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Demographics and Urban Housing Prices: New Evidence from 12 US Cities

Author:

Shane Dunne

596547

Supervisor:

Prof. Dinand Webbink

Second Assessor:

Prof. Ivo Arnold

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Demographics and Urban Housing Prices: New Evidence from 12 US Cities

Abstract

This paper investigates the effects of demographic changes on US urban housing markets. This topic is of importance to policymakers as many countries are faced with a trend towards ageing over the coming decades. Newly developed housing price indices for 12 large US cities from 1970 to 2006 are analysed. The effects of ageing and population growth on real housing sales and rental prices are estimated using a fixed effects methodology, with data on demographics obtained from the US Census Bureau. The most significant demographic driver of housing prices is found to be ageing, with the total population effect less relevant in comparison. Over the coming decades, projected growth in the size and age composition of the US population is expected to reduce housing prices and rents by around 2.5% per year relative to neutral demographic dynamics in which the population size and composition do not change. This forecast is primarily driven by the negative effect of ageing on housing prices as older populations downsize their homes and liquidate real estate assets upon retirement. The projected effects of demographics on housing prices provided in this paper are to be interpreted *ceteris paribus*, as other drivers of housing prices such as credit conditions, average household income, and housing supply are also likely to impact the trajectory of prices. The key message of this paper is not that a decline in housing prices is necessarily predicted, but that policymakers may have upwardly biased projections for the housing market if they neglect the impact that demographics impart on prices.

Contents

1 Introduction

Population ageing is one of the most prominent structural challenges facing advanced economies over the next number of decades. Projected trends towards older population demographics are expected to have wide ranging economic impacts such as labour supply constraints (Börsch-Supan, 2003), increased pressures on health and pension systems, upwards stress on government debt, and reductions in tax revenues (Rouzet et al., 2019). Another less often considered channel through which ageing may impact the economy is through housing markets. As the population ages, economic theory suggests that demand for housing decreases as older people consume less housing services and become more likely to liquidate their housing assets (Hiller & Lerbs, 2016). Consequently, property prices and market rents are expected to decline as a result of ageing. This possible link between ageing and housing prices is of interest to economists and policymakers due to the systemic importance of housing markets in the economy. The great recession of the late 2000s was sparked by the bursting of the US property bubble, while European countries such as Ireland experienced substantial property-related debt crises. At present, China is experiencing fragility in its property market that threatens its own economic model and the fortunes of the global economy. With a demographic transition on the near horizon for China, the US, and for many other countries around the world, never has the question of how ageing affects the housing market been more relevant.

This paper investigates the link between ageing and housing using yearly US data on 12 cities ranging from 1970 to 2006. An empirical approach is taken to answer the question: what is the effect of ageing - measured by the old age dependency ratio - on real housing rental and sales prices? A two-way fixed effects methodology is employed with additional controls for population, income, and racial shares of cities.

A newly produced and never-used data set is analysed in this paper, allowing for a new and unique contribution to the literature. Real rental and sales indices on 12 US cities are obtained from the HiPHoP dataset - a new collection of historic housing price series for the US. The novelty of the data allows for an investigation of the empirical relationship between demographics and housing prices in a geographical location and period of time that has not been studied before in this context.

The main finding of the paper is that ageing is indeed related to a reduction in real housing prices and rents. The average effect of a 1% increase in the old age dependency ratio (the share of population over the age of 65 divided by the share of working age population) is a 1% reduction in real rental prices and a 1.2% reduction in real sales prices. Furthermore, it is found that the impact of total population growth on housing prices is largely statistically insignificant. Sensitivity analysis and a number of robustness tests are conducted in order to support the validity of these results.

The estimated effects of ageing and population growth on housing prices and rents are applied to demographic projections for the US. This results in estimates of the net effect that ageing and population growth are forecast to have on housing prices and rents relative to neutral demographic dynamics in which the population size and composition do not change. Over the remainder of the 2020s, the old age dependency ratio in the US is expected to increase annually by 2.4% on average, and the total population is forecast to increase by 0.4% per year over the same period. Applying the housing price elasticities with respect to ageing and population growth estimated in the main results section, over the 2020s the US can expect a demography-induced average decrease in real rental prices of 2.3% per year and a yearly decrease in real sales costs of 2.8% relative to neutral demographics. These effects should be interpreted *ceteris paribus*, as other drivers of housing prices such as credit conditions, household income, and housing supply are also likely to impact the trajectory of prices. The key message of this paper is not that a decline in housing prices is necessarily predicted, but that policymakers may overestimate future housing prices and rents if they do not account for the impact of demographics on the property market.

The remainder of the paper proceeds as follows. Section 2 encompasses a review of the literature on demographics and the property market. Section 3 discusses the data used in this paper. Section 4 describes the methodology and empirical strategy. Section 5 presents the main results, sensitivity analysis, and robustness checks. Section 6 outlines the application of the results to demographic forecasts for the US. Section 7 discusses the policy implications of the empirical findings of this paper. Finally, section 8 concludes.

2 Literature Review

2.1 Worldwide and US Demographic Trends and Projections

The world is in the midst of a stark demographic change. In the G20, the rate of population growth has been falling since the 1970s with the rate of growth within the working age population declining since the 1980s (IMF, 2019). This trend has been primarily driven by declining fertility rates. The total worldwide fertility rate - number of children per woman - has decreased from around 5 in the 1960s to 2.5 in the 2010s (Roser, 2014), and is projected to fall to 2 by the end of this century (Yoon et al., 2014). Meanwhile, world life expectancy has increased from around 53 years in the 1960s to about 71 in the 2010s (Roser et al., 2013). The confluence of declining fertility and increased life expectancy has led to an increase in the old age dependency ratio (+65 year-olds as a share of working age population) in most advanced economies. The trends observed in fertility and longevity over recent decades are expected to continue over the rest of this century. The old age dependency ratio is forecast to at least double in most G20 countries by 2060, while the global population aged over 80 is expected to triple over the same horizon (Rouzet et al., 2019). It is clear that governments will need to grapple with substantially heightened old age dependency ratios in future.

The US is currently experiencing a process of ageing as the large Baby Boom cohort (born in the 1950s and 1960s) grows older. The old age dependency ratio in the US fluctuated somewhat during the last decades of the 20th century but is now undoubtedly on course to increase. According to the Federal Reserve Bank of St.Louis, US old-age dependency grew from 16.2 per cent in 1970 to 17.6 per cent in 1980 and further to 19.2 per cent in 1990. A slight fall to 18.7 per cent was recorded by 2000 before the series began to pick up again in the mid-2000s, with growth to 19.4 per cent in 2010 and 25.6 per cent in 2020 recorded. Projections from the US Congressional Budget Office forecast that the old age dependency ratio in the US will reach 35 per cent by 2030, 38 per cent in 2040, and 40 per cent in 2050. Growth in the US population is also expected to slow over the coming years with forecasts expecting annual growth of less than 0.5 per cent for the entire forecast period to 2095.

2.2 Impacts of Demographics on Housing Prices

In their seminal paper on ageing and housing prices, Mankiw and Weil (1989) investigate the link between age and housing demand. Using samples from the 1970 and 1980 US Census, they present cross-sectional evidence for the quantity of housing demand by age. According to the authors, the quantity of housing demanded (measured by the value of the property in which the household resides) increases sharply between the ages of 20 and 30 and declines by about 1% a year after the age of 40. Based on their finding that demand for housing declines as the population grows older, Mankiw and Weil (1989) predicted that US housing prices would crash as a result of the ageing of the Baby Boom generation in the late 20th and early 21st century. Their prediction was not borne out in reality as other drivers of housing prices such as loose credit conditions and increased household incomes drove up property values in the years following their seminal paper. Despite their ultimately inaccurate prediction on the total trajectory of housing prices, the *ceteris paribus* negative relationship between ageing and housing prices remains supported by economic theory and has been supported empirically in a number of papers following Mankiw and Weil (1989).

Tákats (2012) presents an overlapping generations model in which young agents purchase housing but older agents do not. In this model, housing demand depends on the both the total population size and the ratio of old to young people. Demand for housing further depends on economic factors, measured by per capita GDP, as income effects partially determine demand for housing. This model underlies an empirical equation linking housing prices to a total population, the old-age dependency ratio, and a measure of household income.

Three theoretical channels through which ageing can impact housing prices are outlined by Hiller and Lerbs (2016). Firstly, demand for housing services declines as the population gets older. This is driven by both a life-cycle and a cohort effect. According to the life-cycle effect of ageing on housing demand, schooling-aged people demand little housing, workers demand a lot of housing, and retirement-aged people demand less housing as their incomes decrease and children leave home. The cohort effect relates to the fact that ageing populations consist of people born in earlier cohorts who likely had lower lifetime incomes than people born in later generations. Since housing is considered a normal good, demand should decrease as peoples' lifetime income decreases. Both the life-cycle and cohort effect feed into the expected decline in demand for housing services as the population gets older. Secondly, investment-induced demand for housing decreases as a population becomes older. Young people invest in housing as a durable asset, but as people get older and retire, they become more likely to liquidate their assets and downsize their home or choose to rent instead. Thirdly, supply-side effects in the housing market may arise from ageing. For example, zoning laws could be tightened to stabilise housing prices when a demand-driven decline in prices is expected as a result of ageing. This channel is considered the least relevant.

Hiller and Lerbs (2016) further investigate the impact of changes to the age distribution in 87 German cities on housing prices from 1995-2004. They find that real house price appreciation is lower in cities that age more quickly. The effect is heterogeneous across market segments, with a negative association found for sales prices and a positive effect for rents. The finding that rents are positively associated with ageing could be explained by an increase in demand for rental properties as retired people sell their family homes and enter the rental market. Saita et al (2016) investigate the link between ageing and housing prices using regional panel data from Japan and the US. They find that in both countries, real estate prices are negatively correlated with the old age dependency ratio and positively correlated with the total population in that region. Following their development of an overlapping generations model for the demand for housing, Tákats (2012) takes a macro approach in empirically investigating the link between ageing and housing prices. Using data from 22 advanced economies, the author finds that in the past 40 years, demographics increased real house prices by around 30 basis points per year. Over the next years 40, population ageing is projected to decrease housing prices by 80 basis points per year compared to if the age structure of the population was not expected to change.

2.3 Other Drivers of Housing Prices

Aside from demographics, there are many more economic drivers of housing prices. These drivers can be divided into supply-side determinants of housing prices and demand-side effects. Demographic effects on housing are mainly theorised to impact through demand channels, although there could be supply-side effects if governments change housing supply policies to deal with demographic trends (Hiller and Lerbs, 2016). Another demand-side driver of housing prices is the availability and price of credit. Duca et al. (2016) find that price and non-price terms of mortgage credit (i.e. the interest rate and the loan-to-value requirements for borrowers) have a significant impact on housing prices relative to rents [1]. When terms of credit are more favourable to borrowers, as was the case in the US in the early 2000s, effective demand for investment in housing is raised (Duca et al., 2011). This dynamic was excluded from most empirical models of housing pre-crisis which rendered them unable to predict the substantial price appreciation that occurred during the early and mid 2000s.

The supply of housing also has a substantial impact on the dynamics of housing prices. If housing was supplied perfectly elastically, the housing stock would expand to absorb increases in demand and housing prices would not therefore increase. However, there are many obstacles facing the supply of housing such as regulatory and spatial constraints. Glaeser et al. (2008) find that housing price bubbles are more prevalent in places with more inelastic housing supply. The substantial increase in housing prices experienced in the early 2000s was deemed too high by Glaeser et al. (2008) and other authors to be explained by market fundamentals. It is broadly considered that some irrational market exuberance was likely at play regarding the future returns to investment in housing. In locations with more inelastic housing supply, this excess demand for housing translated into higher prices. Regional heterogeneity in the elasticity of housing supply is driven by the availability of land for development along with regulatory barriers to housing development (Saiz, 2008).

[1] The ratio of housing prices to rents is an important indicator of housing market conditions as sales prices tend to be more variable than rents over the business cycle. In the US, in the period preceding the 2007 crisis, the ratio of prices to rents grew substantially. The data used in this paper experiences higher levels of growth and higher volatility in sales prices over the period of examination (table 1).

3 Data

3.1 Dependent Variables

To measure the evolution of housing prices, indices constructed from 'The Historical Prices of Housing Project' (HiPHoP) dataset are used. This dataset includes annual housing data for 12 US cities: Los Angeles, San Francisco, Boston, Chicago, Louisville, Detroit, Washington D.C., Miami, New Orleans, New York City, Philadelphia, Phoenix. The dataset is derived from historical newspaper listings for housing sales and rentals from 1890-2006. As such, the price data are interpreted as listing/asking prices rather than transaction prices. Along with prices, a number of locational and dwelling characteristics are available. For each time period, approximately 150 rental and 250 sales observations are available. Data was selected with a repeated cross-section methodology, i.e., the properties that are observed differ in each period so the dataset relies on the within-period randomisation for comparability of observations over time. Both nominal and real indices for rent and sales were constructed using hedonic regression methodology. The hedonic regressions control for locational and dwelling-specific characteristics to allow for a consistent inter-year comparison of the evolution of housing prices. In line with the previous empirical literature on the link between demographics and housing prices, real housing price and rental indices are used as the dependent variable. Real indices are deflated using US-wide all-items CPI sourced from FRED/FRASER.

A possible issue with the housing indices used in this analysis is the potential for discrepancies between the listing prices found in newspapers and the actual transacted price of residential properties. Furthermore, housing prices are obtained from major newspapers, which may lead to selection effects for the properties chosen for listing. These selection effects could bias listings towards properties more relevant to higher-income and English speaking people, and may not therefore be completely representative of each city's housing market.

3.2 Independent Variables

Demographic data is obtained from the US Census Bureau. Data is set at the US county level with population data available by race, sex, and age. Intercensal data are available annually since 1970. The period of analysis is 1970-2006 as there is both demographic and housing data available for these years. For every year of analysis, the population of each 5-year age bracket is provided for each US county. The old age dependency ratio, the main independent variable of interest, is obtained by dividing the retired population by the working cohort. As is standard in the literature, people over the age of 65 are assumed to be retired and those aged between 20 and 64 and considered as workers. Total population is also used as an independent variable. Data is available on the population shares of black people, white people, and other races in these intercensal data sets. These shares are included in some of the main models as controls. Data on household income was only available from the Census bureau on the county level for the years 1969, 1979, 1989, and 1999[2]. Using these data, I interpolated annual estimates of median household income to use as control variables on the city level using a "straight line method". Linear growth in median household income within each 10 year bracket was assumed in this interpolation methodology.

In the main analysis, for every city apart from New York City, a single "core" county encompassed entirely by the metropolitan area was used. New York City, on the other hand, is comprised of 5 counties, one for each borough. A population-weighted average of these 5 counties is calculated to construct the independent variables for New York.

3.3 US Demographic Forecasts

Long-term demographic forecasts were obtained from the US Congressional Budget Office. The forecasts used in this paper's analysis were published in July 2022. Available from these forecasts were annual projections for population growth and the yearly projected change in the old age dependency ratio. The old age dependency ratio is defined as the population of people aged 65 and over to the working population aged between 20 and 64.

[2] This data was unfortunately not available for Washington, DC, so specifications including household income controls exclude Washington.

Table 1: Descriptive Statistics

Decade	Variable	mean	sd	min	max
1970s	Annual Rent Growth	-0.3	6.2	-12.2	19.9
	Annual Sales Growth	4.3	9.1	-33.8	36.2
	Old-Age Dependency	20.6	3.2	16.3	29.0
	Population	2,544,257	2,521,670	556,807	7,903,051
	Median Household Income	12,025	2,736	6,503	19,187
	White Share	71.3	17.3	28.0	94.8
	Black Share	25.7	18.1	3.2	71.0
	Other Share	3.0	4.8	0.2	21.7
1980s	Annual Rent Growth	0.6	6.9	-17.3	32.9
	Annual Sales Growth	1.2	9.2	-17.8	26.5
	Old-age dependency	21.1	2.5	16.0	27.4
	Population	2,602,119	2,603,063	506,910	8,793,711
	Median Household Income	22,451	5,374	12,480	34,965
	White Share	66.5	17.3	28.2	94.0
	Black Share	28.6	18.6	3.3	70.5
	Other Share	5.0	6.8	0.6	29.3
1990s	Annual Rent Growth	0.9	5.8	-10.5	14.9
	Annual Sales Growth	1.0	8.1	-23.0	23.5
	Old-age dependency	20.9	2.3	16.0	26.1
	Population	2,787,493	2,832,585	485,511	9,437,290
	Median Household Income	33,771	7,465	19,343	55,221
	White Share	62.7	17.4	29.6	92.5
	Black Share	30.2	19.3	3.6	67.8
	Other Share	7.1	8.3	0.9	33.2
2000s	Annual Rent Growth	1.3	8.3	-14.0	36.0
	Annual Sales Growth	6.8	10.8	-18.0	51.9
	Old-age dependency	19.6	2.1	15.8	24.4
	Population	2,950,488	3,009,514	230,172	9,793,263
	Median Household Income	42,181	10,479	27,999	70,486
	White Share	60.4	16.8	28.9	90.1
	Black Share	29.7	19.1	4.0	67.7
	Other Share	9.9	9.2	2.7	38.2

All statistics are in percentages except population (measured as total city-level population size) and household income (median household income in 1989 dollars). For each variable, the mean was calculated across all cities over the 10 years encompassed in each decade apart from the 2000s where the period ends at 2006. Median household income data was unavailable for Washington D.C.

4 Methodology

4.1 Main Analysis

A fixed-effects model is used to estimate the impact of ageing and population growth on real sales and rental prices. City fixed-effects are used in the main analysis to control for all omitted time-invariant factors relating to the city. Some unobservable factors likely to be mostly unchanged over time (and therefore at least partially picked up in city fixed-effects) include the type of housing stock, population density, and industrial composition of cities. Time fixed-effects are used to control for time-specific shocks that impact all cities equally. Time fixed-effects would mainly control for US and worldwide economic shocks that impact all cities in the same way.

The baseline model is based on the econometric equation resulting from the overlapping generations model developed by Tákats (2012) and is specified as follows:

$$lnp_{itr} = \beta_0 + \beta_1 lnold_{it} + \beta_2 lnpop_{it} + \beta_k lnx_{it} + \mu_i + \delta_t + \epsilon_{it}$$

Where p_{itr} is the indexed housing price for tenure r in city i at time t. The possible tenure types are rental and sales, which are in real terms. old_{it} is the old age dependency ratio for city i at time t which is calculated by dividing the retired population (over the age 65) by the working age population (between 20 and 64). pop_{it} is the population of city i at time t. x_{it} is a vector of time-varying city-level control variables. Coefficients measuring the marginal effects of control variables x_{it} on housing prices are captured by a vector of k coefficients β_k. Control variables include median household income and population shares of black and white racial groups (with shares of other races omitted from the regression to avoid multicollinearity). μ_i are city fixed effects and δ_t are time fixed effects. Consistent with the approach of previous studies, independent variables are logged (Takáts, 2012; Saita et al., 2016; Hiller and Lerbs, 2016). When the old age dependency ratio is logged, the coefficient is interpreted as an elasticity, i.e. the percentage change in housing prices as a response to a 1 percent increase in the old age dependency ratio. If the old age dependency ratio was not logged, the interpretation of the coefficient would be the percentage change in housing prices in response to a 1 percentage point increase in the old age dependency ratio. The rationale for taking logs of independent variables in this analysis is for comparability to previous research and to allow for easier construction of forecasts for the effects of demographic shifts on housing prices and rents.

Three models are estimated in the main analysis, differing according to the number of control variables included in each model. The first model does not contain any additional time-varying controls. The second model controls for median household income and the shares of black and white people. The third model just controls for racial shares and does not account for household income. Robust standard errors are reported to adjust for heteroskedasticity.

4.2 Sensitivity Analysis of Main Results

A drawback of the main analysis is that there exists a mismatch between the geographical units used for the dependent and independent variables. Data for the independent variables, obtained from the US Census Bureau, are at the county level. However, the dependent variable for housing prices is at the metropolitan area level. This is because the indices were constructed from a sample of newspaper property listings which are distributed across whole metropolitan areas. Therefore, the housing price indices depend on some properties that are in different counties to the ones used for the main independent variables. To counter this drawback, sensitivity analysis is conducted where a weighted average of all counties that contribute to cities' metropolitan areas are used as the dependent variables. The methodology for choosing which "peripheral" counties to combine with the "core" counties used in the main analysis was to manually check the newspaper archives from which the housing price indices were obtained. Individual listings with locations outside a metropolitan area's "core" county were flagged for each city, and a resulting list of "peripheral" counties for each metropolitan area was created. A drawback of this approach to matching geographical units is that the exact weighting of counties within metropolitan level indices is not known as the exact weighting process behind the indices was not available. The chosen approach was to weight the counties based on their total population. A concern with this approach is that counties which are not entirely within the boundaries of a metropolitan area would be over-weighted since not all of their residents live in the metropolitan area. However, this is likely to be a minor issue since the

Table 2: Counties used for Main Analysis and Sensitivity Analysis

City	**Core County**	**Peripheral counties**
San Francisco	San Francisco County	Marin, Alameda , San Mateo, Contra Costa
Boston	Suffolk County	Middlesex, Essex, Norfolk, Plymouth
Chicago	Cook County	Porter, Will, Kendall, Kane, McHenry, Lake
Detroit	Wayne County	Macomb, Oakland
Los Angeles	Los Angeles County	Ventura, San Bernadino, Riverside, Orange
Miami	Miami-Dade County	Broward, Fort Lauterdale
New Orleans	Orleans Parish	Jefferson, Plaquemines, St.Bernard, St. Charles, St.John the Baptist, St.Tammany
New York City	5 Boroughs*	
Philadelphia	Philadelphia county	Delaware, Camden, NJ
Phoenix	Maricopa County	Pinal
Washington DC	District of Columbia	Spotsylvania, VA, Frederick, MA, Prince George's, MA, Arlington, VA, Charles, MA, Alexandria, VA, Stafford VA, Prince William, VA, Loundoun, VA, Montgomerey, MA
Louisville, KY	Jefferson county	Clark, IN, Floyd, IN

* The core county for New York City is denoted as "5 Boroughs" since for the main analysis, a population-weighted average of Manhattan, Queen's, Staten Island, Brooklyn and the Bronx was used for the independent variables. No peripheral counties were added for New York City when sensitivity analysis was conducted as it was deemed that according to newspaper listings, New York's metropolitan area was confined to the 5 boroughs that were accounted for in the main analysis anyway.

parts of peripheral counties that are not entirely within a metropolitan areas are invariably rural areas with low populations outside the metropolitan area, so the biased induced should be minor. A list of "core" counties, "peripheral" counties, is available in table 2.

4.3 Robustness Checks

The above models do not account for spillover effects between cities that are of close geographical proximity to each other. The results could be inaccurate if demography-induced demand changes for housing in one city spill over to adjacent housing markets. To account for this, a robustness check is conducted where standard errors are clustered at the state level as a proxy of closeness of city pairs. In practise, this only affects one pair of cities, San Francisco and Los Angeles, as all other cities are the sole city in their state included in the sample.

A further robustness check is conducted to account for the possibility of reverse causality. It could be the case that there is sorting of older people into cities with relatively less expensive property prices as they grow older and look to liquidate some of their housing investments or reduce their consumption of housing services. The plausibility of this mechanism is relatively high as retirees are less likely to be geographically constrained to labour markets after retirement, so their flexibility in terms of migrating to cities with cheaper property could be high. To account for this, the main specification is altered to include 1, 3, and 5 year lagged values of the old age dependency ratio. The likelihood of reverse causality under this specification is low since it would require people sort into cities based on future property prices. Under the lagged specification, the hypothesised mechanism proposed in this paper - that ageing induces decreases in property prices and rents through decreased demand for housing - would likely be the only explanation for the link between demographics and housing prices since people may exhibit delayed housing investment responses to ageing.

4.4 Application of Results to Demographic Forecasts

Estimates of the ageing and population elasticities of housing prices are applied to demographic forecasts for the US obtained from the Congressional Budget Office. The aim of this exercise is to use the estimates of the effect of demographics on housing prices and rents based on 1970-2006 data to make a prediction for the net effect that expected changes in population and old-age dependency ratio will have *ceteris paribus* on property market in future. Annual forecasts for population growth and old-age dependency growth are multiplied by the sales and rental price elasticities with respect to ageing and population growth obtained in the main analysis. This calculation results in the *ceteris paribus* contribution of ageing and population growth to growth in housing prices. The sum of the ageing and population growth effects gives the total projected demographic effect on housing.

5 Results

5.1 Main Results

The main hypothesis of this analysis is that ageing, measured by the old age dependency ratio, induces an increase in housing prices due to the reduction in demand for housing as people get older. The main coefficient of interest in the analysis is the log of the old-age dependency ratio. Also of interest are the coefficients on the log of total population. The predicted coefficient on this variable is positive. Due to the inelasticity of housing supply, additional demand from more people living in a city is expected to increase housing prices, holding all else constant.

The specification used in this analysis takes the logged values of the variables of interest. This is standard practise in the existing literature on this topic. (Takáts, 2012; Saita et al., 2016; Hiller and Lerbs, 2016). The interpretation of the coefficients estimated for the log of the old age dependency ratio is the percentage response of housing prices to a 1% change in old age dependency. The use of logs results in elasticities of housing prices with respect to changes demographic variables. These elasticities are easy to apply to forecasts for demographics in order to obtain predictions for the future impacts of ageing and population growth on housing rents and sales prices.

The main results shown in table 3 indicate that demographics do indeed have an effect on real housing prices. The coefficients on the logged old age dependency ratio are negative and statistically significant, mainly at the 1% level. On average across the three models for rents, a 1% increase in the old age dependency ratio induces an average decrease in real rental prices of 1%. Across the three models for sales, the impact of a 1% increase in the old age dependency ratio is a 1.2% decrease in real sales prices. These results are both economically and statistically significant and are in line with economic theory and notably consistent with findings from previous studies in this area (Takáts, 2012; Saita et al., 2016; Hiller and Lerbs, 2016). These three papers found coefficients on logged old age dependency ranging from -0.5 to -1.7, a range within which all of the reported estimates in table 3 lie. It is also notable that the coefficients on the log of median household income is significantly positive but less than 1, a result that is also strikingly similar to previous studies.

Table 3: Fixed Effects Estimates of Old Age Dependency on Real Housing Prices and Rents

	(1) logrentreal	(2) logrentreal	(3) logrentreal	(4) logsalereal	(5) logsalereal	(6) logsalereal
logpop	0.0918	-0.0681	0.127	0.199	-0.120	0.260
	(0.0837)	(0.0512)	(0.0853)	(0.208)	(0.0860)	(0.170)
logoldage	-1.046***	-1.051***	-0.903***	-1.461*	-1.230***	-0.948*
	(0.271)	(0.155)	(0.276)	(0.679)	(0.271)	(0.484)
logincome		0.218***			0.471***	
		(0.0292)			(0.0806)	
logblackshare		-0.300**	-0.290*		-0.218	-0.190
		(0.0960)	(0.160)		(0.187)	(0.311)
logwhiteshare		0.544***	-0.338		0.289	-1.503*
		(0.157)	(0.241)		(0.503)	(0.703)
Constant	-2.805**	-2.964***	-3.675**	-4.640	-4.655***	-5.695*
	(1.250)	(0.728)	(1.286)	(3.017)	(1.118)	(2.693)
Observations	444	407	444	444	407	444
R^2	0.319	0.547	0.366	0.165	0.625	0.353

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All models are estimated with time and city level fixed effects. Robust standard errors are reported in each case. In specifications with race controls, the share of other races is omitted to avoid multicollinearity. Observations in columns (2) and (4) are lower due to the absence of data on median household income for Washington, D.C.

The higher relative magnitude of the coefficients for sales prices - compared to rental prices - is consistent with the additional investment channel through which ageing theoretically impacts housing prices. As people get older, many homeowners liquidate their housing assets and either enter the rental market or downsize their property. This would lead to more severe reductions in demand for sales properties due to substitution effects from purchased property to rental properties amongst older people. This interpretation is empirically supported by Boehm and Schlottmann (2014) who found that the US housing market is particularly dynamic and there is a relatively high probability that people who are initially homeowners return to the rental market. In the models considered in this paper, controlling for the racial composition of cities and median household income does not substantially impact the magnitude or statistical significance of estimates for the coefficients on the log of old age dependency.

The findings on the impact of population size on housing prices are less clear. A 1% increase in the total population is associated with an average increase in real rental prices of 0.05% across the three models. None of the three estimated coefficients on the log of population for real rental prices are statistically significant. For real sales prices, the average impact of a 1% increase in the old age dependency on prices is a 0.11% increase. The coefficients on the log of the total population for real sales prices are all statistically insignificant. A similarly insignificant relationship between total population and housing prices was found in a similar specification by Hiller and Lerbs (2016).

5.2 Sensitivity Analysis

Sensitivity analysis was conducted as described in the methodology section of this paper in order to account for the geographical unit mismatch between the housing price data and demographic census variable data. The results presented in table 4 alter the geographical unit on the independent variables to a population-weighted-average of each metropolitan area's core and peripheral counties. This brings the geographical unit of the dependent and independent variables more closely in line with each other since the property listings upon which the housing prices indices are built include observations from outside the core counties - and hence in the peripheral counties - of each city. When this process is followed and the geographical unit includes peripheral counties, the significance

Table 4: Fixed Effects Regression Estimates with Metropolitan Area City Boundaries

	(1) logrentreal	(2) logrentreal	(3) logsalereal	(4) logsalereal
logpop	0.339*	0.178*	0.824**	0.234**
	(0.163)	(0.0883)	(0.314)	(0.0927)
logoldage	-0.453**	-0.636***	-0.135	-0.764***
	(0.193)	(0.162)	(0.434)	(0.190)
logpopblackshare		-1.340***		-3.619***
		(0.388)		(0.323)
logpopwhiteshare		-0.268		-0.0636
		(0.315)		(0.404)
Constant	-5.660**	-4.420**	-12.08**	-5.395**
	(2.377)	(1.596)	(4.550)	(1.741)
Observations	444	444	444	444
R^2	0.185	0.364	0.194	0.612

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

For each of the dependent variables, the unit of observation is the metropolitan area which is defined by the population-weighted average of both the core and peripheral counties for each city listed in table 2. Estimates are produced using two-way fixed effects regressions, and all reported standard errors reported are robust.

and magnitude of the results is not substantially altered. On average, the effect of a 1% increase in the old age dependency ratio on real rental prices is a 0.55% decrease in real rental prices. These estimated coefficients in the first and second model are significant at the 5% and 1% levels. The average effect of a 1% increase in the old age dependency ratio on real sales prices is an average reduction of 0.45%. In this case, there is a substantial difference in the magnitude and significant of the results across models. In the first model without racial controls, the coefficient is -0.135, which is not statistically significant. In the second model including controls for racial composition, the coefficient is -0.764 and is significant at the 1% level. The magnitudes of the coefficients for the log of old age dependency are smaller than in the main analysis but are nonetheless pointed in the same direction and maintain the same level of statistical significance.

For the coefficients on total population, the results in the sensitivity analysis are more in line with the economic theory and are more statistically significant than the in main analysis. For rental prices, the average impact of a 1% increase in the total population is a 0.26% increase in housing prices. The coefficients in both models are statistically significant at the 10% level. For sales prices, the average effect of a 1% increase in the total population is a 0.53% increase in housing prices. For both models, these coefficients are significant at the 5% level.

5.3 Robustness Checks

5.3.1 Clustering of Standard Errors at the State Level

Standard errors are clustered at the state level to account for possible interaction effects between housing markets in the same states. Interactions between same-state housing markets could operate through a geographical proximity mechanism or through state-level characteristics that are common to all cities within states (e.g. state laws that influence housing supply elasticities). Clustering standard errors at the state level accounts for this within-state correlation between housing markets.

As outlined in table 5, the statistical significance of the coefficients estimated in the main analysis is not changed when standard errors are clustered at the state level as opposed to the city level. This alleviates some concerns of incorrectly estimated results due to interdependencies between

Table 5: Fixed Effects Regression Estimates with Standard Errors Clustered at the State level

	(1)	(2)	(3)	(4)	(5)	(6)
	logrentreal	logrentreal	logrentreal	logsalereal	logsalereal	logsalereal
logpop	0.0918	-0.0681	0.127	0.199	-0.120	0.260
	(0.0889)	(0.0523)	(0.0921)	(0.213)	(0.0903)	(0.183)
logoldage	-1.046***	-1.051***	-0.903***	-1.461*	-1.230***	-0.948*
	(0.272)	(0.156)	(0.275)	(0.679)	(0.281)	(0.490)
logincme		0.218***			0.471***	
		(0.0289)			(0.0771)	
logblackshare		-0.300***	-0.290		-0.218	-0.190
		(0.0800)	(0.192)		(0.161)	(0.375)
logwhiteshare		0.544***	-0.338		0.289	-1.503*
		(0.154)	(0.273)		(0.509)	(0.762)
Constant	-2.805*	-2.964***	-3.675**	-4.640	-4.655***	-5.695*
	(1.438)	(0.692)	(1.487)	(3.247)	(0.960)	(3.049)
Observations	444	407	444	444	407	444
R^2	0.319	0.547	0.366	0.165	0.625	0.353

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The specifications of the models in this table are identical to those reported in table 3. The only difference is that these standard errors are clustered at the state level to account for housing market interdependencies between geographically proximate cities.

nearby property markets.

5.3.2 Lagged Old Age Dependency Models

A potential concern with the specification used in the main analysis is the possibility of reverse causation. While a strong correlation between the old age dependency ratio and housing prices is estimated, it is possible that the chain of causality goes in the opposite direction to what is hypothesised in this paper. Specifically, older people could move to cities with more affordable housing as they reach retirement age and look to downsize their property.

To account for the possibility of this type of reverse causality, a robustness check is conducted where the old age dependency ratio is lagged by 1, 3, and 5 years. The results are reported in table 6, 7, and 8. Under this specification, reverse causality is less likely since contemporaneous housing prices are unlikely to cause shifts in the lagged old-age dependency ratio through the mechanism of older people choosing to live in cities with cheaper housing. This would require people to have accurate information on the future path of property prices and base their present housing investment decisions based on this information. It is more likely that a significant negative relationship between the lagged old age dependency ratio and housing prices would be driven by a delayed housing investment reaction to people reaching old age. This dynamic supports this paper's hypothesised chain of causality from ageing to a reduction in housing prices.

As tables 6, 7, and 8 show, when the old age dependency ratio is lagged, the estimates for the impact on housing prices remain broadly similar for lags between 1 and 5 years. The signs of the coefficients are all the same, and most statistical significance is retained throughout. As the lag becomes longer, the magnitude of the coefficients decreases and the statistical significance wanes somewhat. This is to be expected as the delayed investment response to ageing would be finite. Overall, this robustness check supports the interpretation that the estimated coefficients in the main analysis represent a reduction in demand for housing as the age composition of a city becomes older, rather than a selection effect whereby older people move to cities with cheaper housing.

Table 6: 1-year Lagged Old-Age Dependency Specification

	(1)	(2)	(3)	(4)	(5)	(6)
	logrentreal	logrentreal	logrentreal	logsalereal	logsalereal	logsalereal
logpop	0.123	-0.0477	0.158*	0.217	-0.0991	0.266
	(0.0865)	(0.0500)	(0.0865)	(0.201)	(0.0894)	(0.160)
lag1logoldage	-1.003***	-0.990***	-0.844**	-1.360*	-1.169***	-0.893*
	(0.282)	(0.156)	(0.281)	(0.685)	(0.269)	(0.496)
logincome		0.233***			0.459***	
		(0.0271)			(0.0840)	
logblackshare		-0.271**	-0.278		-0.193	-0.208
		(0.0912)	(0.172)		(0.185)	(0.301)
logwhiteshare		0.532***	-0.394		0.168	-1.544**
		(0.148)	(0.258)		(0.522)	(0.684)
Constant	-3.175**	-3.276***	-4.033**	-4.735	-4.755***	-5.733**
	(1.258)	(0.680)	(1.305)	(2.943)	(1.187)	(2.561)
Observations	432	396	432	432	396	432
R^2	0.300	0.544	0.348	0.149	0.607	0.345

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The models specified in this table are the same as in the main results reported table 3 except that the log of the old age dependency ratio is lagged by 1 year.

Table 7: 3-year Lagged Old-Age Dependency Specification

	(1) logrentreal	(2) logrentreal	(3) logrentreal	(4) logsalereal	(5) logsalereal	(6) logsalereal
logpop	0.185*	-0.0194	0.219**	0.270	-0.0792	0.286*
	(0.0999)	(0.0648)	(0.0953)	(0.189)	(0.0965)	(0.138)
lag3logoldage	-0.806**	-0.805***	-0.630*	-1.095	-1.055***	-0.734
	(0.292)	(0.149)	(0.294)	(0.695)	(0.256)	(0.518)
logincome		0.265***			0.449***	
		(0.0323)			(0.0964)	
logblackshare		-0.217**	-0.278		-0.116	-0.232
		(0.0845)	(0.201)		(0.183)	(0.287)
logwhiteshare		0.530***	-0.497*		0.0277	-1.591**
		(0.157)	(0.273)		(0.600)	(0.654)
Constant	-3.757**	-3.637***	-4.613***	-5.049	-4.692***	-5.806**
	(1.405)	(0.744)	(1.420)	(2.875)	(1.272)	(2.279)
Observations	408	374	408	408	374	408
R^2	0.218	0.501	0.283	0.113	0.564	0.316

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The models specified in this table are the same as in the main results reported table 3 except that the log of the old age dependency ratio is lagged by 3 years.

Table 8: 5-year Lagged Old-Age Dependency Specification

	(1)	(2)	(3)	(4)	(5)	(6)
	logrentreal	logrentreal	logrentreal	logsalereal	logsalereal	logsalereal
logpop	0.251*	0.0217	0.284**	0.342	-0.0479	0.328**
	(0.118)	(0.0877)	(0.107)	(0.193)	(0.116)	(0.128)
lag5logoldage	-0.556*	-0.615***	-0.373	-0.755	-0.934***	-0.491
	(0.274)	(0.133)	(0.299)	(0.680)	(0.232)	(0.542)
logincome		0.287***			0.448***	
		(0.0458)			(0.113)	
logblackshare		-0.197**	-0.329		-0.0403	-0.281
		(0.0762)	(0.216)		(0.162)	(0.279)
logwhiteshare		0.524**	-0.562*		-0.0756	-1.629**
		(0.195)	(0.261)		(0.708)	(0.638)
Constant	-4.298**	-4.122***	-5.250***	-5.526	-4.857**	-6.110**
	(1.711)	(0.954)	(1.589)	(3.127)	(1.588)	(2.190)
Observations	384	352	384	384	352	384
R^2	0.144	0.450	0.225	0.075	0.516	0.276

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The models specified in this table are the same as in the main results reported table 3 except that the log of the old age dependency ratio is lagged by 5 years.

6 Forecasts for Demographics Effects on Housing Prices

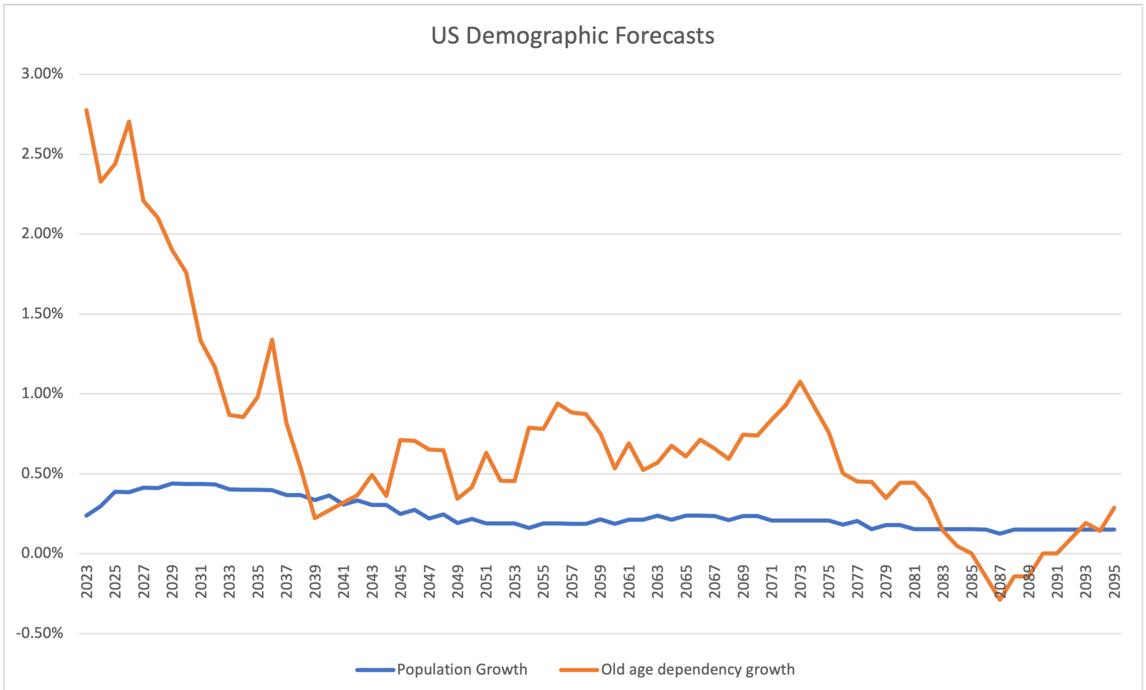

Figure 1: Congressional Budget Office Demographic Forecasts

Projections for population growth and growth in the old age dependency ratio are obtained from the US Congressional Budget Office. These projections are illustrated graphically in figure 1. For the majority of the forecasting period, old age dependency growth is expected to exceed population growth on a year-on-year basis. Growth in the old age dependency ratio is forecast to be especially high in the upcoming decades, with average growth of 2.35% expected in the 2020s and 0.99% in the 2030s. Population growth is expected to be more muted over the coming decades, with growth of 0.36% expected over the remainder of the 2020s and 0.39% forecast for the 2030s. The implication for the ultimate effects that demographics will have on housing prices is that the ageing will likely be of more relevance than total population growth.

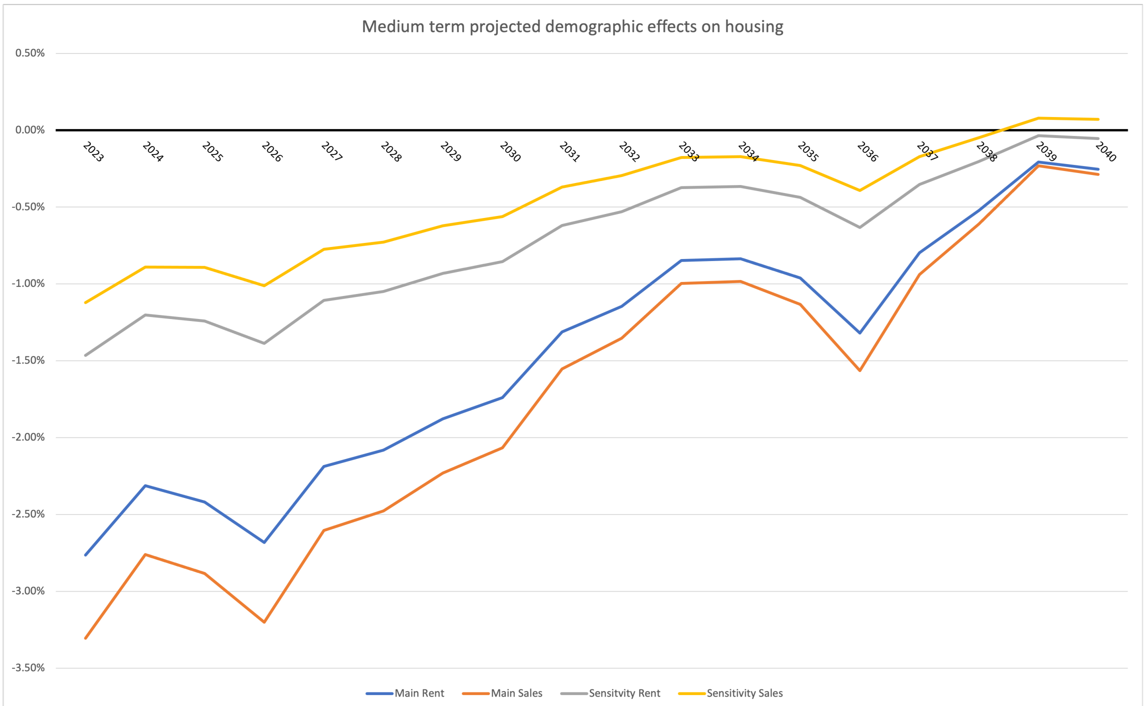

Figure 2: Medium-Term Forecasts for the Impact of Demographics on Housing

The average rental and sales housing price elasticities with respect to population size and the old-age dependency ratio are applied to annual demographic forecasts in order to estimate the effect that demographics will have on the US housing market in the coming decades. The net effect of ageing and population growth is illustrated in figure 2, which together gives the total effect of demographics on housing prices. The exercise is repeated with estimated elasticities from both the main analysis and sensitivity analysis.

Over the 2020s, the average net annual demographic effect on rental prices is expected to be a decrease of -2.33% based on the main analysis and a fall of -1.2% based on the sensitivity analysis. Over the same period, the average net annual demographic effect on sales prices is expected to be -2.78% based on the main analysis and -0.86% based on the sensitivity analysis. For the 2030s, the demographic effect on rents is forecast at -0.97% based on the main analysis and -0.44% based on the sensitivity analysis. Meanwhile, the effect on sales prices is projected to be -1.44% based on the main analysis and -0.23% based on the sensitivity analysis. Forecasts past 2040 are presented in figure 3 for completeness, but it is not expected that these would be very insightful due to the low likelihood that elasticities calculated with 1970-2006 data would be applicable this far in the future. Due to both the higher projected growth in the old age dependency ratio growth relative to total population growth and the magnitudes of the elasticities, the main driver of the projected effects of demographics on housing prices is expected to be ageing. This should be of note to policymakers and private actors in housing markets regarding the drivers of future growth in housing prices.

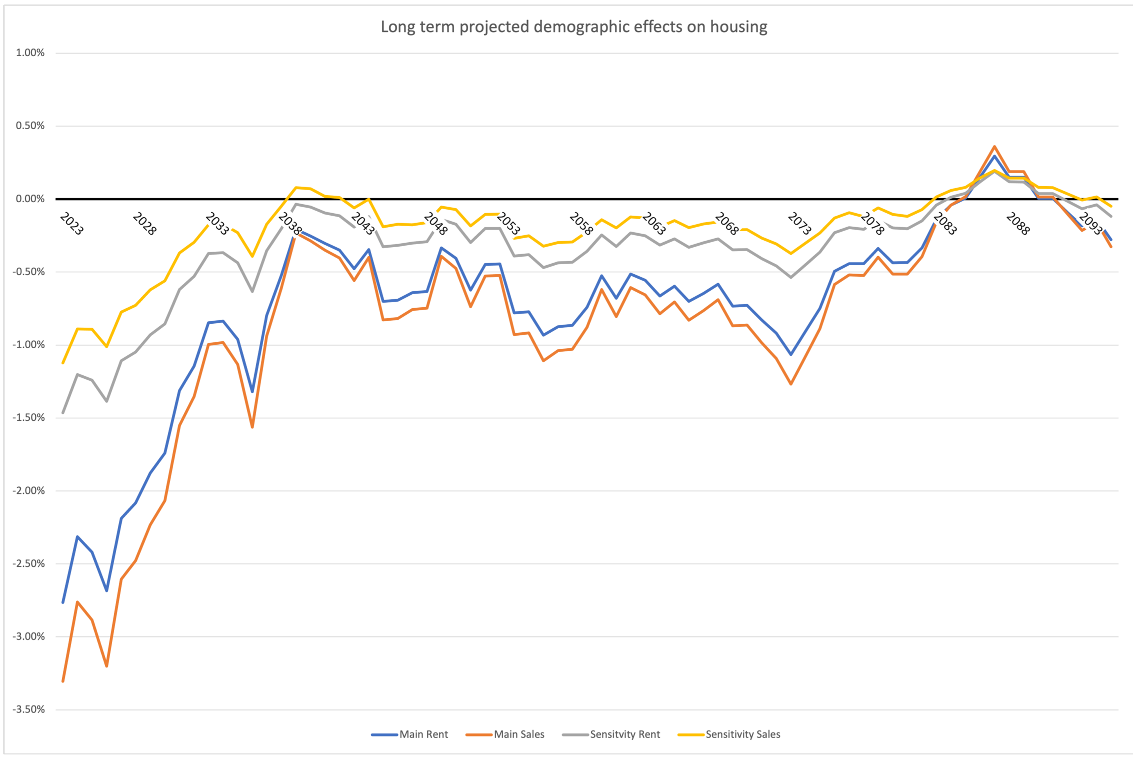

Figure 3: Long-Term Forecasts for the Impact of Demographics on Housing

A clear drawback of this exercise is the extrapolation of elasticities calculated with 1970-2006 data to forecasts from 2023-2095. Whether the future housing price elasticities with respect to ageing and population growth will be greater or less than those obtained in this paper is not clear. An important determinant of how these elasticities will likely change in future is the evolution of the elasticity of housing supply. Saiz (2010) found that the US supply of housing has become less elastic over recent years, suggesting that the market can respond less effectively to shifts in housing demand induced by drivers such as ageing and population growth. It is unclear how this trend will evolve in future, but it is wholly possible that supply effects have permanently shifted since the period that the data used in paper covers. However, when considering the negative demographic effects on housing prices projected in this analysis, the type of elasticity that is relevant the housing market's ability to contract its supply in order to keep prices elevated in the face of declining demand. This would likely involve the demolition of existing housing stock that is not needed due to declining demand. However, at this juncture it is important to consider that the projected demographic effects on the housing market should be considered *ceteris paribus*. There are plenty of other drivers of housing sales and rental prices that could likely outweigh these demographic effects in future. The oversight of this fact led to the incorrect predictions of Mankiw and Weil (1989) that the US housing market would crash over the 1990s and 2000s. It is plausible that supply constraints stemming from labour supply and material shortages, zoning laws, and environmental taxes and regulations on building materials could constrain the future expansion of housing supply to the extent that prices continue to increase in the same way as they have in recent decades.

7 Policy Implications

7.1 Property Market Concerns

The changing structure of the world's demographics is one of the greatest challenges facing policymakers over the coming decades. The housing market effects of demographic shifts are likely to already be in motion in many parts of the world as the pace of ageing approaches its highest levels. In the US, the most pressing economic issue is inflation. The Federal Reserve has responded to inflation with aggressive policy rate hikes in recent months (Smith, 2022), and signs have emerged that downwards pressure is being placed on housing prices as credit conditions worsen (Bushey, 2022). Over the medium term, housing prices may slow as a result of these developments. Economists and policymakers should also account for the demographic trends towards ageing that occur in parallel with the current inflationary cycle in their projections of the outlook for the property market. If the demographic effects on housing reported in this paper are not accounted for by policymakers in their projections, the outlook for housing prices could be overestimated by up to 3% per annum over the coming years. Failure to account for these impacts could lead to pressures on the financial system of a similar vein to those experienced in 2007, although likely not to such a drastic extent.

Another context in which the findings of this paper are of contemporary interest is China. While the Chinese economy is not directly comparable to that of the US, and the estimates from this paper would not be externally valid for the case of China, it is nonetheless useful to discuss the case of China to illuminate the discussion surrounding the link between demographics and the housing market. Pending data availability, further empirical research of a similar vein to this paper would be of great interest for the case of China.

China currently experiences a concurrent decline in property prices (Gao & Woo, 2022) and a rapid ageing of its population (Textor, 2022). While other factors - such as liquidity crises in a number of systemically important property developers (Kynge et al., 2022) - are at play in China's property market meltdown, a fundamental driver of the decline is likely to be demography. China's enormous property sector has long been driven by housing demand from the migration of workers from the countryside to urban centres in search of industrial jobs. However, as the population grows older, fewer young people are left to migrate to urban centres and provide what was previously considered by developers as an endless source of demand for new apartments. Largely owing to its ”one-child” policy, the overall population of China is forecast to stagnate over the coming years and eventually decline over the medium term (World Bank, 2022). According to the estimated positive elasticity of property prices with respect to population size, the expected slowdown in China's population is another possible driver of proerty price decreases in future.

7.2 Demographics and Inflation

According to the US Bureau of Labour Statistics, housing rents represent the largest component of inflation (BLS, 2021). The projected negative effects of ageing on the rental sector may provide some unexpected inflationary relief for households during the current inflationary cycle. A demography-induced reduction in real rent of around 2.3% per annum - relative to the scenario where demographics evolved neutrally - is forecast over the remainder of the 2020s, a period in which inflation is at risk of becoming entrenched in the system.

Some limited research has been conducted on the inflationary impacts of demographics outside the realm of the housing market. Through the contribution of demography-induced changes in housing rents to CPI, this paper also indirectly contributes to the strand of economic literature focused on the inflationary impacts of demographics. According to conventional macroeconomic theory, ageing is an inflationary phenomenon. The traditional view of the inflationary impact of ageing is derived from the life-cycle hypothesis proposed by Modigliani and Brumberg (1954). As the average age increases, people retire and finance their consumption with savings while not producing added value. Furthermore, ageing can cause inflation through the labour market as older people retire and wages increase as a result of a smaller labour supply. More recently, empirical evidence has emerged to suggest that ageing may have deflationary consequences (Gajewski, 2015; Yoon et al., 2014). Using a panel of OECD countries from 1970 to 2013, Yoon et al. (2014) finds evidence that ageing is deflationary. A fixed effects model finds that a one percentage point increase in the share of population over the age of 80 decreases the inflation rate by approximately 1%, a finding that is highly significant. A proposed explanation for ageing imparting a deflationary effect is that older voters tend to be more averse to inflation due to their likelihood of holding government bonds (Yoon et al., 2014). When this cohort grows, they gain more political influence, and deflationary policies are implemented. Considering the role of rental prices in the CPI basket, the negative link between ageing and the price of housing may also play a key part in explaining the negative relationship between ageing and inflation. While not often considered by policymakers, the relationship between demographics and inflation is an important topic in the context of the current economic cycle as the world is faced with the almost-certain phenomenon of ageing and the rising possibility of an extended period of inflation.

8 Conclusion

Over the coming decades, projected increases the old-age dependency ratio are expected to impart a negative impact on US housing prices and rents. The dominant demographic driver of housing prices over the course of this century is likely to be ageing rather than population growth. There are two main reasons for this. Firstly, the impact of total population growth on housing prices and rents is of ostensibly lesser magnitude and statistical significance than the effect of ageing. Secondly, in the US, projections for ageing are higher than for population growth.

The main finding of this paper is that for the 12-city sample utilised, a 1% increase in the old age dependency ratio is associated with a 1% decrease in real rental prices and a 1.2% decrease in real sales prices. These findings are in accordance with economic theory and are firmly within the range of empirical findings of previous authors in this field. Furthermore, the significance of the findings are robust to lagged specifications and to clustering standard errors at the state level to account for interdependencies among neighbouring property markets. The results also remain significant and consistent with economic theory when sensitivity analysis is carried out based on the geographical unit of observation for demographic data.

Applying the estimated housing price elasticities to US forecasts for ageing and population growth, over the remainder of this decade the expected average yearly effect of demographics on housing prices will be a 2.3% decrease in real rents and a 2.8% decrease in real sales prices relative to neutral demographics and holding all else equal. This is an economically significant effect given the typical magnitude of growth in the property market.

It is important to remember that the effects of demographics on property prices projected in the paper should be interpreted *ceteris paribus.* Real housing prices and rents will not necessarily decrease as a result of ageing due to other factors driving rents and housing prices. Sophisticated property price forecasting models should also account for factors such as the supply of housing, changes in household incomes, and the prevailing credit conditions. However, this paper provides a strong argument for forecasters and policymakers to seriously consider the effects of demography on housing prices when projecting the future trajectory of the property market.

References

BLS. (2021). 2021.htm : U.s. bureau of labor statistics. *www.bls.gov*. Retrieved November 22, 2022, from https://www.bls.gov/cpi/tables/relative-importance/2021.htm

Boehm, T. P., & Schlottmann, A. M. (2014). The dynamics of housing tenure choice: Lessons from germany and the united states. *Journal of Housing Economics*, *25*, 1–19. https://doi.org/https://doi.org/10.1016/j.jhe.2014.01.006

Börsch-Supan, A. (2003). Labor market effects of population aging. *Labour*, *17*, 5–44.

Bushey, C. (2022). The us housing market's big chill. *Financial Times*. Retrieved November 22, 2022, from https://www.ft.com/content/b9df3102-a7d2-483d-8216-f507c0460d3d

Duca, J. V., Muellbauer, J., & Murphy, A. (2011). House prices and credit constraints: Making sense of the us experience. *The Economic Journal*, *121*(552), 533–551.

Duca, J. V., Muellbauer, J., & Murphy, A. (2016). How mortgage finance reform could affect housing. *American Economic Review*, *106*(5), 620–24.

Gajewski, P. (2015). Is ageing deflationary? some evidence from oecd countries. *Applied Economics Letters*, *22*(11), 916–919.

Gao, L., & Woo, R. (2022). China's new home prices fall for second month on weak sentiment. *Reuters*. Retrieved November 22, 2022, from https://www.reuters.com/markets/asia/china-new-home-prices-fall-02-mm-september-2022-10-24/

Glaeser, E. L., Gyourko, J., & Saiz, A. (2008). Housing supply and housing bubbles. *Journal of urban Economics*, *64*(2), 198–217.

Hiller, N., & Lerbs, O. W. (2016). Aging and urban house prices. *Regional Science and Urban Economics*, *60*, 276–291.

IMF. (2019). Macroeconomics of aging and policy implications prepared by staff of the international monetary fund. https://www.imf.org/external/np/g20/pdf/2019/060519a.pdf

Kynge, J., Yu, S., & Hale, T. (2022). China's property crash: 'a slow-motion financial crisis'. *Financial Times*. Retrieved November 22, 2022, from https://www.ft.com/content/e9e8c879-5536-4fbc-8ec2-f2a274b823b4

Mankiw, N. G., & Weil, D. N. (1989). The baby boom, the baby bust, and the housing market. *Regional science and urban economics*, *19*(2), 235–258.

Modigliani, F., & Brumberg, R. (1954). Utility analysis and the consumption function: An interpretation of cross-section data. *Franco Modigliani*, *1*(1), 388–436.

Roser, M. (2014). Fertility rate [https://ourworldindata.org/fertility-rate]. *Our World in Data*.

Roser, M., Ortiz-Ospina, E., & Ritchie, H. (2013). Life expectancy [https://ourworldindata.org/life-expectancy]. *Our World in Data*.

Rouzet, D., Sánchez, A. C., Renault, T., & Roehn, O. (2019). Fiscal challenges and inclusive growth in ageing societies.

Saita, Y., Shimizu, C., & Watanabe, T. (2016). Aging and real estate prices: Evidence from japanese and us regional data. *International Journal of Housing Markets and Analysis*.

Saiz, A. (2008). On local housing supply elasticity. *Available at SSRN 1193422*.

Saiz, A. (2010). The geographic determinants of housing supply. *The Quarterly Journal of Economics*, *125*(3), 1253–1296.

Smith, C. (2022). Jay powell warns us rates will peak at higher level than expected. *Financial Times*. Retrieved November 22, 2022, from https://www.ft.com/content/2fba4664-a496-4a5b-820e-f258b3e2bd81

Takáts, E. (2012). Aging and house prices. *Journal of housing economics*, *21*(2), 131–141.

Textor, C. (2022). Topic: Aging population in china. *Statista*. Retrieved November 22, 2022, from https://www.statista.com/topics/6000/aging-population-in-china/#dossierKeyfigures

World Bank, W. B. (2022). Population estimates and projections — databank. *databank.worldbank.org*. Retrieved November 22, 2022, from https://databank.worldbank.org/source/population-estimates-and-projections

Yoon, M. J.-W., Kim, M. J., & Lee, J. (2014). *Impact of demographic changes on inflation and the macroeconomy*. International Monetary Fund.

Appendix

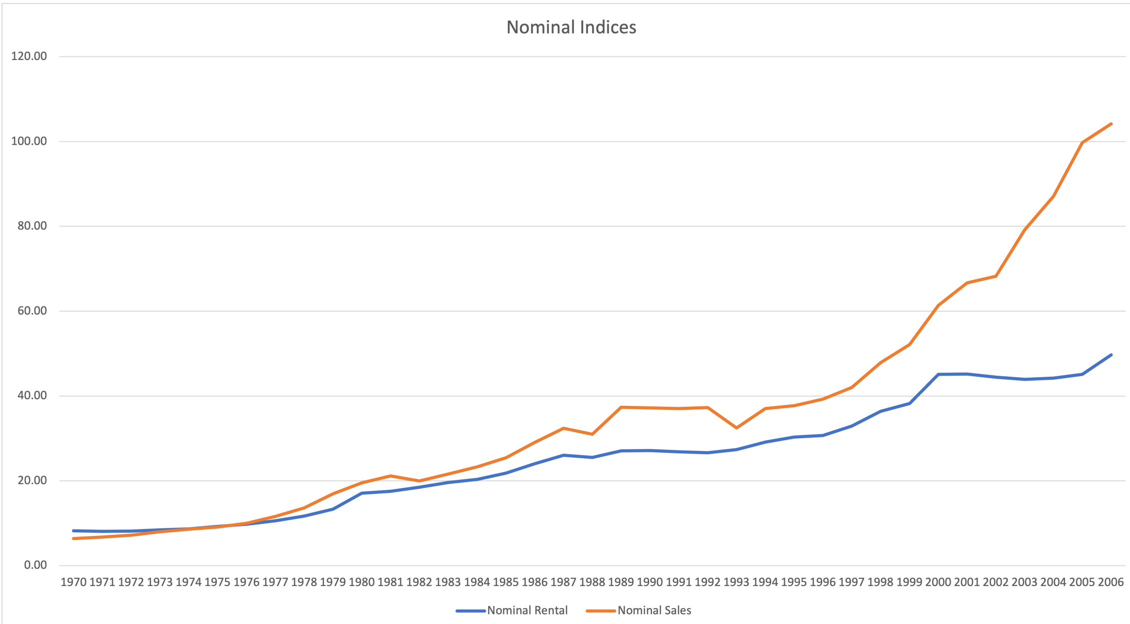

Figure A1: Averaged nominal HiPHoP price indices for 12 US cities

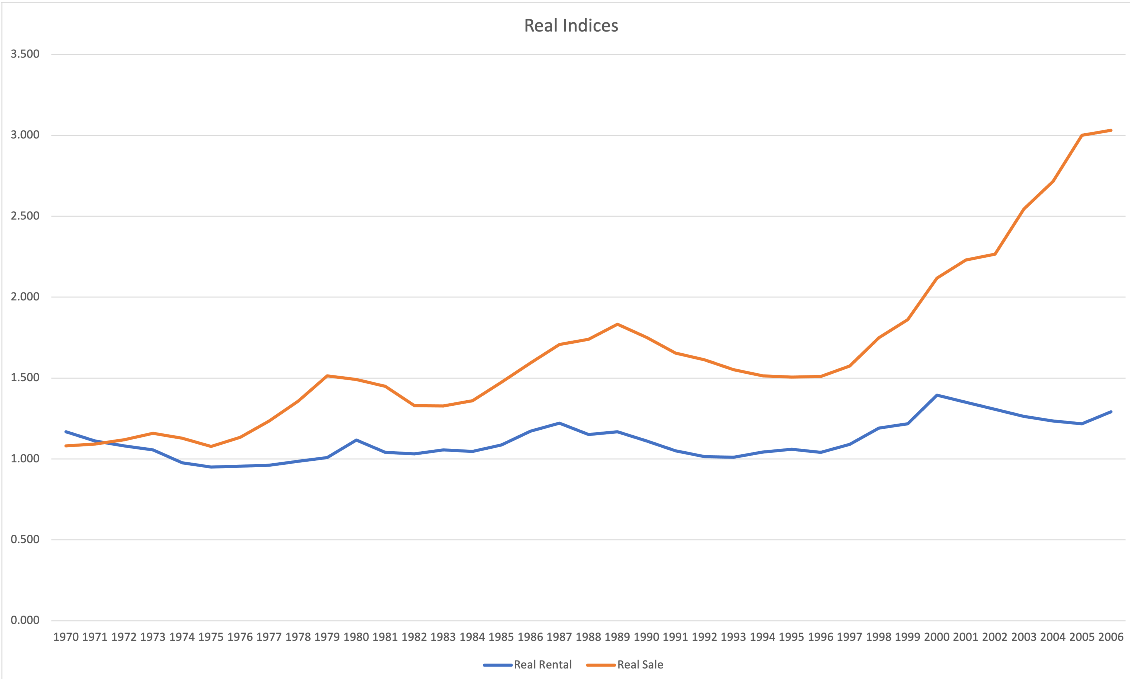

Figure A2: Averaged real HiPHoP price indices for 12 US cities

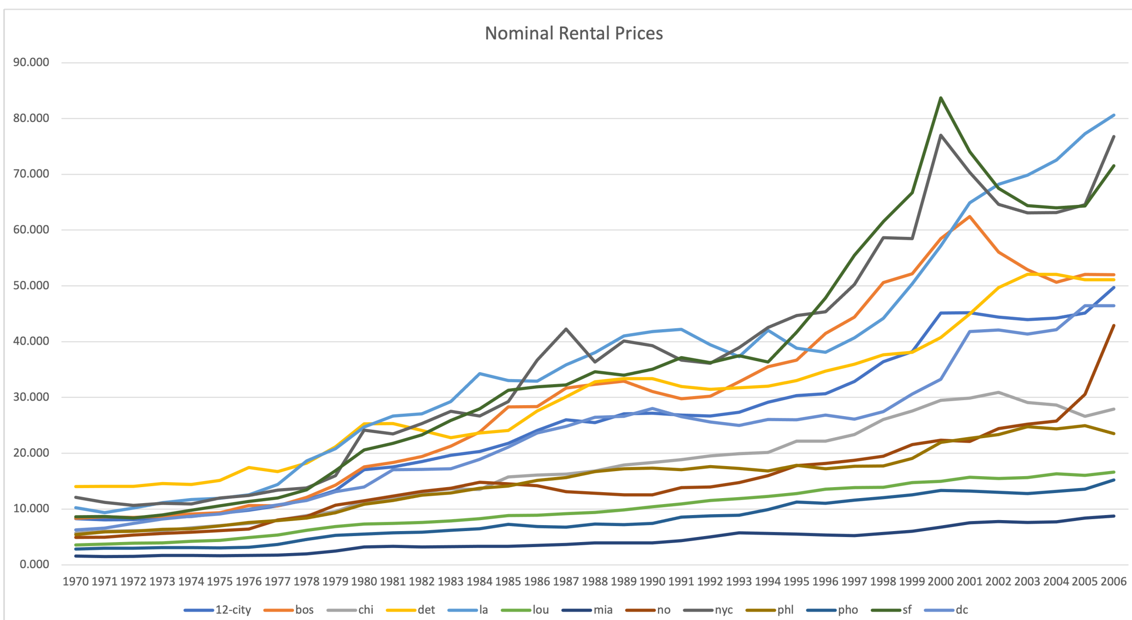

Figure A3: Nominal rental HiPHoP price indices for 12 US cities

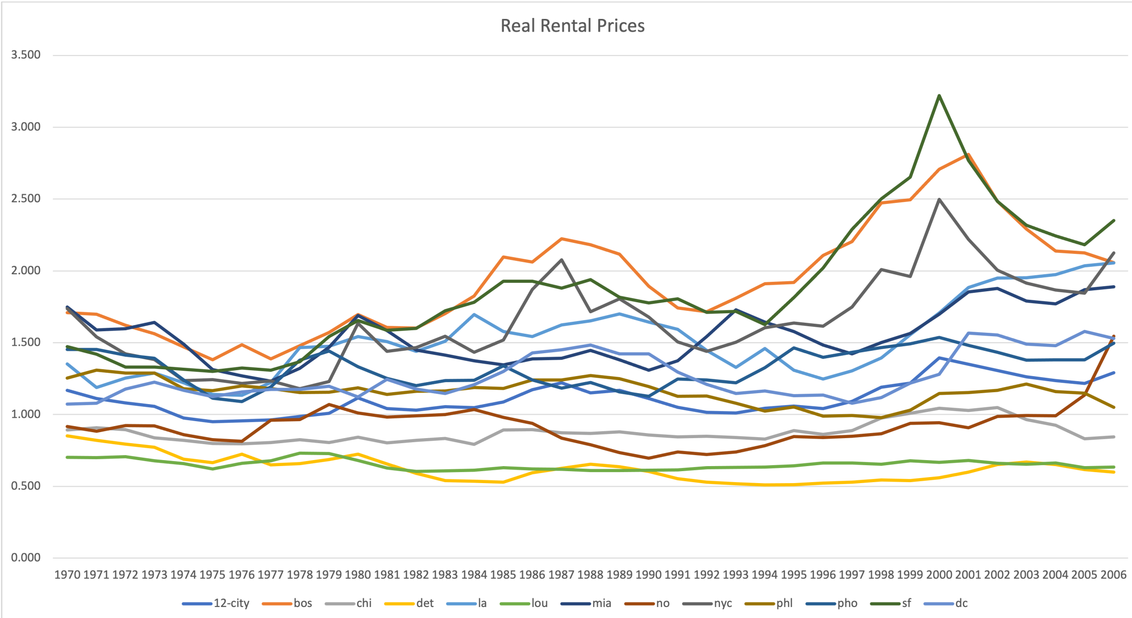

Figure A4: Real rental HiPHoP price indices for 12 US cities

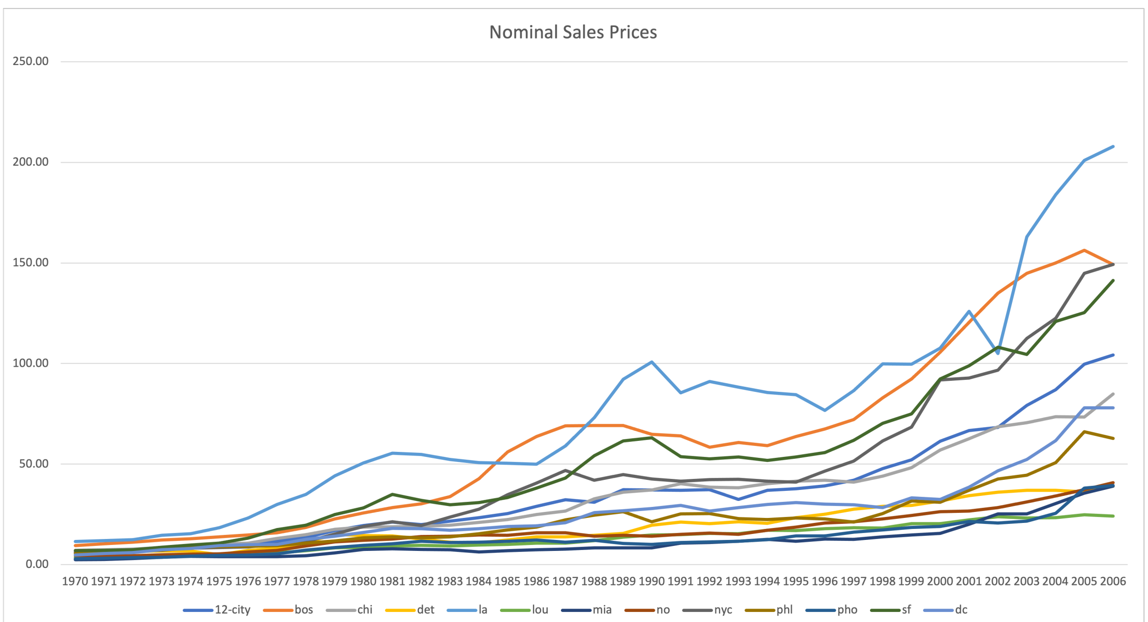

Figure A5: Nominal sales HiPHoP price indices for 12 US cities

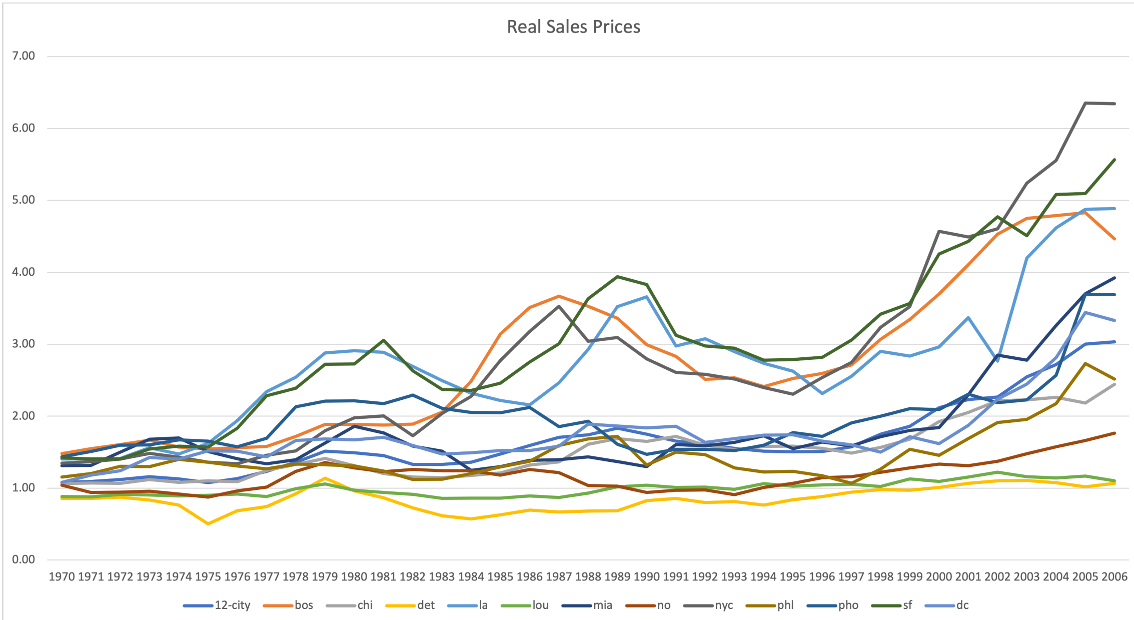

Figure A6: Nominal sales HiPHoP price indices for 12 US cities

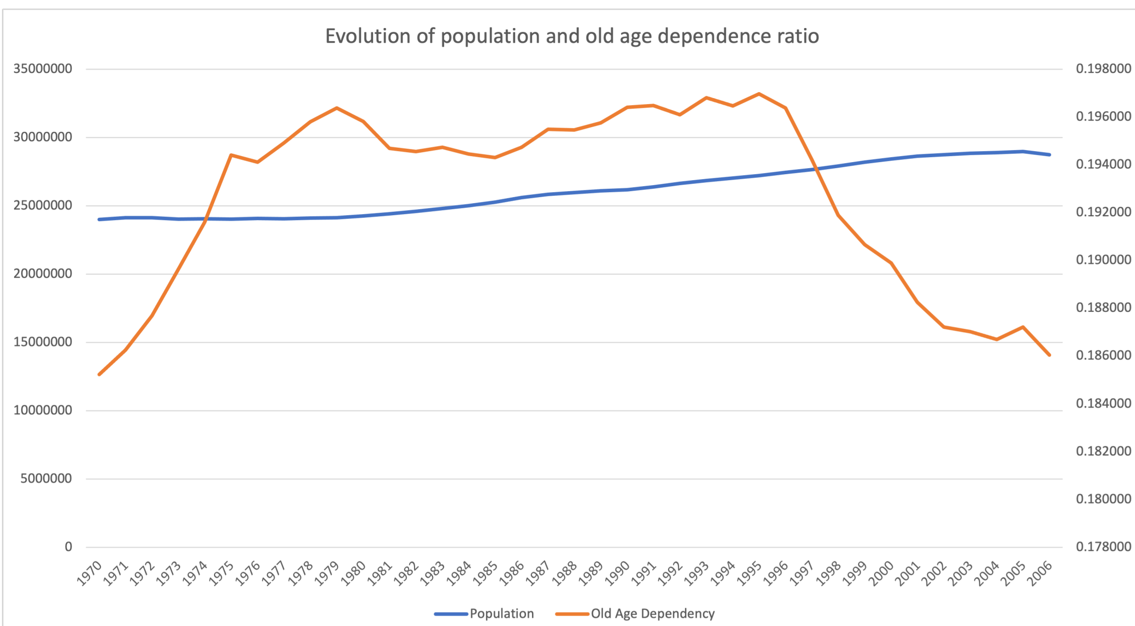

Figure A7: Weighted average old age dependency ratio for 12 cities & total population

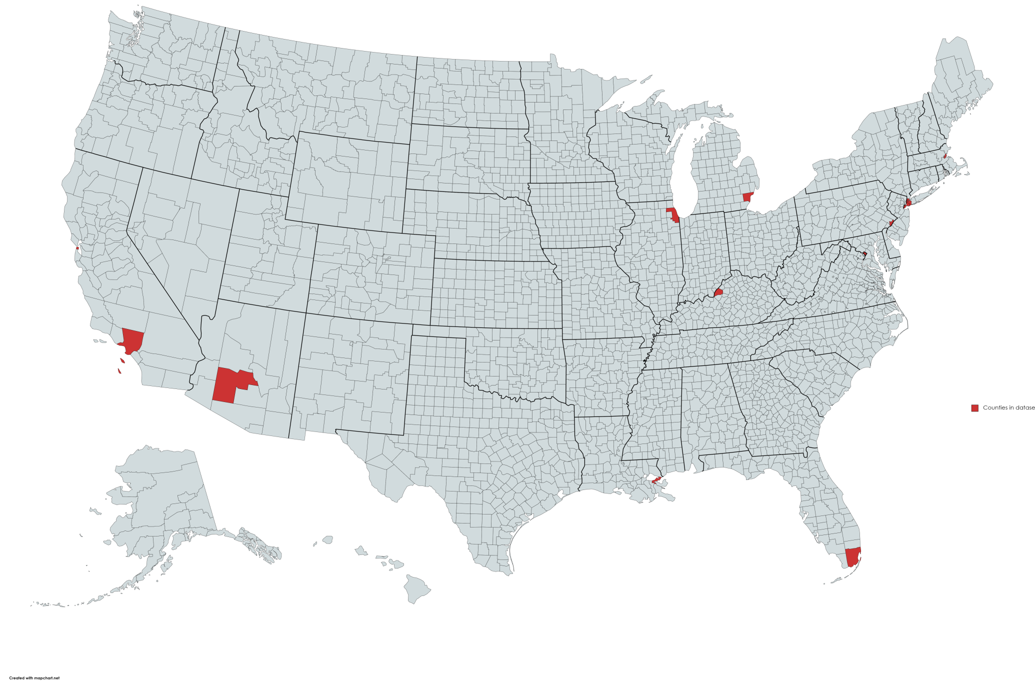

Figure A8: Map of counties included in main analysis