considering the discrepancy between the methods used to measure and calculate the house price index and house value, this positive effect of population aging on the house price index in largely urbanized areas may suggest that there are other factors which contribute to the increase in housing transaction prices.

I now turn to a brief summary of the literature to draw comparisons between my findings and prior research on the topic. First, Mankiw and Weil found that the increasing elderly population would cause housing prices to decline by 47 percent from 1987 to 2007. Although my analysis suggests that population aging is an important factor that may influence housing prices, it will not likely cause a meltdown as predicted by Mankiw and Weil. This is illustrated by the regression results in my thesis: the coefficient of the elderly-dependency ratio in the model with the house price index as the indicator of the local housing market is equal to - 0.0019, and the coefficient is not statistically significant; turning to the model with house value as the indicator of the local housing market, the coefficient for the elderly-dependency ratio is equal to - 0.1918, which suggests that a one percent increase in the elderly-dependency ratio only decreases house values by a 0.1918 percent decrease. This is a substantially smaller impact than that found in many prior studies. Second, Takats (2012) found that a one percent increase in the elderly-dependency ratio is associated with a 0.6818 percent decrease in housing prices, and Saita, Shimizu, and Watanabe (2016) found that a one percent increase in the elderly-dependency ratio is associated with a 0.9067 percent decrease in housing prices throughout the 50 states across the country. Compared to prior studies conducted at the country level by Takats (2012) and at the state level by Saita, Shimizu, and Watanabe (2016), this county-level study for my thesis suggests that a one percent increase in the elderly-dependency ratio decreases the house value by 0.1918 percent; this suggests that, at the local level, the effect of population aging on the local housing market may be smaller than those derived from national- or state-level analyses. Third, regarding the heterogeneous effects and age-related characteristics, consistent with the work by Hiller and Lerbs (2016), my analysis suggests that population aging has negative effects on the housing market, and that these effects vary over housing submarkets categorized by both housing size and urbanization. Specifically, Hiller and Lerbs' study suggests that a one percent increase in the elderly-dependency ratio is associated with a 0.7856 percent decrease in real condominium prices, and a 0.5155 percent decrease in real single-family house prices. The results in my thesis suggests that a one percent increase in the elderly-dependency ratio is associated with a 0.1918 percent decrease in the house value calculated for the whole market, a 0.0990 percent decrease in the house value for units with three bedrooms, and a 0.1348 percent decrease in the house value for units with four bedrooms or more. However, population aging shows no statistically significant impact on housing transaction prices and the house value for units with two bedrooms or less.

5.2. Conclusion

My analysis contributes to existing literature in the following aspects. First, a study at the county level allows researchers to focus more precisely on the way that the issue of population aging impacts the local housing market (rather than across larger states or the country) and allows for a relatively large sample of 408 observations (counties) over three time periods. Second, I constructed a panel dataset covering 1990 to 2010 using the data at the individual and housing-unit level drawn from IPUM USA. I then estimated fixed effects regression models to control time-invariant factors which might have an impact on housing prices. Third, I calculated house values for units with various number of bedrooms to investigate whether demographic shifts have differential impacts on housing units with varying numbers of bedrooms. Fourth, considering that age-related characteristics (e.g., tenure changes, income changes, and downsizing) among the elderly population might have impacts on housing prices, I improve on prior studies by incorporating age-related control variables specifically calculated for the elderly population: income, homeownership rate, and housing size indicated by the number of bedrooms.

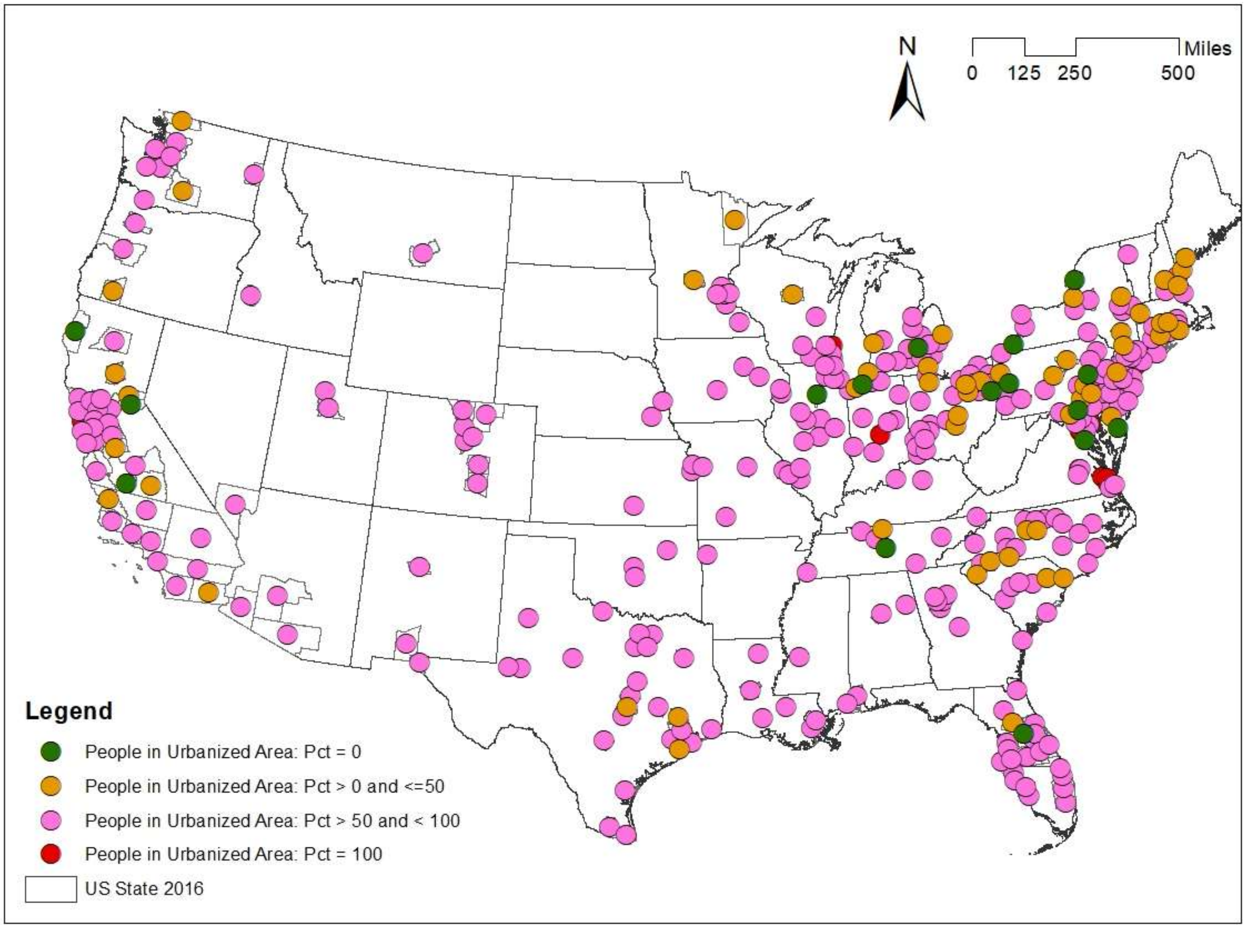
The analysis of this study suggests that population aging does have negative influences on the overall housing market as suggested by some prior research (Levin, Montagnoli, & Wright, 2009; Saita, Shimizu, & Watanabe, 2016; Takats, 2012), however, the effects will not likely cause a crash of the local housing market. The results in this study show that the elderly population aged 65 years old above are more likely to live in small homes because of housing downsizing, and the housing units with two or fewer bedrooms is particularly attractive for the elderly population. In addition, the positive relationship between economic status specifically calculated for the elderly and housing prices suggest that the negative effects of population aging on house value may be counterbalanced as economic conditions among the elderly population improve. These findings are expected to provide suggestions to planners and participants in the housing market who work on providing appropriate house types for various population groups in an aging society.

The results of this study may help planners to implement promising housing policies in an aging society. A study related to demographic structural transitions and the local housing market may help planners and housing developers to evaluate the demand for and supply of newly built housing units, to plan for impending housing market changes such as accommodating new demand

and dealing with excess supply, and to identify investment opportunities in the housing market in specific localities. More importantly, studying the effects of the increase in the population aged 65 years old and above on the local housing market due to age-related factors among the elderly would help planners to understand if and how the increasing elderly population impacts the local housing market. Meanwhile, identifying the housing types that are suitable for the elderly population can help planners to facilitate the appropriate allocation of the newly-built housing units such as units with two bedrooms or less. Providing appropriate housing units for the population aged 65 years old and above benefits the "well-being" of the elderly population and helps them to age in place. Overall, my analysis suggests that the heterogeneous effects of demographics on the housing submarkets needs more attention and that providing housing units which align with various needs from different age groups have become an important topic for planners.

APPENDICES

APPENDIX A. U.S. County Map by Percentage of Population Who Live in Urbanized Areas.



APPENDIX B. Selected Stata Commands for Data Processing.

The following commands were used in Stata to clean and transform individual- and household-level data into county-level estimates.

gen *newvar* = //* generate a new variable

tostring *varlist*, gen(*newvar*) //* convert a numeric variable to a string variable

destring *varlist*, gen(*newvar*) //* convert a string variable to a numeric variable

drop *varlist* //* drop an existing variable

set matsize 11000 //* expand the capacity of Stata

svyset cluster [*pweight=perwt*], strata(strata) //* tell Stata this is a survey data set, and the dataset is weighted by persons

ssc install parmest //* install the parmest package which allows Stata to produce parameter estimates and save the results in Stata version

svy: mean *varlist* if year == *yearlist*, over(*countycode*)

parmest, saving("*newfilename*", replace) //* generate the mean value at the county level for the person-weighted variables

svyset cluster [*pweight=hhwt*], strata(strata) //* tell Stata this is a survey data set, and the dataset is weighted by households

search epctile //* install epctile package

ssc install parmest

epctile *varlist*, percentiles(50) over(*countycode*)

svy parmest, saving("*newfilename*", replace) //* generate the mean value at the county level for the household-weighted variables append using *filename* //* combine two Stata files with the same number of variables

merge 1:1 *countycode yearlist* using *filename*, keep(master match)

drop _merge //* add new variable to the master Stata file

egen *newvarlist*= mean(*varlist*), by(*countycode*)

gen *MeanCenteredVarlist* = *varlist*- *newvarlis* //* generate the mean center value for each variable which is suitable for a panel dataset

xtreg *depedentvar1 varlist* i.*year*, fe cluster(*countycode*)

estimate store m1

xtreg *depedentvar2 varlist* i.*year*, fe cluster(*countycode*)

estimate store m2

xtreg *depedentvar3 varlist* i.*year*, fe cluster(*countycode*)

estimate store m3

xtreg *depedentvar4 varlist* i.*year*, fe cluster(*countycode*)

estimate store m4

xtreg *depedentvar5 varlist* i.*year*, fe cluster(*countycode*)

estimate store m5

esttab m1 m2 m3 m4 m5, se r2 star (* .05 ** .01 *** .001) b(3) //* use the fixed effects model to produce the regression outcomes for a panel dataset

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