Age, Demographics, and the Demand for Housing, Revisited

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ABSTRACT

The United States is aging, and many baby boomers are reaching or will soon reach the retirement age of sixty-five. On the other hand, the Millennials, the largest generation in the U.S. history, has faced the problems of high rents relative to incomes and volatility in housing market. Given the shifts, we are again seeing growing debates about how these changes in age structure will affect housing and labor markets.

To address these concerns, we revisit Green and Hendershott (1996) and analyze the links between the willingness to pay for a constant-quality house and demographics using the Census 2000 and 2005-2011 American Community Survey 1-Year Public Use Microdata Sample data. The results generally reconfirm what Green and Hendershott (1996) found: The massive demographic shift will not result in another housing crisis. This is because the educational and income levels of the current and future seniors are relatively higher than before, leading them to consume more than previous generations. Also, the size of the Millennial generation will drive the growth of aggregate housing demand, although the growth of per household housing demand may be relatively modest.

Keywords: Age, Cohort Effects, Demographics, Housing Demand, Projections

1. Introduction

On the heels of collapse in the U.S. housing market in late 2007, some scholars and practitioners (e.g. Myers and Ryu, 2008; Pendall et al., 2012; McIlwain, 2012) fear that another crisis is on the horizon. This concern arises from the nation's rapid aging and loss of veteran workers to retirement. Since 2011, the first wave of 76-million baby boomers has been reaching the retirement age of sixty-five, and many of the remaining 49 million workers in this birth cohort will soon retire and as a result, perhaps change aggregate preferences, particularly for housing. Given this inexorable trend, several scholars have warned that this potential mismatch between retiring baby boomers who would wish to downsize their housing and young buyers who might not be ready to absorb these houses yet may result in massive sell-offs, drops in property values, and falling property tax revenues: in short, another housing crisis.

We disagree with this prophecy. Indeed, we are reminded of a similar controversy. About 25 years ago, Mankiw and Weil (1989) purported to show that, in 1970 and 1980, people's demand for housing increased until they reached about the age of 40, after which it fell. This finding led to their famous forecast that inflation-adjusted house prices would fall by 47 percent between 1987 and 2007, as the massive baby-boom population gradually turned 40 and beyond, thus reducing per capita housing demand. Understandably, the study caused a great sensation. Media outlets covered how the changes in the age distribution would shift the future of house prices. Scholars fiercely debated whether the forecast was correctly made (Woodward, 1991; Hamilton, 1991; Hendershott, 1991; Holland, 1991; Mankiw and Weil, 1991).

Fortunately for homeowners, and unfortunately for Mankiw and Weil, such a decline in housing prices never happened: The S&P/Case-Shiller Home Price Index showed that real house prices doubled between 1987 and 2007. Even in the aftermath of the housing bust, prices are about 6.2 percent higher nationally in real terms than they were in 1987.[1]

A comprehensive explanation for why the prophecy proved false may be found in Green and Hendershott (1996), as well as Pitkin and Myers (1994). Distinguishing a cohort effect from an age effect, these studies suggested that the reason Mankiw and Weil found that older people had lower housing demand was not because they consumed less housing as they became old (an age effect), but rather that, in 1970 and 1980, older generations tended to be not as well educated as younger generations. Hence older generations earned less money over their entire lives than did younger generations, which in turn meant they consumed less housing over their entire lives (a cohort effect).

This discovery of a cohort effect led Green and Herdershott (1996) to project modestly increasing housing demand because the better educated (and more affluent) baby-boomers would consume more housing even at older ages compared to those of previous generations. Yet, although they suggested education and income as the source of generational difference, they could not examine the cohort effect itself as the paper used single year cross-sectional data. Also, since the study was published about eighteen years ago and was based on 1980 Census micro data, the findings might not apply to the current housing market.

Given the gap between the most current research on cohort effects on housing demand and the recent concerns of collapse in the price of houses, we believe the time has come to revisit and update Green and Hendershott (1996). We will therefore once again examine the effects of demographic factors, especially age and cohort effects, and socio-economic characteristics on the

[1] The calculation is based on the S&P/Case-Shiller U.S. National Home Price Index and the BLS's Consumer Price Index (CPI-U). In 2014, the real prices are about 39.4 percent higher than those in 1987.

willingness of households to pay for houses (and the individual components of houses) during the recent boom and bust period. The pooled annual micro-data from the decennial Census and American Community Survey will allow us to do so. Based on the updated information on the relationship, we will also forecast how future demographic changes will reshape future per-household and aggregate housing demand.

The remainder of the paper is organized as follows. The next section, Section 2, briefly reviews previous research on the relationship between demographic factors and housing demand. Section 3 provides the theoretical and empirical framework of our analysis, developing the models presented in Rosen (1974), Mankiw and Weil (1989), and Green and Hendershott (1996). In Section 4, this paper describes the decennial census and the American Community Survey data we use and how we use it. Section 5 presents and describes the regression results. Based on these findings, Section 6 analyzes different housing demands across demographic groups and forecasts housing demands, per household and aggregate, for the next several decades. Section 7 draws policy implications and concludes the paper.

2. Literature Review: Demographics and Housing Demand

A seminal and ambitious paper, Mankiw and Weil (1989) examined the link between age and housing demand. On the one hand, the article provided an innovative way to relate demographic change to housing demand dynamics, and further to housing price dynamics. On the other hand, the study had limitations. Perhaps the most important conceptual problem is that it used cross-section regressions as the foundation for a dynamic forecast.

Moreover, the cross-sectional regressions were simply bivariate regressions with a flexible functional form. The only explanatory variable—a person's age—was divided into 1-year age dummies to create the right hand side of their regression. The left hand side was house value, which was defined as either self-reported value (for owners) or a multiple of self-reported rent (for renters). Using 1970 and 1980 Census micro data, the authors found that the average quantity of housing demanded remained at a low value for the first 20 years of life, rose sharply between the ages of 20 and 40, and then declined gradually after age 40, falling by around one percent per year of peak demand. The gradual decrease in the demand for housing after age 40 was surprising, but Mankiw and Weil explained that the decline was result of decreasing labor productivity and lower expected remaining lifetime income with age. These would lead older people to spend less money on housing. This finding led Mankiw and Weil to make their famous prediction that housing demand would fall, and therefore that the real house prices would fall about 3 percent per year or 47 percent between 1987 and 2007.

The paper attracted great attention as soon as it was published, and led to serious debates over the validity of its argument and prediction. First, both Holland (1991) and Hendershott (1991) pointed out that Mankiw and Weil erroneously used non-stationary time series variables in their forecasting model. Hendershott (1991) also noted the absence of explanatory variables apart from age. After controlling for user cost-related variables such as real after-tax interest rates and change in the rates, Hendershott (1991) found that his expanded model predicted substantially more modest declines in real house prices than the Mankiw-Weil prediction. On the other hand, Woodward (1991) and Hamilton (1991) raised questions about the implicit underlying assumption in the Mankiw and Weil paper that the housing market was not efficient enough to produce supply responses to changing housing demand. However, at the end of the conversation, Mankiw and Weil contended that their critics failed to reach consensus (Mankiw and Weil, 1991).

Even though these commentaries pointed out a number of mis-specifications and flaws of the Mankiw and Weil model, all of them missed the most important reason for why the forecast failed: the difference between an age effect and a cohort effect (Pitkin and Myers, 1994). Mankiw and Weil (1989) implicitly assumed that the demand for housing by age would be constant across generations, thus overlooking the effect of birth cohort on housing demand. At some level, the assumption is understandable: there did seem to be stable age-specific housing demand and age-income relationships up until 1980 (McFadden, 1994). Nevertheless, there were considerable differences in education and income levels between baby-boomers and previous generations, and Green and Hendershott (1996) clearly showed how these differences might bring about substantially different outcomes.

Using 1980 Census micro data, Green and Hendershott (1996) related the demands for housing characteristics to demographic and socio-economic variables using Rosen (1974)'s two-stage hedonic price model. In the paper, they computed two age-specific housing demand measures: One estimated how the demand for housing varied solely with age while controlling for other socio-economic factors (a partial derivative), and other measured the same age-specific demands without controlling for other factors (a total derivative). The total age derivative curve had a very similar pattern, an inversed u-shape having a peak at age 36 to 40, to the pattern Mankiw and Weil (1989) plotted. The partial derivative curve, however, depicting pure age effects, reflected gradually *increasing* demand for housing even after age 40.

Green and Hendershott (1996) asserted that the difference between the two derivatives could be mainly explained by the differences in educational levels between the birth cohorts. Educational attainment is closely related to permanent income, and tends to remain constant (and certainly doesn't fall) once adults reach maturity. Because boomers were better educated than previous generations, their lifetime earnings were higher throughout their lives than other generations. Boomers therefore have consumed (and can be expected to continue to consume) more housing, as well as everything else, throughout their lives. Thus demographics should produce greater, rather than lower, housing demand.

This finding gets support from other studies that used techniques from demography, rather than econometrics. Pitkin and Myers (1994) and Myers (1999) also argued that Mankiw and Weil model wrongly related the housing demands to age, while ignoring the cohort effect. Using the cohort transition technique, which follows the housing demand of cohorts across time, Pitkin and Myers (1994) plotted age-housing demand curve that was very similar to the partial derivative curve in Green and Hendershott (1996).

From the period 1987 to 2007, real housing prices actually increased substantially, contrary to the Mankiw-Weil's prediction. Consequently, the discussion over the links between age, cohort, and housing demand faded (Ottaviano and Minerva, 2007). However, in an era of aging baby boomers, and in the aftermath of a housing crash (albeit one that left real house prices still higher than they were in 1987), the relationship between demographics and the demand for housing has once again become the focus of growing attention. This paper thus aims to answer the following questions: (1) How does household willingness to pay for housing attributes vary depending on the stage of household life cycle, while controlling for other factors? (2) Are there generational differences in housing demands between birth cohorts, after controlling for income?

(3) How will demand for housing services be changed by ongoing demographic change in the near future? The remainder of this paper seeks to answer these questions.

3. Theoretical Framework[2]

Following Green and Hendershott (1996), this paper examines the relationship between demographics and housing demand using Rosen's (1974) two-stage hedonic price model. In the first stage, the hedonic model provides a theoretical framework to decompose the value of a good or service into the contributions of its hedonic characteristics. In the second stage, the model relates the implicit prices for hedonic characteristics to economic constraints and taste variables of consumers. Thus, it is the second stage where the model links consumer's tastes, at least partially determined by his/her demographic characteristics, to willingness to pay for a hedonic characteristic.[3]

This two-stage hedonic model is applied to the U.S. housing market through the following steps. In the first stage, the value of a housing unit is defined as quantity of housing services generated from the housing capital in a year. The flow of housing services can be seen as a function of *n* hedonic characteristics of the housing unit:

$$q = f(\boldsymbol{Z}) = f(z_1, z_2, z_3, \dots, z_n), \tag{1}$$

[2] This section closely follows the corresponding section in Green and Hendershott (1996).
[3] For a more comprehensive and detailed discussion about the hedonic price model, please refer to Taylor (2003) and Palmquist (2005). Theoretical and practical issues have limited the use of the second stage model in the literature.

where q is the real flow of housing services and $\boldsymbol{Z}$ is a vector of n hedonic characteristics of the house, $z_1, z_2, \ldots, z_n$. Then, as Rosen (1974) shows q_i, the implicit marginal price of i^{th} housing characteristic z_i, can be recovered by taking derivatives of (1):

$$q_i = \frac{\partial f}{\partial z_i}(\boldsymbol{Z}). \tag{2}$$

Given the estimated implicit marginal prices of housing attributes, we relate the marginal willingness to pay for the i^{th} housing characteristic, q_i, to a set of hedonic characteristics of the housing unit, demographic and socio-economic attributes of the household, and non-housing household income:

$$q_i = g_i(\boldsymbol{Z}, N, \boldsymbol{A}, \boldsymbol{C}, \boldsymbol{X}, \boldsymbol{Y}, \boldsymbol{AY}), \tag{3}$$

where $\boldsymbol{Z}$ is a vector of n hedonic characteristics as before, N is household size, $\boldsymbol{A}$ and $\boldsymbol{C}$ are age and birth cohort variable sets, $\boldsymbol{X}$ is a vector of other demographic and socio-economic characteristics, $\boldsymbol{Y}$ is the household's real income net of housing expenditures, and $\boldsymbol{AY}$ is between age and income interactions.

The Rosen (1974) paper does not specify the functional form of the hedonic model. There are various functional forms for estimating consumer demand functions (Deaton and Muellbauer, 1980), but in this paper we use a log-log model because it is relatively simple and intuitive among the functional forms that allow (1) variation in implicit marginal prices across consumers and (2) imposition of linear homogeneity on the hedonic function p (Diewert, 2003):

$$\ln q = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln z_i + \varepsilon, \tag{1a}$$

Where q is the flow of housing services, z_i is the i^{th} housing characteristic, and the disturbance term ε is independently distributed. We impose upon the log-log model a restriction that forces it to be homogeneous of degree one.[4] The assumption that the function $f(\boldsymbol{Z})$ is homogeneous of degree one is admittedly strong but necessary to estimate the demand for an entire house as the sum of the willingness to pay for each one of its characteristics. Given that the log-log function (1a) is restricted to be homogeneous of degree one, the aggregate quantity of housing services from the house with a vector of n housing characteristics $\boldsymbol{Z}$ can be obtained as

$$q = \sum_{i=1}^{n} q_i z_i, \tag{4}$$

by Euler's Theorem. Using this relationship, we can estimate the willingness to pay for a constant-quality house.[5] Keeping housing quality constant is important for estimating and comparing real house prices across households and over time. For the log-log model (1a), the homogeneity restriction is:

$$\sum_{i=1}^{n} \alpha_i = 1. \tag{5}$$

Thus, we estimate (1a) by constrained linear regression subject to the homogeneity restriction (5). Based on the estimated regression coefficients, we obtain the hedonic prices, q_i, by taking partial derivatives of q with respect to the $\underline{z_i}$ as:

$$\frac{\partial f}{\partial z_i} = \frac{\partial f}{\partial q}\frac{\partial q}{\partial z_i} = \frac{1}{q}\frac{\partial q}{\partial z_i} = \frac{\alpha_i}{z_i}, \quad q_i = \frac{\partial q}{\partial z_i} = \frac{\alpha_i q}{z_i}. \tag{2a}$$

In estimating (3), we regress the implicit marginal price q_i on household's demographic and socioeconomic characteristics:

[4] The inclusion of the homogeneity restriction and fixed effects terms (which will be explained later) into the hedonic model was the main reason that we choose the log-log model over the translog function model which Green and Hendershott (1996) utilized. The statistical package we used (Stata 11.2) did not allow us to impose the homogeneity restriction to hundreds of spatial fixed effects and thousands of their second-order interactions in the translog model. Although we might not be able to take the advantages of the translog model (such as its flexibility), we hope the simpler log-log model with limited spatial fixed effects performs fairly well as the translog model does (Kuminoff et al., 2010; Cropper et al., 1988).

[5] The constant-quality house is defined here as a hypothetical housing unit with average housing characteristics of the housing units in our data set.

$$q_i = \alpha_i + \beta_i \boldsymbol{Z} + \nu_i N + \gamma_i \boldsymbol{A} + \zeta_i \boldsymbol{C} + \psi_i \boldsymbol{X} + \upsilon_i \boldsymbol{Y} + \iota_i \boldsymbol{AY} + \mu_i, \tag{3a}$$

where $\boldsymbol{Z}$ is a vector of *n* hedonic characteristics of the dwelling unit, *N* is household size, $\boldsymbol{A}$ and $\boldsymbol{C}$ are vectors of the number of household members by age and birth cohort, respectively, $\boldsymbol{X}$ is a vector of the household's other demographic and socio-economic characteristics, $\boldsymbol{Y}$ is non-housing household income, which is the household income after housing cost incurred, $\boldsymbol{AY}$ is interaction terms between age and income, and μ is an independently distributed error term.

Borrowing from Mankiw and Weil (1989), we assume that the total willingness to pay for a house of a household is equal to the sum of its members' willingnesses. With regard to age, the willingness to pay for the i^{th} housing characteristic of the r^{th} household member q_{ir} can be seen as a function of a set of age dummy variables:

$$q_i = \sum_{r=1}^{N} q_{ir}, \quad q_{ir} = \gamma_{i0} + \gamma_{i1} age_{1r} + \cdots + \gamma_{ik} age_{kr}$$

where age_{1r}, …, age_{kr} is a set of *k* dummy variables for age of the r^{th} household member, taking the value one for the member's age and the value zero otherwise, and where *N* is household size. If there is an age effect, the estimated coefficient will be statistically significantly different from zero. If we assume that there is a cohort effect that influences an individual's willingness to pay regardless of the age effect, it would be also captured by a set of cohort dummy variables for the r^{th} household member, resulting in:

$$q_{ir} = \gamma_{i0} + \gamma_{i1} age_{1r} + \cdots + \gamma_{ik} age_{kr} + \zeta_{i1} cohort_{1r} + \cdots + \zeta_{il} cohort_{lr}$$

where $cohort_{1r}$, …, $cohort_{lr}$ is a set of *l* dummy variables for birth cohort of the r^{th} household member. Then the household-level willingness to pay for i^{th} hedonic characteristic would be obtained by aggregating *N* individual willingnesses to pay for the housing attribute,

$$q_i = \sum_{r=1}^{N} q_{ir} = \sum_{r=1}^{\mathrm{N}} \left(\gamma_{i0} + \sum_{v=1}^{\mathrm{k}} \gamma_{iv} age_{vr} + \sum_{w=1}^{\mathrm{l}} \zeta_{iw} cohort_{wr}\right)$$

$$= \sum_{r=1}^{\mathrm{N}} \gamma_{i0} + \sum_{v=1}^{\mathrm{k}} \gamma_{iv} \sum_{r=1}^{\mathrm{N}} (age_{vr}) + \sum_{w=1}^{\mathrm{l}} \zeta_{iw} \sum_{r=1}^{\mathrm{N}} (cohort_{wr})$$

$$= \gamma_{i0} N + \sum_{v=1}^{\mathrm{k}} \gamma_{iv} A_v + \sum_{w=1}^{\mathrm{l}} \zeta_{iw} C_w,$$

where N is the household size, A_v is the number of household members in age v, and C_w is the number of household members in birth cohort w. We also go beyond Mankiw and Weil (1989) and include other relevant factors such as $\boldsymbol{Z}$, $\boldsymbol{X}$, $\boldsymbol{Y}$, and $\boldsymbol{AY}$ into the model as well.

From the regression coefficients of Eq. (3a), the estimated average willingness to pay of households headed by j-year old householders for the i^{th} hedonic characteristic is:

$$\widehat{q_{\iota J}} = \widehat{\alpha}_\iota + \widehat{\beta}_\iota \boldsymbol{Z} + \widehat{\nu}_\iota \overline{N}_J + \widehat{\gamma}_\iota \overline{\boldsymbol{A_J}} + \widehat{\zeta}_\iota \overline{\boldsymbol{C}_J} + \widehat{\psi_\iota} \overline{\boldsymbol{X_J}} + \widehat{\upsilon}_\iota \overline{\boldsymbol{Y_J}} + \widehat{\iota}_\iota \overline{\boldsymbol{AY_J}}, \tag{3b}$$

where $\boldsymbol{Z}$ is a vector of n housing characteristics, $\overline{N}_J$, $\overline{\boldsymbol{A_J}}$, $\overline{\boldsymbol{C}_J}$, $\overline{\boldsymbol{X_J}}$, $\overline{\boldsymbol{Y_J}}$, and $\overline{\boldsymbol{AY_J}}$ are the averages among the households headed by j years old headers of the number of household members, those by age and birth cohort, other demographic and socio-economic characteristics, non-housing household income, and age-income interactions respectively. When $\boldsymbol{Z}$ gets the averages of households with j-year old householders, we can estimate the willingness to pay for housing characteristics that the households with j-year headers on average have; if we put the $\boldsymbol{Z_c}$, housing characteristics of a constant-quality house, then we can estimate the willingness to pay of households headed by j-year old for the i^{th} housing characteristic of a constant-quality house.

Using Euler's theorem, the real house prices of a household with a j-year-old head for a constant-quality house can be derived by aggregating the dot products of a vector of implicit marginal prices of the household, $\boldsymbol{\widehat{q}_J}$, and $\boldsymbol{Z_c}$:

$$q_j = \widehat{\boldsymbol{q}_j} \cdot \boldsymbol{Z_c} = \sum_{i=1}^{n} \widehat{q_{ij}} z_{ci}. \tag{4a}$$

We will forecast the future real house prices, both per household and in aggregate, using the recovered willingness to pay for a housing unit and household projections. First, for each age category, we will estimate the willingness to pay for an average house for the age category. We also estimate for each age group the willingness to pay for a house with average characteristics for the entire population. The projection based on age specific housing characteristics tells us the willingness to pay for a house *assuming the household never changes house type*. Alternatively, the projection based on average housing characteristics for the whole population forecasts housing demand for a constant quality of house.

Then we estimate per household housing demand for both houses by calculating the weighted average of the willingness to pay for a house with average qualities by age of householder and a constant-quality house, using the share of households whose householders are j years old, w_j, as weights. Lastly, the aggregate housing demand would be obtained by multiplying per household housing demand by the number of households. The forecast will be based on the projected number of households and share of households by age of householder.

4. Data Set

The primary sources of data are the Census 2000 5-percent Public Use Microdata Sample (PUMS) file and American Community Survey (ACS) 1-Year PUMS files from 2005 to 2011. As the nation experienced a boom and bust in housing prices over the time period, the eight years of PUMS data will allow us to infer how tastes and preferences for housing may have changed through the rise, decline, and nascent recovery. Given the rapid expansion and harsh recession, and the fact housing was an important cause of it, we expect that the average preferences for housing reached their peak and ebb within the course of the twelve years. In addition, using data from different stages of the economic cycle, we may infer a range of possible future housing demands arising from a wide range of house price expectations.

Using repeated cross-sections of the U.S. households, we are also able to separate a cohort effect from an age effect by distinguishing people of the same age but different birth cohorts across census years (e.g. comparing the 60 years old baby boomers in 2010 with the 60 year olds of other generation in 2000). This is not possible with a single-year of cross-sectional data, because each individual's age and cohort are perfectly multi-collinear in such data (e.g. all the 50-year-old people in 2010 must be the members of the baby-boom generation).

The pooled cross-sectional data provides consistent geographic boundaries, which enable us to control for housing submarket fixed effects. The most consistent geographic unit would be state (and state equivalent), but some are too large to capture unique locational characteristics. The most detailed geography available in the PUMS file is Public Use Microdata Areas (PUMAs), but the Census Bureau changes the definition of PUMA every ten years to update changes in the population distribution. To control for time-invariant local housing market conditions, we decide to use 2000 PUMA boundaries, which were defined for the 2000 Census and remained in place for the 2005 to 2011 ACS PUMS files. Therefore, the repeated cross-sectional data set enables us to not only distinguish age and cohort effects, but also control for differences in housing sub-market characteristics with consistent geographic boundaries.

Since housing services are generally consumed at the household level, our unit of analysis is the household. Household attributes include the demographic and socio-economic characteristics of the individuals occupying the housing unit. From the roughly 13.6 million original housing records (about 5.3 million from the Census 2000 and 1.2 million per year from the 2005 to 2011 ACS PUMS), we delete group quarter units, units classified as 'boat, RV, van, etc.,' and occupied units without payment of rent. The resulting data set we use is comprised of the remaining 13.2 million housing records (about 98.0 percent of original data set), which represent 103 to 113 million households in the United States from 2000 to 2011.

In the log-log hedonic regression models, q is the flow of housing services consumed, which is annual gross rent for renters and user cost for owners. We easily calculate the annual gross rent by multiplying the inflation-adjusted monthly gross rent by twelve. The user cost, the cost that an owner would pay for owning and living in a housing unit, is the product of a user cost rate and the inflation-adjusted property value the owner reported. Although there are many variations in estimating the user cost, we estimated it by the following formula:

$$\text{user cost}_t = (r_t(1-m_t) + \rho + \tau_t(1-m_t) + \delta - g_t) \times \text{property value}_t$$

where r_t is the nominal interest rate at time t, m_t is the marginal tax rate, δ is the rate of depreciation, ρ is a risk premium, τ is property tax rates, and g_t is the expected capital gain or loss. The values for the parameters are assigned by reasonable assumptions and previous empirical studies; the values for nominal interest rates (r_t) are collected from the Freddie Mac 30-year fixed-rate mortgages; the risk premium (ρ) is set to 1 percent per year; the depreciation rate (δ) is assumed to be 2.5 percent per year based on the empirical evidence in Harding *et al*. (2007); the property tax rates (τ_t) are estimated by averaging reported property tax rates by state in the Census and ACS PUMS files in each year; and the expected capital gain or loss (g_t) is ignored in this analysis because of the high uncertainty and volatility in the market during the time period the data is from. Therefore, the user cost in our analysis reflects only real net cash flows. Lastly, the marginal tax rates (m_t) are estimated using the National Bureau of Economic Research's Internet TAXSIM Program (version 9.2).[6]

The housing characteristics for the hedonic regression model include house age, number of bedrooms, number of other rooms; whether it is owned or rented; whether it is a single-family detached, single-family attached, condominium, or a mobile home; distance to CBD, population density, share of people age 25 and over in PUMA with a bachelor's degree or higher, and share of people in PUMA who are non-Hispanic white, and metropolitan statistical area (MSA)/state fixed effects.[7] We use PUMAs to determine whether a household lives inside or outside of one of the nation's largest 100 MSAs. Those within the 100 most populous MSAs in 2010 are assigned an appropriate MSA fixed effect, and those outside of the MSAs are assigned to a corresponding state's fixed effect.[8] Although imprecise, we hope the MSA/state fixed effects account for many unobserved characteristics of local housing submarkets, such as economic situation, public services, and natural amenities. To address different neighborhood characteristics within the housing submarket, we include four PUMA-level variables, distance to

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[6] The TAXSIM is a micro-simulation program for calculating federal and state income tax liabilities and marginal tax rates (Feenberg and Coutts, 1993). The estimation is based on taxpayer demographic and economic characteristics, which are comprised of up to 21 variables. In the Census 2000 and 2005 to 2011 ACS 1-Year PUMS files, we could find appropriate data for 10 key variables, including tax year, state, marital status, number of taxpayers over 65 years, wage and salary incomes of primary and secondary taxpayers, taxable pension income, gross social security benefits, rent paid, and property tax paid. Then, we use estimated federal and state marginal tax rates for households to compute the user costs.

[7] Ideally, the smallest geography, PUMA, would be the best for controlling for time-invariant local factors of housing prices; however, as the Stata allows limited number of 800 operators while there are more than 2,000 PUMAs within the United States, we decided to set sub-housing market by metropolitan areas. The most populous MSA is 'New York-Northern New Jersey-Long Island, NY-NJ-PA Metro Area' and the least is 'Modesto, CA Metro Area.'

[8] All of the PUMAs in District of Columbia and Rhode Island are within the metropolitan statistical areas so that there are no non-MSA DC and non-MSA RI fixed effects.

CBD, population density, the share of adult neighbors with a bachelor's degree or higher, and share of local residents who are non-Hispanic white. For the PUMAs, the distance to CBD is determined by the distance to the closest city hall of the primary city in the metropolitan areas.

With respect to physical housing characteristics, to avoid the "log zero value" issue, the number one is added to the house age and the numbers of bedrooms, and the dummy variables are assigned a value of the natural number *e* (2.718) if the household belongs to the category, and equal to one otherwise. By doing this, the logs of dummy variables become one or zero, and this simplifies the model. The descriptive statistics of the resulting first stage hedonic regression model variables are presented in Table 1.

[insert Table 1 here]

In Rosen's theory (1974), willingness to pay for housing characteristics, recovered by the results of the first stage hedonic regression, is linked to a vector of housing attributes and demand shift variables (e.g. income, age, education) in the second stage model. As Bartik (1987) and Epple (1987) demonstrated, however, consumers simultaneously choose both prices and quantities of housing characteristics. Therefore, the second stage hedonic model suffers a well-known, yet difficult to solve, identification problem (Taylor, 2003; Malpezzi, 2008). Not a few studies have made various suggestions to solve this issue, including instrumental variables (Bartik, 1987; Green and Hendershott, 1996; Boyle et al., 1999; Palmquist, 1984), market segmentation (Brown and Rosen, 1982; Brasington and Hite, 2005), and parametric model (Bishop and Timmins, 2011). The suggested instruments have often been found to be weak, however, and there is no consensus on which method performs the best, at least so far.

Given that the main purpose of this paper is projecting future real house prices, we decided to use a reduced form approach to analyze the relationship between demographics and the implicit prices of a constant-quality house. By definition, a constant-quality house has physical and geographical characteristics that are exogenous relative to household characteristics. We are thus analyzing varying willingness to pay for a constant-quality house by differing household characteristics for an exogenously given level of housing quantity.

The key variable in this paper, the number of household members by age, is obtained from the age variable, while those 90 years old and over are grouped. Likewise, the number of household members by birth cohort is calculated based on the census year and age. Following Carlson (2008)'s categorization of generations, people are classified into Good Warriors and earlier generations (or Greatest Generation and earlier, who were born before 1929), Lucky Few (or Silent Generation, born between 1929 and 1945), Baby Boomers (born from 1946 through 1964), Generation X (born between 1965 and 1982), and New Boomers and later generations (or Millennials, born after 1982).

For other demographic and socio-economic attributes, we include each household's highest earner's race/ethnicity (non-Hispanic white, African American, Asian and Pacific Islander, Hispanic, and other), and his/her nativity and length of residence in the United States (native-born residents, recent immigrants who entered into the U.S. within the past ten years, and long-established immigrants who have lived in the U.S. for more than ten years), and educational attainment (high school dropout, high school graduate, some college/associate degree, bachelor's degree, and master's degree or higher). The marital status and presence of partners of household head is also included (married couple, widowed, divorced, separated, never married living alone, and never married living with unmarried partners).

The non-housing household income is equal to the reported household income for owner-occupied households, as the total income includes imputed rent (i.e. reported income essentially adds and subtracts imputed rent). For renters, the non-housing household income would be the household income less rent expenses. Household income, housing value, and rents are adjusted for inflation in 2014 dollars.

5. Demographics and Housing Demand

We estimated the first stage hedonic price model Eq (1a) separately for each year, rather than with pooled data. By doing this, we allowed implicit marginal prices of housing characteristics to vary over time as economic conditions change. Table 2 presents the results of both constrained and unconstrained regressions for the first stage hedonic model. Even though the goodness of fit measures such as R-squared are not available for the constrained linear regression, the OLS regression without the homogeneity fits the data fairly well, explaining between 44.4 to 57.4 percent of the variations in the log of the housing service flow *q*, depending on census year. Only one of the seven structural characteristic coefficients and one of the four neighborhood characteristics are not statistically different from zero at the one percent significance level for one year and three years, respectively (tenure in 2010; population density in 2005, 2006, and 2011), and only five to seventeen out of 148 MSA/state fixed effects are statistically not significant at the one percent level for each year.

[insert Table 2 here]

Two things are immediately noticeable. First, for structural characteristics of housing and neighborhood characteristics there are no substantial differences between the restricted and unrestricted regression models in the estimated coefficients and corresponding standard errors, although the differences are apparent for MSA/state fixed effects. This gives us confidence to impose the homogeneity restriction on the model: It indicates that recovered implicit marginal prices using the estimated coefficients from the constrained model will be almost identical to those based on the OLS estimates, at least for structural and neighborhood characteristics, and therefore we can add up the set of house characteristics multiplied by the implicit prices of those characteristics to recover the total value of housing demanded. Given the advantage of using the constrained model, we will use it in our later analysis.

Otherwise, we can see that estimated coefficients, and thus implicit marginal prices, have dramatically changed during the recent housing boom and bust (Figure 1). For example, taking a housing unit with average price and average housing characteristics, the implicit marginal price of bedroom increased from $2,050 (per year, 2014 inflation-adjusted dollars) in 2000 to $3,888 in 2006, before it dropped to $2,445 in 2011. The implicit value of ownership fluctuated even more, growing rapidly from $1,214 in 2000 to $3,354 in 2007, and then falling to a negative value (about -$557 per year) in 2011, reflecting depressed consumer demands for owner-occupied housing during and after the Great Recession.[9]

[insert Figure 1 here]

[9] There might be unobserved neighborhood characteristics that are systemically correlated with both housing characteristics and the flow of housing services, yet not fully accounted for by the MSA/state FE. However, the estimated coefficients from (unrestricted) log-log regression model with the MSA/state FE are almost identical to those with PUMA FE, which assuage our concerns.

For the second stage hedonic model, we estimate (3a) for each hedonic characteristic using the pooled cross-sectional data set. To do this, we first recover the willingness to pay of a household for housing characteristic i, $\widehat{q_i}$, using the formula (2a) with estimated regression coefficients in (1a), a vector of housing characteristics $\boldsymbol{Z}$, and the flow of housing services q of each household. Then, we relate the estimated implicit prices to the demographic and socio-economic characteristics of the household living in the dwelling unit.

[insert Table 3 here]

The estimates of the second stage hedonic regression generally have expected values and signs (Table 3). Other housing and household characteristics held constant, non-housing household income is, on average, negatively associated with the willingness to pay for inferior housing characteristics such as house age, single-family attached home, condominium, mobile home, and distance to CBD. On the other hand, income is positively correlated with the implicit prices of normal goods such as bedrooms, other rooms, tenure, and share of people age 25 and over with a bachelor's degree or higher. The relationship between income and non-Hispanic white share is insignificant at customary levels of confidence.

Comparing two households having the same characteristics except age composition, a household with more children, seniors, and non-Hispanic white college graduates tends to have greater willingness to pay for owning a large single-family detached home in a neighborhood that is closer to the urban center, while a household with more working-age adults, on average, has lower demands for such a house (Figure 2).

[insert Figure 2 here]

This somewhat counter-intuitive result can be explained by two possible reasons. First, the life-cycle hypothesis suggests that, given a certain fixed level of income, people appear to over-consume, including housing services, in younger and senior years and appear to under-consume in during this working years (Modigliani and Brumberg, 1954). If apparent over-/under-consumption is reflected as greater/smaller willingness to pay, the results are consistent with the life-cycle theory. Second, the ceteris paribus condition makes larger households have lower per-capita income within the household. Therefore, we may expect a household with more working-age household members (and less per-capita income) to have smaller demand for housing services per person than another having the same household income but fewer household members. Blumenschein et al. (2008) and Bajari and Kahn (2008) also report the same negative effects of household size on willingness to pay

The interaction terms between age and non-housing household income present different income effects on willingness to pay by age (Figure 3). In general, non-housing household income has relatively stronger impacts on the willingness to pay of a household with more school aged children and seniors, while it is relatively smaller through the working ages, 20s though 40s.

[insert Figure 3 here]

The second stage regression results also present distinct differences across birth cohorts in willingness to pay for housing characteristics that cannot be fully explained by generational gaps in education and household income. In general, the members of the Lucky Few and earlier generations have relatively higher demand for owning a new and spacious single-family detached home in a community with more college graduates than other generations, while the members of the Generation X have the lowest willingness to pay for such a home. Interestingly, Generation X has the greatest willingness to pay for old, single-family attached, and mobile homes; otherwise, they have the lowest willingness to pay for bedrooms and other rooms among the generations. Among the birth cohorts, the Millennials to this point have the lowest demand for owing a home and for condominiums: other cohorts have had, at particular ages, higher demand.

The estimated coefficients on educational attainment, usually seen as a proxy for permanent income, have expected signs and values. Controlling for other factors, households with highly educated highest earners are more willing to pay for normal goods (bedrooms, other rooms, tenure, and share of neighbors with a bachelor's degree or higher) and less willing to pay for inferior goods (house age, single-family attached home, condominium, and mobile home). Notably, the gaps between undergraduate and graduate degree holders are not as large as the gap between high school graduate and associate degree holder or between two-year and four-year degree holders.

The willingness to pay also varies by race/ethnicity and immigration status. Compared to non-Hispanic whites, African American and Hispanic households have relatively lower willingness to pay for owning single-family detached dwellings with more rooms in a neighborhood with more college graduates. Asians and Pacific Islanders have relatively greater demand for new houses and other rooms, but lower demand for single-family detached homes in a neighborhood with more non-Hispanic white college graduates than non-Hispanic white households. Ceteris paribus, immigrant households have higher demand for recently built units, bedrooms, other rooms, homeownership, and neighborhoods with greater shares of people with a bachelor's degree or higher, and lower demand for single-family attached homes, condominiums, mobile homes, and homes closer to urban centers. Long-term resident immigrants have even higher demands for new and spacious single-family detached dwellings in a community with more non-Hispanic white college graduates than both native-born and recent immigrant households.

When we look at household status, we find that singles, especially divorced ones, have lower willingness to pay for recently built single-family detached homes with more rooms than married couple households, after controlling for income. The only exception is when the never married householder is living with partners: they have a greater willingness to pay for bedrooms, other rooms, tenure, and proximity to urban centers, and lower demand for attached single-family homes, condominiums, and mobile homes in a neighborhood with more college graduates. It may be the case that once income is controlled for, non-married people want more spaces than married couples because of a desire for privacy.

6. Real House Prices and Forecast

Using the formula (3b) and (4a), we estimate the willingness to pay for (1) a house with the average characteristics consumed by *j*-year old heads, for each age j, and (2) a constant-quality house, for each age j. We can think of the first as $p_a q_a$, where p_a is average price and q_a is average quantity for each age group, and the second as $p_a \overline{q}$, with p_a as before and $\overline{q}$ as average quantity of housing for *all* age groups. Figure 4 presents total and partial derivative curves with respect to age of willingness to pay for a house where quality varies with householder age. Here, the total derivative reflects allowing households' demographic and socio-economic characteristics to vary with age: for example, when we look at the willingness to pay of 30-year-olds, we take into account the average 30-year-olds' race, educational attainment, etc. The partial derivative keeps all household characteristics constant, *except* age. The total derivative curve fits well the actual average flow of housing services by age of householder, indicating that the model performs well in estimating average housing prices. Age alone appears to have a small effect on housing demand—the relationship between age and demand is flat relative to the total derivative. Housing demand appears to decrease with age not because of age, but rather because of characteristics associated with age within a cohort, such as income, educational levels, and marital status. The differences between the total and partial derivative curves are not that large for the age-specific-average-quality house.

[insert Figure 4 here]

Figure 5 presents the total and partial derivative curves of willingness to pay for a constant-quality house with respect to age. As housing qualities are fixed, we can see much less variation between the curves across ages. The total derivative curve shows that housing demand for a family would gradually increase over most of its life-cycle, not declining until age 65, at which point it declines gradually until age 80. The relationship between partial and total age derivatives for $p_a\overline{q}$, resemble our estimates for $p_a q_a$: the partial derivative has greater values in young and senior years, although the seniors' willingness to pay for a constant-quality house slightly increases or stays flat with age. This result implies that currently middle aged adults will have greater housing demand per unit quality when they become seniors and reconfirms what Green and Herdershott (1996) found based on the 1980 Census, although the difference between the partial and total derivative has attenuated, in large part because today's seniors are better educated and have greater income relative to the young than those in 1980.

[insert Figure 5 here]

Lastly, we analyze the willingness to pay for a constant-quality house by various demographic and socio-economic groups under the ceteris paribus assumption (Figure 6). In general, the willingness to pay for a constant-quality house is not substantially different among generations, once other factors, including education and income, are held constant. The Lucky Few has the greatest housing demand: it is about 1.0 percent higher than the Great Warriors and earlier generations, while the Millennials have the lowest willingness to pay for a constant-quality house, at about 1.1 percent less than the Great Warriors and earlier generations. Racial and ethnic minority households tend to be less willing to pay for a constant-quality house, at about ten percent less than non-Hispanic white households. Holding other factors constant (including race/ethnicity, income, and education), immigrants have greater willingness to pay for a constant-quality house, especially when they have stayed in the United States for a long time. Even though singles have lower willingness to pay for a constant-quality house than married couples, those widowed and never married living with partners have relatively higher housing demands, when compared with married couples. The willingness to pay dramatically increases as educational attainment grows, with the sharpest increase happening between two and four year degrees. The change in real house prices by year present how housing demand grew and fell over the time period studied.

[insert Figure 6 here]

Finally, we forecast future housing demand based on household projections made by McCue (2014) and Myers and Lee (forthcoming). Using these household projections and our results, we can make fifteen projections. First, the McCue (2014) and Myers and Lee (forthcoming) papers provide respectively three and two scenarios for household growth based on different assumptions about growth rates.[10] Then we estimated three sets of willingness to pay by age of householder, using the data from 2000 to 2011, 2005 to 2007, and 2009 to 2011. Among the fifteen combinations of household projections and willingness to pay, we select the highest, middle, and the lowest housing demand projections to provide a range of possible future housing demands. Figure 7 presents the forecasted willingness to pay for a constant-quality house and an age-specific-average-quality house by age of householder.

[insert Figure 7 here]

All of the projections show growing housing demands in aggregate terms. The differences in the projected demands between a constant-quality house and an age-specific-average-quality house are not substantial (less than one percent), but those based on using total and partial derivatives are material. The most optimistic view (a combination of high scenario of McCue (2014) and willingness to pay in 2005-2007 demonstrates what would happen if housing demand were to return to its 2005-2007 level with robust household growth. The most pessimistic case (a combination of scenario 2 of Myers and Lee (forthcoming) and willingness to pay in 2009-2011) indicates what would happen if the housing demand were to fall back to 2009-2011 levels with a weak recovery of household growth. The middle two can be understood as the future housing demand based on the most likely household projections (middle cases) and the average willingness to pay for the period 2000-2011. All projections feature some demand growth, though there are some variations in the growth rates. This result does not necessarily

[10] Myers and Lee (forthcoming) actually present four scenarios, but as the authors mentioned that the two extreme optimistic and pessimistic cases are almost impossible to happen, we use only the two highly plausible scenarios in the middle.

predict that the growth will actually occur, but does suggest that it is unlikely that demographic forces alone will lead to decreased aggregate housing demand.

[insert Table 4 here]

When we project future housing demand per household, the growth rates are much more modest than they are in aggregate (this is to be expected, given that we expect population growth); under certain assumptions, we even find a small decline in per household housing demand). Table 4 presents a full list of projected growth rates. If we hold housing quality constant over the life-cyle, we find that per household housing demand tends to increase. But if we take into account that people demand higher quality houses at come ages relative to others, we find that demographics will, depending on assumed population projections, either push per household housing demand slightly up or slightly down. All of the growth rates of housing demand per household based on McCue (2014) have positive values, and all the projections for a constant-quality house have positive values as well. Only the housing demand for an age-specific-average-quality house with Myers and Lee (forthcoming)'s household projections ever produce negative growth rates. This is because the Myers and Lee projects that there will be fewer shares of households headed by middle-aged adults in the future, mainly due to the lagged effects of current twenty-somethings' hardship in housing market. Therefore, the projections indicate that in general, there should be no substantial decline in housing demand, both in aggregate and per household terms, although there might be a slight decline in per household housing demand if the Millennials suffer the lagged effects of recently poor housing market.

7. Conclusion

The United States is aging and changing demographically. Many baby boomers are reaching or will soon reach the retirement age of sixty-five. The biggest generation in the U.S. history, the Millennials, is also the most racially/ethnically diverse group in the history. The changes in social norm are reflected in attitudes in sexual preferences, transition to adulthood, family formation and composition, and so on. Given the shifts, we are again seeing growing debates about how these changes in age structure will affect our housing and labor market.

To address the concerns, we revisit Green and Hendershott (1996) and analyze the links between the willingness to pay for a constant-quality house and demographics using the current data. The results generally reconfirm what Green and Hendershott (1996) found: The massive demographic shift will not result in another housing crisis. This is because the educational and income levels of the current and future seniors are relatively higher than before, leading them to consume more than previous generations. Also, the size of the Millennial generation will drive the growth of aggregate housing demand, although the growth of per household housing demand may be relatively modest.

We are not arguing that our projections will be realized. What we want to argue is that the demographic-driven changes in housing demand are not as negative as some might think. We have witnessed how extreme and threatening forecasts, unfortunately without reasonable and probable grounds, not only caused confusion but also cost the academic development of the field of study.

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Table 1. Descriptive statistics for first stage hedonic regression model variables

		2000	2005	2006	2007	2008	2009	2010	2011
Household level variables									
Observations (thousands)		5,156	1,135	1,139	1,150	1,162	1,168	1,179	1,178
Weighted obs. (thousands)		103,380	108,756	109,309	110,105	110,901	111,363	112,297	112,667
Flow of	Mean	17,395	21,732	23,846	23,871	22,557	19,970	18,802	17,579
housing svc.	Std. Dev.	20,133	25,079	27,513	27,240	29,869	25,283	22,386	20,687
House age	Mean	37.38	38.88	39.10	39.34	39.87	40.33	40.32	40.83
	Std. Dev.	29.94	29.44	29.49	29.40	29.12	28.98	28.80	28.63
Number of	Mean	2.62	2.74	2.76	2.77	2.77	2.77	2.77	2.77
bedrooms	Std. Dev.	1.13	1.09	1.09	1.09	1.17	1.14	1.16	1.17
Number of	Mean	2.96	2.97	2.97	2.98	3.16	3.14	3.12	3.10
other rooms	Std. Dev.	1.40	1.37	1.37	1.38	1.66	1.63	1.65	1.64
Tenure	Mean	0.67	0.68	0.69	0.69	0.68	0.67	0.67	0.66
	Std. Dev.	0.47	0.47	0.46	0.46	0.47	0.47	0.47	0.47
Single-family	Mean	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
attached	Std. Dev.	0.23	0.23	0.23	0.23	0.23	0.24	0.24	0.24
Condominium	Mean	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Std. Dev.	0.44	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Mobile home	Mean	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	Std. Dev.	0.25	0.24	0.24	0.24	0.24	0.24	0.23	0.23
PUMA-level variables									
Observations									
Distance to	Mean	45.93	46.06	46.07	46.06	46.12	46.11	46.25	46.26
CBD	Std. Dev.	77.52	77.74	77.41	77.61	77.94	77.87	79.16	79.77
Population	Mean	3,151.4	2,936.1	2,913.4	2,917.7	2,932.6	2,983.7	2,910.6	2,933.0
density	Std. Dev.	7,731.7	7,254.6	7,219.4	7,303.9	7,358.5	7,454.4	7,217.8	7,228.0
% people 25+	Mean	24.60	27.43	27.72	28.23	28.44	28.66	29.03	29.37
with a BA+	Std. Dev.	12.53	13.38	13.32	13.47	13.59	13.60	13.56	13.78
% people who	Mean	70.33	68.15	67.75	67.47	67.07	66.65	65.33	64.95
are NH-white	Std. Dev.	23.99	24.67	24.47	24.39	24.27	24.25	24.49	24.51

Table 2. The first stage hedonic regression results, 2000-2011 (Dependent variable: log of the flow of housing services)

	2000	2005	2006	2007	2008	2009	2010	2011
With homogeneity restriction								
House Age	-0.150	-0.156	-0.152	-0.147	-0.158	-0.163	-0.166	-0.172
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Number of bedrooms	0.426	0.615	0.613	0.613	0.525	0.529	0.524	0.524
	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Number of other rooms	0.257	0.283	0.284	0.276	0.237	0.244	0.239	0.233
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Tenure	0.151	0.209	0.293	0.306	0.228	0.069	0.003	-0.068
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Single-family attached	-0.179	-0.140	-0.138	-0.135	-0.150	-0.146	-0.149	-0.163
	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Condominium	-0.179	-0.171	-0.172	-0.161	-0.199	-0.192	-0.204	-0.212
	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Mobile home	-1.027	-1.119	-1.117	-1.115	-1.141	-1.126	-1.118	-1.108
	(0.002)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
Distance to CBD	-0.040	-0.050	-0.047	-0.048	-0.044	-0.040	-0.041	-0.039
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Population density	-0.003	0.001	0.001	0.002	0.003	0.003	0.002	0.001
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
% people 25+	0.354	0.344	0.350	0.343	0.364	0.374	0.380	0.388
with a BA+ in PUMA	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
% people who are	0.043	0.057	0.051	0.052	0.038	0.042	0.036	0.037
NH-white in PUMA	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
New York Metro Area	0.555	0.709	0.709	0.697	0.696	0.702	0.709	0.713
	(0.001)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
...	...	...	...	...	...	...	...	...
Constant	7.970	7.732	7.731	7.731	7.899	7.865	7.897	7.891
	(0.004)	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)	(0.011)	(0.012)
Without homogeneity restriction								
House age	-0.150	-0.156	-0.151	-0.147	-0.158	-0.163	-0.166	-0.172
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Number of bedrooms	0.426	0.614	0.613	0.612	0.525	0.529	0.524	0.523
	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Number of other rooms	0.257	0.283	0.284	0.275	0.237	0.244	0.239	0.233
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Tenure	0.151	0.209	0.293	0.306	0.228	0.069	0.003	-0.068
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Single-family attached	-0.179	-0.140	-0.138	-0.136	-0.150	-0.147	-0.149	-0.164
	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Condominium	-0.178	-0.170	-0.171	-0.160	-0.198	-0.191	-0.203	-0.211
	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Mobile home	-1.024	-1.116	-1.113	-1.111	-1.137	-1.122	-1.115	-1.105
	(0.002)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
Distance to CBD	-0.031	-0.037	-0.035	-0.036	-0.033	-0.031	-0.032	-0.031
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Population density	-0.002	0.003	0.003	0.004	0.005	0.004	0.003	0.002
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
% people 25+	0.350	0.339	0.345	0.339	0.361	0.370	0.376	0.385
with a BA+ in PUMA	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
% people who are	0.041	0.055	0.049	0.050	0.036	0.041	0.035	0.036
NH-white in PUMA	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
New York Metro Area	0.785	1.035	1.026	1.003	0.993	0.948	0.945	0.932
	(0.003)	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)
...	...	...	...	...	...	...	...	...
Constant	7.724	7.384	7.393	7.405	7.581	7.603	7.647	7.658
	(0.005)	(0.014)	(0.013)	(0.013)	(0.014)	(0.014)	(0.014)	(0.014)

Table 3. The second stage hedonic regression results

	House age		No. of bedrooms		No. of other rooms		Tenure	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Housing characteristics								
House age	5.81	(0.01)	-3.87	(0.05)	-3.04	(0.03)	-2.05	(0.03)
Bedrooms	-49.56	(0.38)	-417.97	(1.86)	333.48	(1.90)	243.60	(1.14)
...	...	...	...	...	...	...	...	...
HH size	9.52	(4.89)	-6.73	(15.53)	-37.70	(14.53)	37.56	(9.69)
Age effect								
Age 1	-0.20	(5.31)	32.39	(14.89)	22.92	(14.95)	3.68	(10.48)
Age 2	1.74	(5.77)	51.47	(14.24)	36.61	(15.05)	6.76	(10.25)
...	...	...	...	...	...	...	...	...
Age 20	-1.12	(4.97)	155.25	(18.05)	105.50	(14.88)	103.87	(11.16)
...	...	...	...	...	...	...	...	...
Age 40	24.14	(5.75)	-108.08	(15.83)	-56.60	(14.78)	-75.76	(10.95)
...	...	...	...	...	...	...	...	...
Age 60	29.52	(5.15)	-103.13	(17.82)	-44.19	(16.99)	-118.01	(11.69)
...	...	...	...	...	...	...	...	...
Cohort effect								
Lucky Few	-3.84	(0.74)	27.59	(6.62)	1.24	(4.42)	53.80	(3.50)
Boomers	1.56	(1.15)	-66.70	(8.55)	-36.37	(5.88)	7.78	(4.71)
Gen X	7.45	(1.55)	-90.75	(9.78)	-52.51	(6.86)	-57.27	(5.60)
Millennials	1.02	(1.73)	-48.48	(10.66)	-29.42	(7.57)	-94.76	(6.20)
Race/ethnicity								
Black	1.12	(0.63)	-272.32	(3.30)	-182.63	(2.30)	-144.20	(2.11)
Asian PI	-41.20	(1.70)	-238.14	(8.49)	66.32	(7.23)	-165.58	(5.18)
Hispanic	9.10	(0.78)	-323.83	(4.53)	-235.93	(3.36)	-148.91	(2.73)
Others	1.47	(1.27)	-176.01	(7.56)	-107.25	(5.72)	-103.94	(4.56)
Immigrants								
Recent	-21.65	(1.31)	8.63	(6.30)	112.69	(4.92)	81.17	(3.99)
Long-term	-27.19	(1.00)	125.00	(5.65)	201.78	(4.27)	72.60	(3.33)
Marital status and presence of partners								
Widowed	27.31	(0.58)	-43.47	(4.98)	-67.86	(3.29)	-18.48	(2.83)
Divorced	25.64	(0.58)	-209.85	(3.59)	-150.09	(2.53)	-79.09	(2.17)
Separated	8.66	(0.93)	-87.65	(6.03)	-79.66	(4.57)	-27.84	(3.77)
Never	10.07	(0.64)	-151.33	(4.05)	-111.77	(2.87)	-75.14	(2.38)
Never (w/p)	-2.45	(1.16)	21.22	(7.84)	3.60	(4.63)	12.28	(3.56)
Educational attainment								
HS Grad.	13.57	(0.42)	55.17	(3.23)	50.90	(2.34)	61.88	(1.91)
Associate's	16.06	(0.49)	100.35	(3.40)	90.54	(2.48)	89.79	(2.03)
Bachelor's	-5.61	(0.74)	305.81	(4.53)	224.30	(3.21)	175.24	(2.69)
Master's +	-9.24	(1.04)	475.69	(5.55)	328.97	(3.94)	239.65	(3.43)
HH Income	-0.78	(0.02)	7.61	(0.10)	3.90	(0.07)	3.82	(0.06)
× HH size	-0.34	(0.07)	1.27	(0.17)	0.94	(0.19)	0.83	(0.11)
× age 1	0.00	(0.08)	-0.01	(0.22)	-0.13	(0.22)	0.13	(0.16)
× age 2	-0.05	(0.09)	-0.25	(0.21)	-0.34	(0.23)	0.24	(0.15)
...	...	...	...	...	...	...	...	...
× age 20	0.53	(0.08)	-2.98	(0.27)	-1.96	(0.23)	-1.75	(0.17)
...	...	...	...	...	...	...	...	...
Year fixed effects								
2000	-22.91	(0.76)	-323.57	(4.66)	205.44	(3.12)	2,003.41	(2.43)
2005	-50.29	(0.82)	1,069.63	(4.97)	681.13	(3.33)	2,817.73	(2.56)
2006	-72.81	(0.84)	1,351.89	(4.99)	880.33	(3.38)	3,911.26	(3.20)
2007	-63.63	(0.78)	1,313.67	(4.85)	786.77	(3.24)	4,053.81	(3.25)
2008	-44.14	(0.80)	605.69	(4.85)	384.78	(3.18)	3,065.46	(2.81)
2009	-20.41	(0.68)	311.06	(4.45)	243.96	(3.03)	1,297.45	(1.85)
2010	-9.52	(0.65)	151.44	(4.18)	133.50	(2.79)	651.82	(1.90)
Constant	-35.53	(2.42)	592.73	(15.86)	-9.07	(11.39)	-2,297.80	(9.37)

	Single-family attached		Condominium		Mobile home		Distance to CBD	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Housing characteristics								
House age	4.09	(0.05)	6.13	(0.06)	31.32	(0.37)	-0.66	(0.01)
Bedrooms	-526.68	(2.06)	-623.69	(2.60)	-3,978.69	(15.69)	-11.69	(0.24)
...	...	...	...	...	...	...	...	...
HH size	32.72	(15.77)	238.32	(18.86)	960.57	(125.18)	7.26	(3.52)
Age effect	...	...	...	...	...	...	...	...
Age 1	-9.78	(16.16)	2.54	(18.78)	-132.93	(129.43)	-8.40	(3.69)
Age 2	-14.98	(16.48)	32.12	(18.97)	-152.42	(127.18)	-10.79	(3.24)
...	...	...	...	...	...	...	...	...
Age 20	-85.80	(18.27)	-17.69	(20.45)	-810.49	(144.92)	-12.16	(3.46)
...	...	...	...	...	...	...	...	...
Age 40	239.08	(16.75)	456.93	(19.99)	1,798.32	(134.51)	-1.98	(3.89)
...	...	...	...	...	...	...	...	...
Age 60	278.24	(19.55)	405.40	(23.19)	1,924.61	(152.51)	-6.35	(3.82)
...	...	...	...	...	...	...	...	...
Cohort effect								
Lucky Few	-11.74	(6.54)	-99.96	(7.76)	-382.12	(48.90)	-1.00	(0.81)
Boomers	88.08	(8.54)	-99.61	(10.26)	84.06	(64.23)	2.15	(1.05)
Gen X	132.17	(9.83)	-108.75	(11.91)	249.93	(74.39)	1.89	(1.23)
Millennials	70.89	(10.68)	-118.84	(12.95)	-88.04	(80.78)	-0.04	(1.37)
Race/ethnicity								
Black	210.18	(3.14)	218.61	(3.88)	1,709.38	(24.40)	29.87	(0.57)
Asian PI	232.36	(8.19)	217.25	(9.93)	1,663.13	(63.87)	13.76	(1.08)
Hispanic	274.67	(4.15)	299.80	(5.05)	2,189.05	(32.21)	13.38	(0.65)
Others	153.44	(6.95)	175.00	(8.65)	1,199.23	(52.90)	6.00	(1.05)
Immigrants								
Recent	-56.56	(5.75)	-94.02	(6.89)	-362.30	(44.83)	13.47	(0.97)
Long-term	-188.98	(5.35)	-241.26	(6.45)	-1,483.32	(41.74)	2.96	(0.71)
Marital status and presence of partners								
Widowed	103.04	(4.63)	171.07	(5.59)	747.81	(35.73)	-3.05	(0.58)
Divorced	216.42	(3.45)	293.88	(4.24)	1,587.15	(26.75)	0.91	(0.47)
Separated	74.00	(5.67)	100.62	(6.88)	529.25	(43.67)	-1.63	(0.76)
Never	206.75	(3.60)	264.30	(4.37)	1,635.19	(27.97)	-9.35	(0.66)
Never (w/p)	-24.50	(5.50)	11.77	(6.42)	-188.91	(41.59)	-17.49	(1.02)
Educational attainment								
HS Grad.	28.11	(2.88)	86.99	(3.51)	316.80	(21.72)	3.73	(0.36)
Associate’s	32.87	(3.14)	99.71	(3.83)	377.39	(23.83)	6.11	(0.40)
Bachelor’s	-139.66	(4.27)	-119.03	(5.20)	-948.72	(32.94)	0.06	(0.57)
Master’s +	-324.15	(5.56)	-334.58	(6.79)	-2,401.59	(43.09)	-21.88	(0.83)
HH Income	-6.13	(0.11)	-5.02	(0.13)	-47.79	(0.81)	-0.60	(0.02)
× HH size	-2.14	(0.18)	-2.58	(0.21)	-17.51	(1.50)	-0.12	(0.05)
× age 1	-0.20	(0.25)	-0.42	(0.29)	-0.98	(2.01)	0.11	(0.06)
× age 2	-0.11	(0.25)	-0.83	(0.29)	-0.85	(1.96)	0.14	(0.05)
...	...	...	...	...	...	...	...	...
× age 20	3.71	(0.29)	3.89	(0.33)	29.40	(2.30)	0.24	(0.05)
...	...	...	...	...	...	...	...	...
Year fixed effects								
2000	-467.99	(4.43)	172.01	(5.29)	-338.76	(31.76)	-31.86	(0.55)
2005	-231.95	(4.50)	-182.33	(5.44)	-5,485.39	(33.86)	-56.88	(0.64)
2006	-434.81	(4.47)	-503.52	(5.45)	-7,502.56	(33.85)	-57.00	(0.62)
2007	-334.45	(4.34)	-210.33	(5.17)	-7,116.57	(33.00)	-55.96	(0.62)
2008	-444.41	(4.90)	-709.59	(6.14)	-5,903.79	(36.06)	-39.32	(0.62)
2009	-22.89	(4.42)	-107.85	(5.46)	-2,810.69	(32.41)	-17.20	(0.52)
2010	78.32	(4.17)	-112.72	(5.25)	-1,501.82	(30.04)	-11.29	(0.51)
Constant	1,917.02	(15.47)	1,296.35	(18.06)	17,698.57	(119.07)	53.89	(1.88)

	Population density		% residents with a BA+		% residents NH-white		
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	...
Housing characteristics							
House age	0.00	(0.00)	-0.62	(0.00)	-0.04	(0.00)	...
Bedrooms	0.03	(0.00)	41.10	(0.17)	3.31	(0.24)	...
...	...	...	...	...	...	...	...
HH size	-0.13	(0.01)	-0.38	(1.30)	0.81	(1.67)	...
Age effect							
Age 1	0.01	(0.01)	1.11	(1.16)	-1.88	(1.51)	...
Age 2	0.00	(0.01)	2.18	(1.21)	1.01	(1.24)	...
...	...	...	...	...	...	...	...
Age 20	-0.03	(0.01)	11.81	(1.31)	6.02	(1.20)	...
...	...	...	...	...	...	...	...
Age 40	-0.06	(0.01)	-5.03	(1.25)	0.08	(1.49)	...
...	...	...	...	...	...	...	...
Age 60	0.01	(0.01)	-4.06	(1.43)	-1.48	(1.76)	...
...	...	...	...	...	...	...	...
Cohort effect							
Lucky Few	0.07	(0.01)	-0.23	(0.60)	0.96	(0.39)	...
Boomers	0.16	(0.01)	-10.34	(0.79)	0.06	(0.64)	...
Gen X	0.17	(0.01)	-13.39	(0.91)	-1.02	(0.85)	...
Millennials	0.13	(0.01)	-8.06	(1.01)	-1.24	(1.33)	...
Race/ethnicity							
Black	-0.06	(0.00)	-35.55	(0.34)	17.85	(0.53)	...
Asian PI	-0.04	(0.01)	-27.74	(0.66)	-21.48	(0.90)	...
Hispanic	-0.09	(0.00)	-13.81	(0.44)	-4.06	(0.48)	...
Others	0.40	(0.03)	-16.65	(0.75)	-2.60	(0.66)	...
Immigrants							
Recent	0.02	(0.01)	9.31	(0.54)	1.06	(0.70)	...
Long-term	-0.06	(0.00)	22.36	(0.50)	9.88	(0.80)	...
Marital status and presence of partners							
Widowed	-0.03	(0.01)	-11.93	(0.45)	2.37	(0.50)	...
Divorced	-0.07	(0.00)	-24.39	(0.33)	1.74	(0.48)	...
Separated	-0.02	(0.01)	-16.10	(0.58)	0.27	(0.74)	...
Never	-0.04	(0.00)	-13.78	(0.37)	-0.35	(0.50)	...
Never (w/p)	-0.02	(0.01)	-1.82	(0.53)	0.23	(0.72)	...
Educational attainment							
HS Grad.	0.01	(0.00)	4.76	(0.35)	0.43	(0.58)	...
Associate's	0.00	(0.00)	10.97	(0.36)	0.46	(0.48)	...
Bachelor's	0.05	(0.01)	31.08	(0.42)	2.43	(0.51)	...
Master's +	0.04	(0.01)	43.55	(0.49)	4.04	(0.56)	...
HH Income	0.00	(0.00)	0.45	(0.01)	-0.03	(0.03)	...
× HH size	0.00	(0.00)	0.10	(0.01)	0.01	(0.01)	...
× age 1	0.00	(0.00)	0.02	(0.01)	0.03	(0.03)	...
× age 2	0.00	(0.00)	0.02	(0.01)	0.00	(0.01)	...
...	...	...	...	...	...	...	...
× age 20	0.00	(0.00)	-0.20	(0.02)	-0.05	(0.01)	...
...	...	...	...	...	...	...	...
Year fixed effects							
2000	-0.74	(0.01)	1.49	(0.40)	-2.42	(0.49)	...
2005	0.15	(0.00)	34.16	(0.42)	23.82	(0.64)	...
2006	0.15	(0.00)	63.54	(0.42)	17.00	(0.30)	...
2007	0.35	(0.00)	53.54	(0.40)	16.49	(0.25)	...
2008	0.54	(0.01)	49.20	(0.43)	10.67	(0.39)	...
2009	0.38	(0.01)	22.80	(0.40)	2.56	(0.14)	...
2010	0.24	(0.00)	10.61	(0.36)	0.91	(0.15)	...
Constant	0.89	(0.06)	162.32	(1.50)	67.28	(1.71)	...

Table 4. Estimated annualized household and housing demand growth rates

		Growth rates				Growth rates	
	Household	Aggregate	Per HH		Household	Aggregate	Per HH
Constant-quality house				Age-specific-average-quality house			
Total derivative				Total derivative			
McCue (2014) + 2000-11				McCue (2014) + 2000-11			
High	0.94	0.97	0.03	High	0.94	0.94	0.01
Middle	0.86	0.89	0.03	Middle	0.86	0.87	0.01
Low	0.78	0.82	0.04	Low	0.78	0.80	0.01
McCue (2014) + 2005-07				McCue (2014) + 2005-07			
High	0.94	0.96	0.02	High	0.94	0.93	0.00
Middle	0.86	0.88	0.02	Middle	0.86	0.86	0.00
Low	0.78	0.81	0.03	Low	0.78	0.79	0.01
McCue (2014) + 2009-11				McCue (2014) + 2009-11			
High	0.94	0.98	0.05	High	0.94	0.96	0.02
Middle	0.86	0.91	0.05	Middle	0.86	0.89	0.03
Low	0.78	0.84	0.06	Low	0.78	0.82	0.04
Myers and Lee (forthcoming) + 2000-11				Myers and Lee (forthcoming) + 2000-11			
Scenario 2	0.80	0.75	0.02	Scenario 2	0.80	0.70	-0.03
Scenario 3	0.73	0.81	0.01	Scenario 3	0.73	0.76	-0.04
Myers and Lee (forthcoming) + 2005-07				Myers and Lee (forthcoming) + 2005-07			
Scenario 2	0.80	0.75	0.01	Scenario 2	0.80	0.69	-0.05
Scenario 3	0.73	0.81	0.01	Scenario 3	0.73	0.75	-0.05
Myers and Lee (forthcoming) + 2009-11				Myers and Lee (forthcoming) + 2009-11			
Scenario 2	0.80	0.76	0.03	Scenario 2	0.80	0.72	-0.02
Scenario 3	0.73	0.82	0.02	Scenario 3	0.73	0.77	-0.03
Partial derivative				Partial derivative			
McCue (2014) + 2000-11				McCue (2014) + 2000-11			
High	0.94	0.99	0.06	High	0.94	0.97	0.04
Middle	0.86	0.92	0.06	Middle	0.86	0.90	0.04
Low	0.78	0.85	0.07	Low	0.78	0.83	0.04
McCue (2014) + 2005-07				McCue (2014) + 2005-07			
High	0.94	0.99	0.05	High	0.94	0.96	0.03
Middle	0.86	0.92	0.06	Middle	0.86	0.89	0.03
Low	0.78	0.84	0.06	Low	0.78	0.82	0.04
McCue (2014) + 2009-11				McCue (2014) + 2009-11			
High	0.94	1.01	0.07	High	0.94	0.99	0.05
Middle	0.86	0.94	0.08	Middle	0.86	0.92	0.06
Low	0.78	0.87	0.08	Low	0.78	0.84	0.06
Myers and Lee (forthcoming) + 2000-11				Myers and Lee (forthcoming) + 2000-11			
Scenario 2	0.80	0.79	0.05	Scenario 2	0.80	0.73	0.00
Scenario 3	0.73	0.85	0.05	Scenario 3	0.73	0.79	-0.01
Myers and Lee (forthcoming) + 2005-07				Myers and Lee (forthcoming) + 2005-07			
Scenario 2	0.80	0.78	0.05	Scenario 2	0.80	0.72	-0.01
Scenario 3	0.73	0.84	0.04	Scenario 3	0.73	0.78	-0.02
Myers and Lee (forthcoming) + 2009-11				Myers and Lee (forthcoming) + 2009-11			
Scenario 2	0.80	0.80	0.06	Scenario 2	0.80	0.75	0.01
Scenario 3	0.73	0.85	0.05	Scenario 3	0.73	0.80	0.00

Figure 1. Changes in estimated regression coefficients and implicit prices for housing unit with average housing characteristics, 2000 to 2011

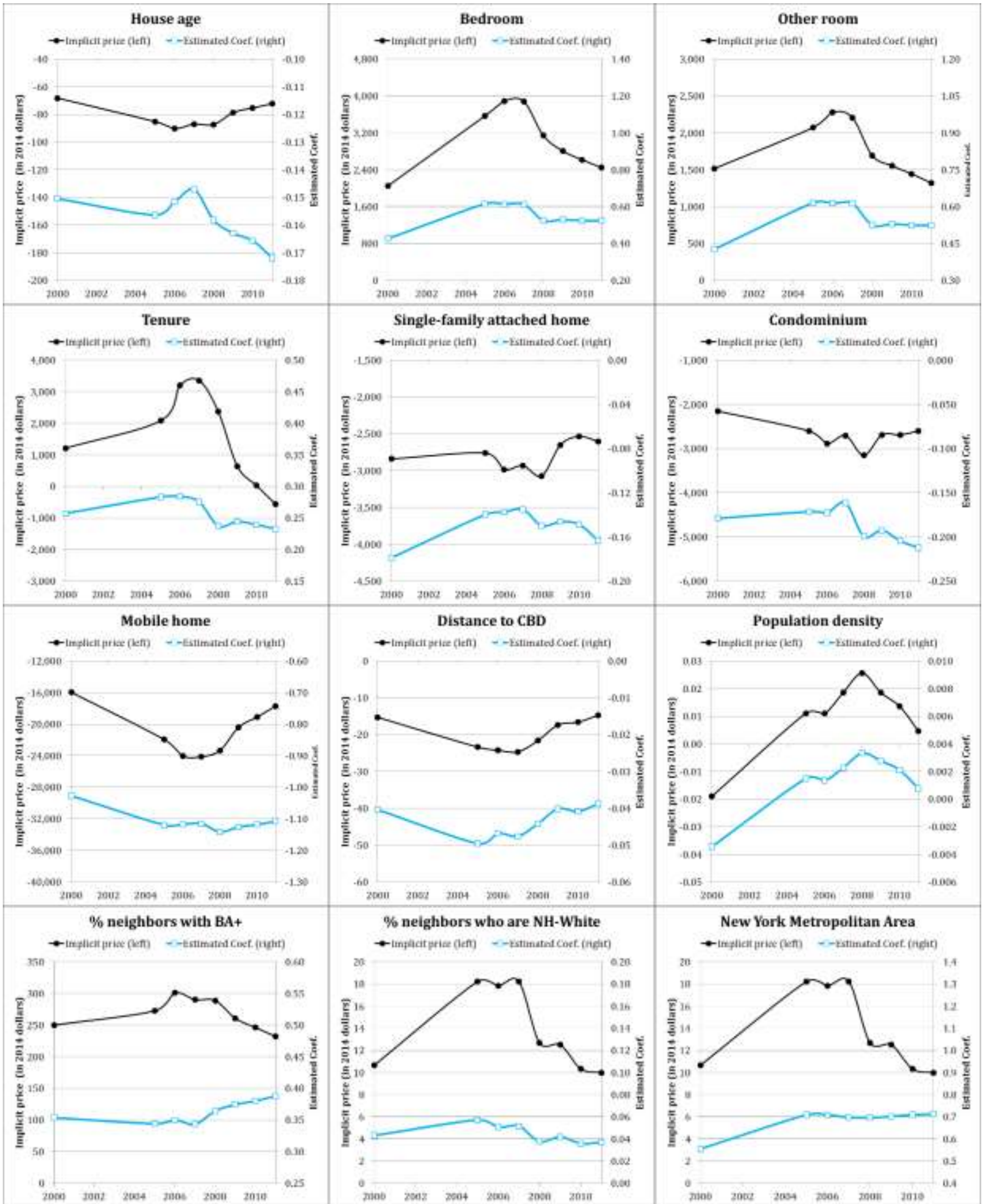


Figure 2. Willingness to pay for housing characteristics by age, households with average non-housing household income

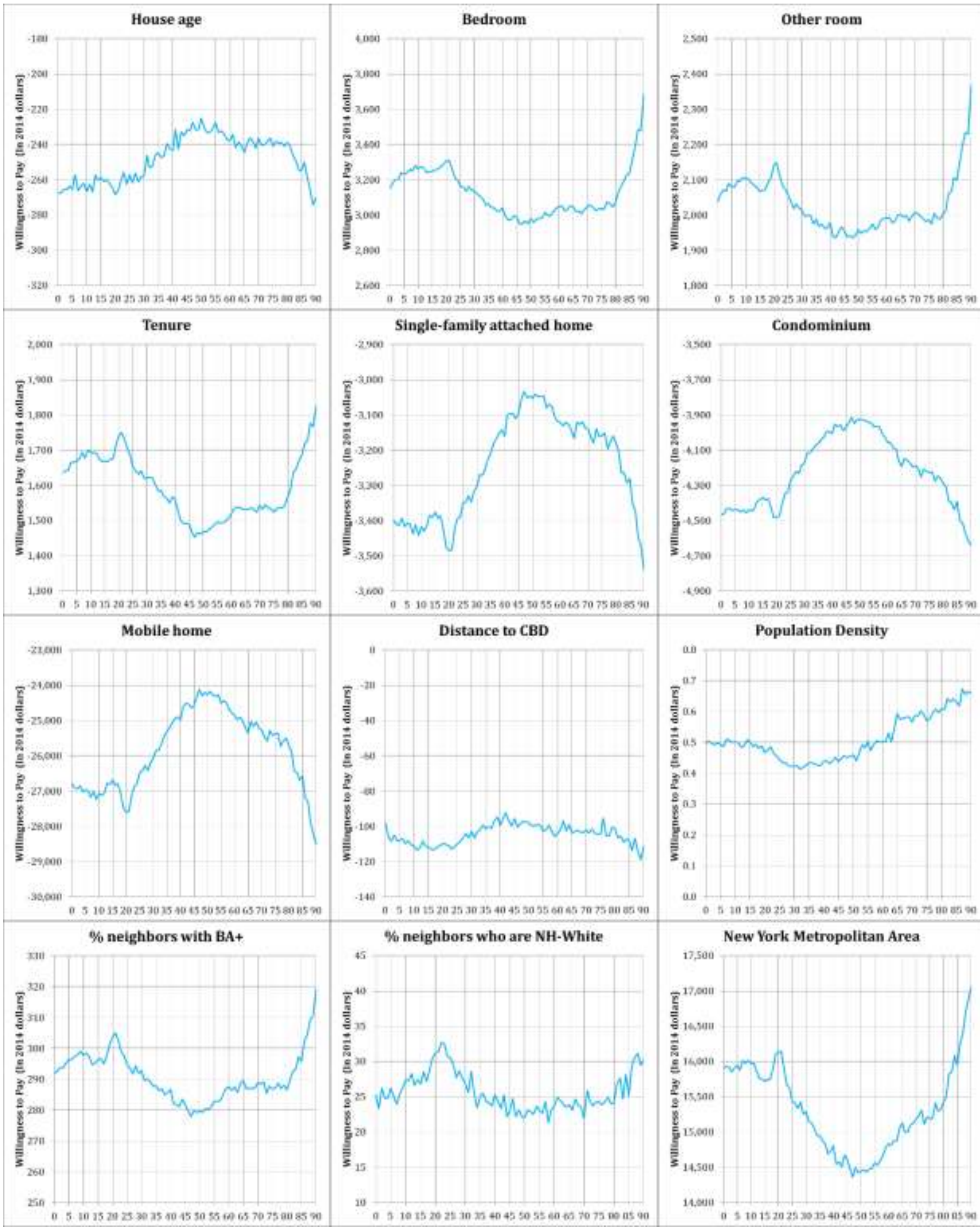


Figure 3. Changes in willingness to pay for housing characteristics as non-housing household income increases by $1,000

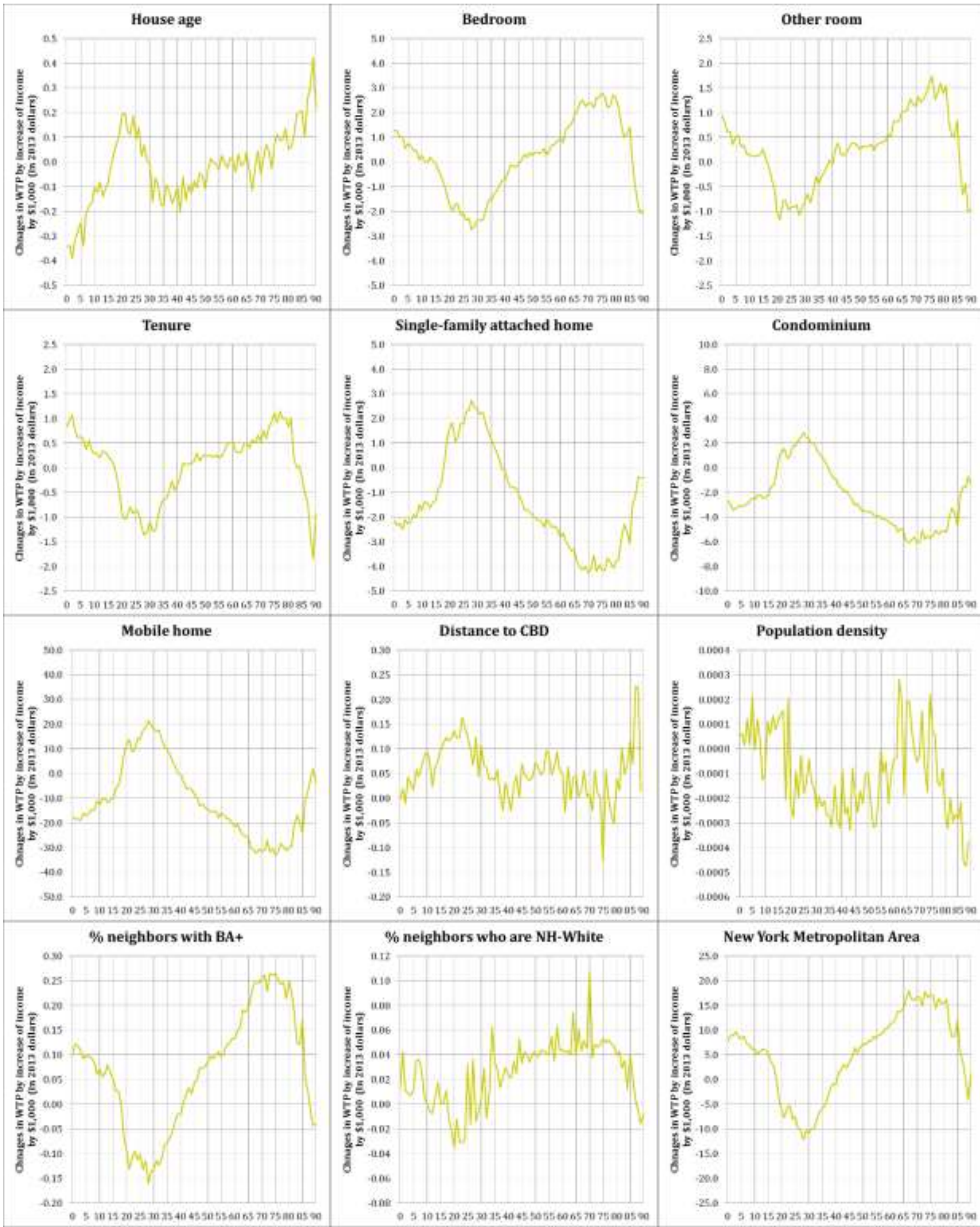


Figure 4. Willingness to pay for a house with average quantities by age of householder, total and partial derivatives with regards to age

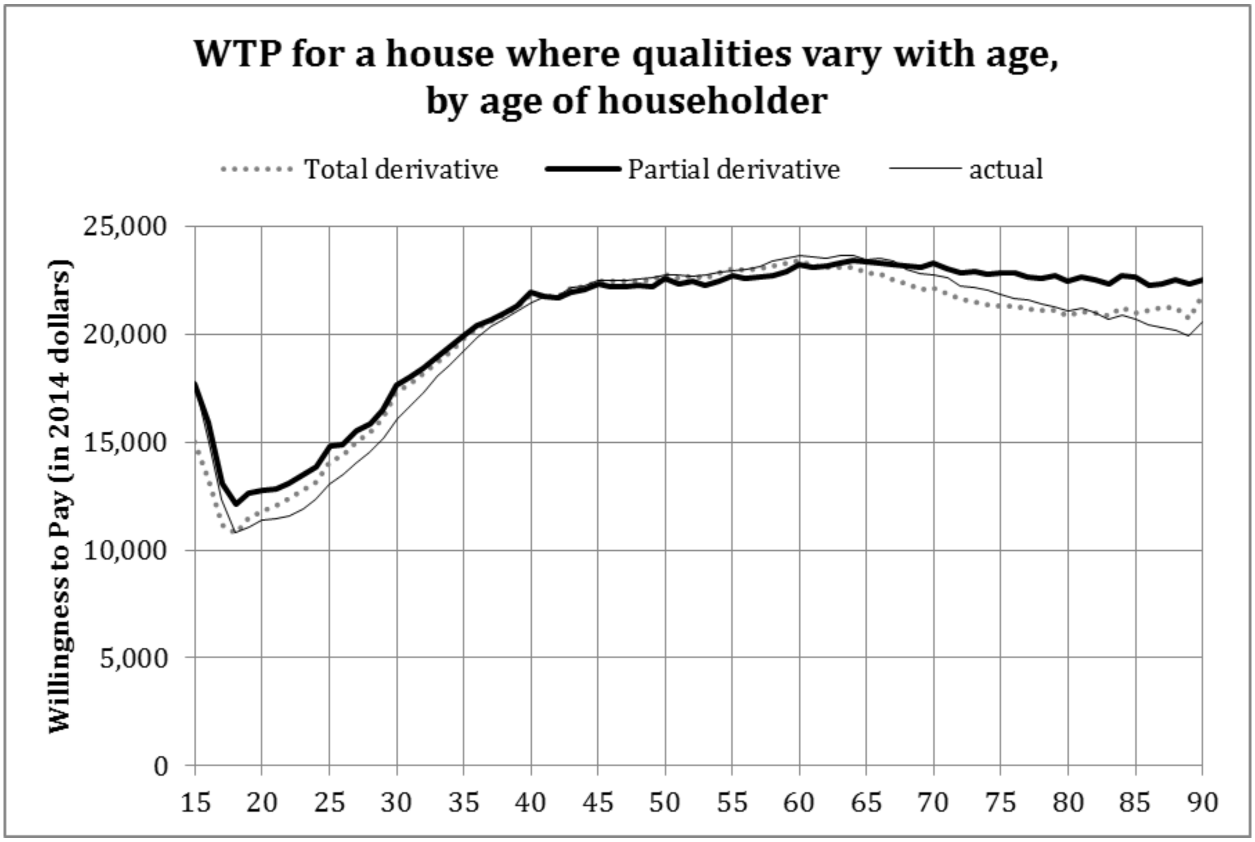


Figure 5. Willingness to pay for a constant-quality house by age of householder, total and partial derivatives with regards to age

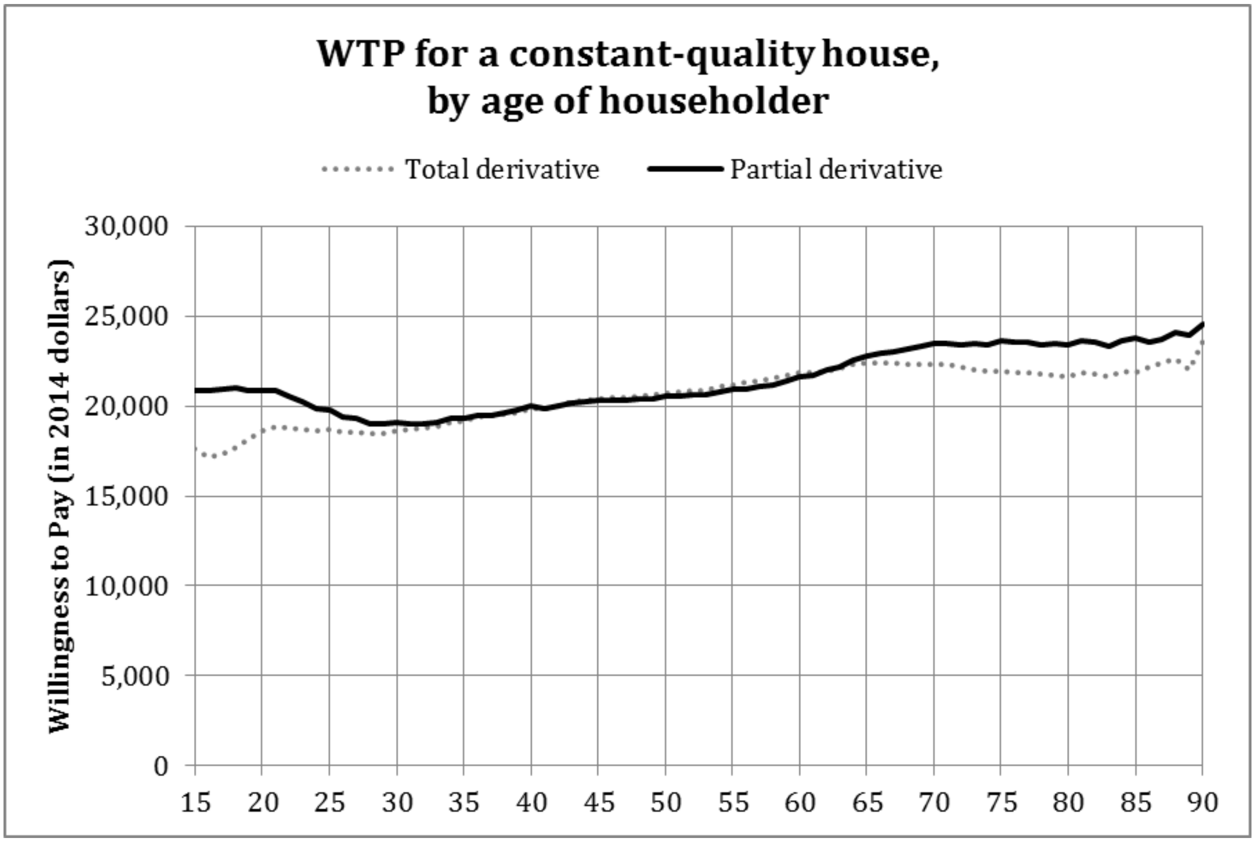


Figure 6. Willingness to pay for a constant-quality house by demographic and socio-economic groups

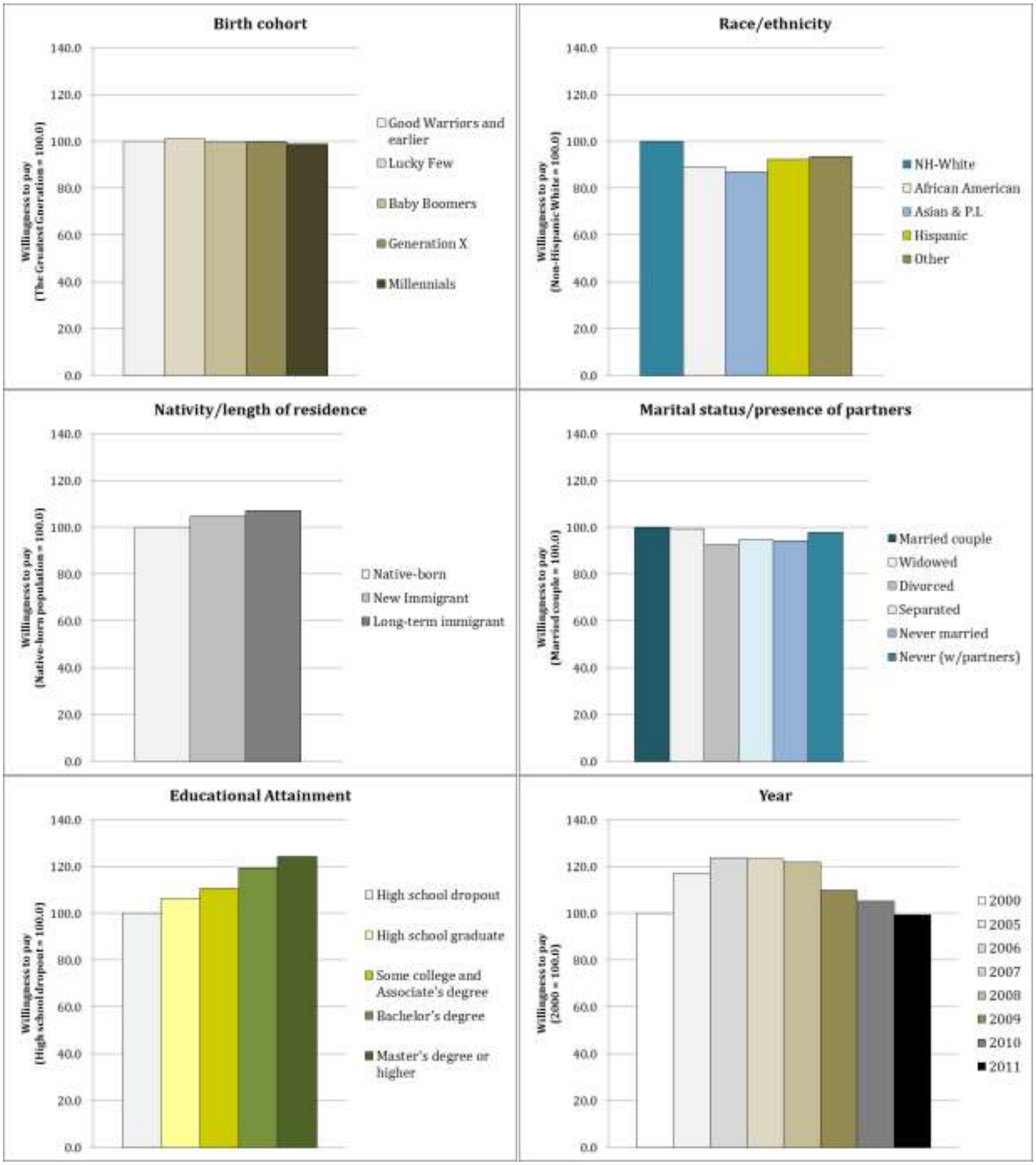
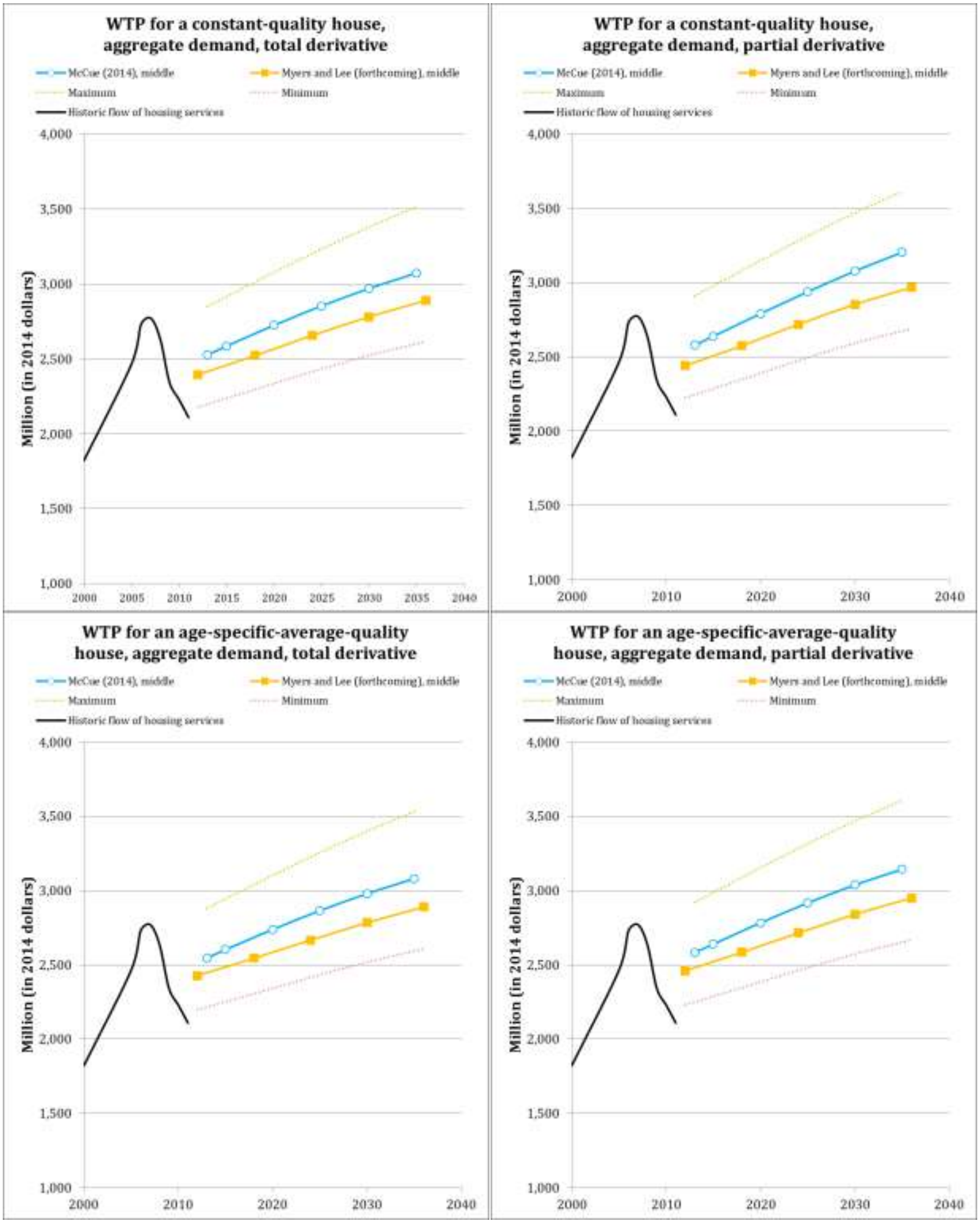
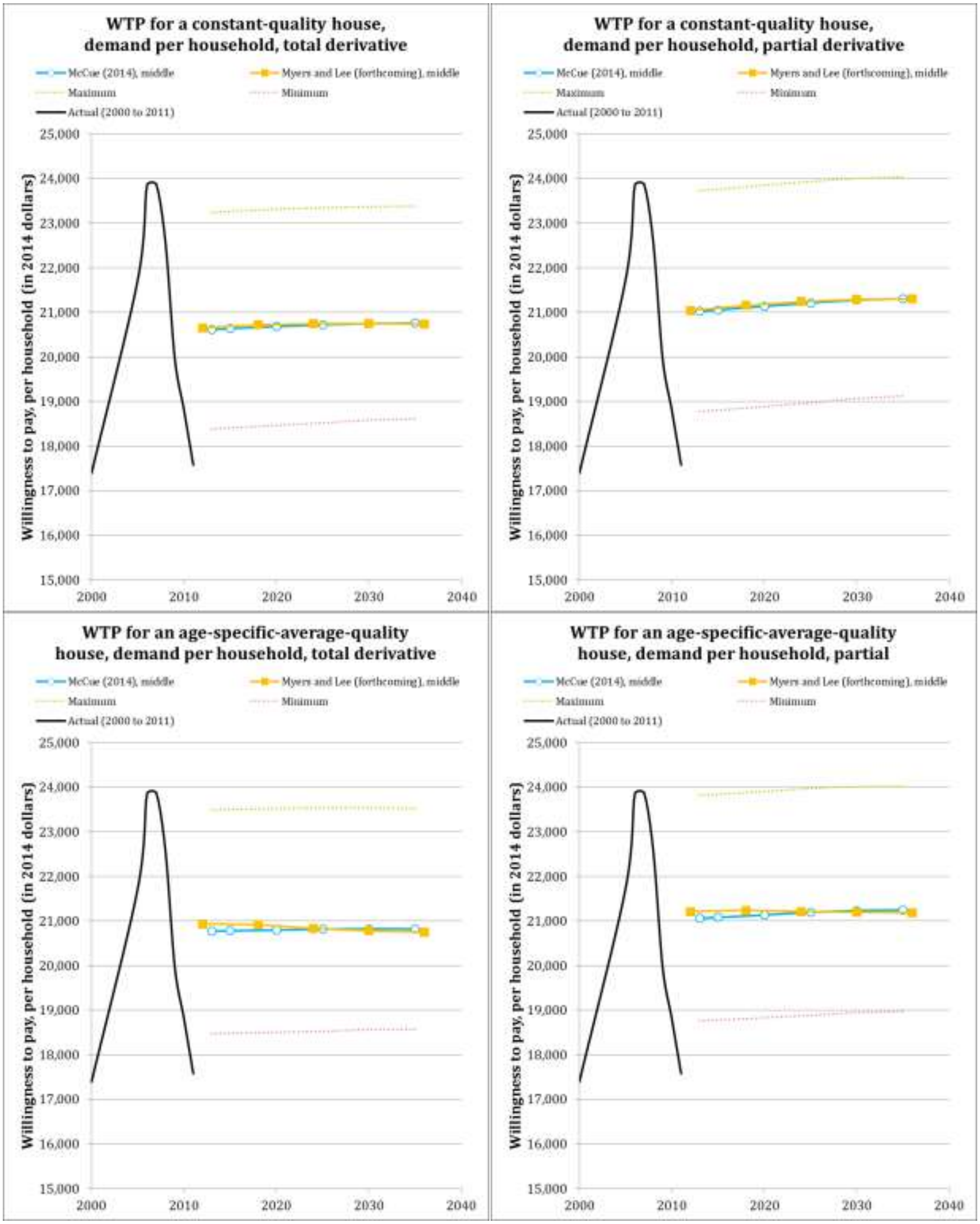


Figure 7. Housing demand projections, for a constant-quality house and an age-specific-average-quality house, 2012 to 2036



(Continued)


WTP for a constant-quality house, demand per household, total derivative
WTP for a constant-quality house, demand per household, partial derivative
WTP for an age-specific-average-quality house, demand per household, total derivative
WTP for an age-specific-average-quality house, demand per household, partial
McCue (2014), middle
Myers and Lee (forthcoming), middle
Maximum
Minimum
Actual (2000 to 2011)
Willingness to pay, per household (in 2014 dollars)
25,000
24,000
23,000
22,000
21,000
20,000
19,000
18,000
17,000
16,000
15,000
2000
2010
2020
2030
2040