Appendices (not for publication)

Appendix A Risk Sharing with housing. Derivation of equation (1)

Consider an endowment economy with nondurable and housing goods, C and H respectively. Each time a stochastic event s_t is drawn from the state space S. The probability of drawing a sequence of states $s^t = (s_1, \dots , s_t)$ is denoted as $\pi(s^t)$. Individual endowments of housing services and nondurable consumption goods at time t depend on s^t.

Consider the Pareto problem where a social planner maximizes the discounted utility flows of N agents in the economy:

$$\max \sum_{i=1}^{N} \omega_i \sum_{t=1}^{\infty} \sum_{s^t} \beta^t \pi(s^t) u \left[C_i(s^t), H_i(s^t), \delta_i(s^t)\right] \tag{A-1}$$

s.t. the feasibility constraints:

$$\sum_{i=1}^{N} C_i(s^t) \leq C(s^t) \text{ for all } t, s^t \tag{A-2}$$

$$\sum_{i=1}^{N} H_i(s^t) \leq H(s^t) \text{ for all } t, s^t, \tag{A-3}$$

where ω_i is the planner's weight attached to individual i's welfare and the weights sum to one; β is the time discount factor; $C(s^t)$ is the aggregate endowment of nondurable consumption goods at time t, history of events s^t; $H(s^t)$ is the aggregate endowment of housing services at time t, history s^t; and $\delta_i(s^t)$ is consumer i's shock to tastes over consumption of nondurables and housing services at time t history of events s^t. Let the instantaneous utility function be $u(C, H) = \frac{\delta_i (C^\alpha H^{1-\alpha})^{1-\sigma}}{1-\sigma}$. Denote the Lagrange multipliers attached to the nondurables feasibility constraint as $\theta(s^t)$ and the housing feasibility constraint as $\lambda(s^t)$. The maximization problem with respect to $C_i(s^t)$ and $H_i(s^t)$ yields the following first-order conditions:

$$\omega_i \beta^t \delta_i(s^t) \alpha \frac{[C_i(s^t)^\alpha H_i(s^t)^{1-\alpha}]^{1-\sigma}}{C_i(s^t)} = \frac{\theta(s^t)}{\pi(s^t)} \equiv \theta'(s^t), \tag{A-4}$$

$$\omega_i \beta^t \delta_i(s^t)(1-\alpha) \frac{[C_i(s^t)^\alpha H_i(s^t)^{1-\alpha}]^{1-\sigma}}{H_i(s^t)} = \frac{\lambda(s^t)}{\pi(s^t)} \equiv \lambda'(s^t). \tag{A-5}$$

Denoting a generic random variable $x(s^t)$ as x_t, it can be shown that the two equations imply the following relationship for individual i's growth of nondurable consumption:

$$\Delta \log C_{it} = \frac{1}{1+\gamma+\phi} [-\phi \Delta \log \theta'_t + (1+\phi)\Delta \log \lambda'_t - \Delta \log \delta_{it} - \log \beta] + \epsilon_{it}, \tag{A-6}$$

where $\gamma \equiv \alpha(1-\sigma) - 1$, $\phi \equiv (1-\alpha)(1-\sigma) - 1$, and ϵ_{it} is individual i's measurement error in nondurable consumption growth.

In our empirical analysis, we consider four-year differences defined as $c_{it} \equiv \log C_{it} - \log C_{it-4} = \sum_{j=0}^{3} \Delta \log C_{it-j}$. Equation (A-6) can be rewritten as:

$$c_{it} = \frac{1}{1+\gamma+\phi} \left[-\phi \tilde{\theta}_t + (1+\phi)\tilde{\lambda}_t - \tilde{\delta}_{it} - \tilde{\beta}\right] + \tilde{\epsilon}_{it}, \tag{A-7}$$

where $\tilde{\theta}_t = \sum_{j=0}^{3} \Delta \log \theta'_{t-j}$; $\tilde{\lambda}_t = \sum_{j=0}^{3} \Delta \log \lambda'_{t-j}$; $\tilde{\delta}_{it} = \sum_{j=0}^{3} \Delta \log \delta_{it-j}$; $\tilde{\beta} = 4 \log \beta$; and $\tilde{\epsilon}_{it} = \sum_{j=0}^{3} \epsilon_{it-j}$.

Subtracting nationwide consumption growth, $\bar{c}_t$, from idiosyncratic consumption growth, we obtain:

$$c_{it} - \bar{c}_t = u_{it}, \tag{A-8}$$

where $u_{it} = \tilde{\epsilon}_{it} + \frac{1}{1+\gamma+\phi}\left(\tilde{\bar{\delta}}_t - \tilde{\delta}_{it}\right)$, $\bar{c}_t$, and $\tilde{\bar{\delta}}_t$ are the nationwide averages of nondurable consumption growth and taste shocks.

Equation (A-8) says that any idiosyncratic variable, D_{it}, net of the nationwide average (and its interaction with any aggregate variable, say, regional house-price growth) independent of taste shocks and measurement error in nondurable consumption growth should not enter significantly in a regression of the form:

$$\begin{aligned} c_{it} - \bar{c}_t =& \mu + \beta\,(hp_{mt} - \overline{hp}_t) + \xi\,(D_{it} - \bar{D}_t) \\ &+ \zeta\,(D_{it} - \bar{D}_t) \times (hp_{mt} - \overline{hp}_t) + (X_{it} - \bar{X}_t)'\delta + \varepsilon_{it}\,, \end{aligned} \tag{A-9}$$

where hp_{mt} denotes house-price growth in the region of household i's residence m. The full risk-sharing allocation of housing services and nondurable consumption therefore implies testing the null that β, ξ, and ζ are all equal to zero.

If nondurable consumption can be fully shared nationally across N agents but housing services can be freely transferred only within regions, the feasibility constraint for housing services will take the following form:

$$\sum_{i=1}^{N_m} H_{im}(s^t) \leq H_m(s^t) \text{ for all } t, s^t, \tag{A-10}$$

where N_m is the number of households residing in region m. $H_m(s^t)$ is the aggregate stock of housing services in region m at time t history of events s^t, and $H_{im}(s^t)$ is individual i's endowment of housing services at time t history s^t residing in region m. Denote the Lagrange multiplier attached to the housing feasibility constraint in region m at time t history of events s^t as $\lambda_m(s^t)$. In this case, equation (A-6) becomes:

$$\Delta \log C_{it} = \frac{1}{1+\gamma+\phi}\left[-\phi\Delta\log\theta'_t + (1+\phi)\Delta\log\lambda'_{mt} - \Delta\log\delta_{it} - \log\beta\right] + \epsilon_{it}. \tag{A-11}$$

Subtracting the nationwide average of nondurable consumption growth over the four-year interval from idiosyncratic consumption growth, we obtain:

$$c_{it} - \bar{c}_t = \frac{1+\phi}{1+\gamma+\phi}\left(\tilde{\lambda}_{mt} - \tilde{\lambda}_t\right) + u_{it}, \tag{A-12}$$

where $u_{it} = \epsilon_{it} + \frac{1}{1+\gamma+\phi}\left(\tilde{\delta}_t - \tilde{\delta}_{it}\right)$, and $\tilde{\lambda}_{mt} = \sum_{j=0}^{3}\Delta\log\lambda'_{mt-j}$ and $\tilde{\lambda}_t$ is the nationwide average of $\tilde{\lambda}_{mt}$. In this situation, consumption growth is higher if the housing constraint in the region of agent i tightens—implying an increasing value of the Lagrange multiplier.

In a decentralized competitive equilibrium with Arrow-Debreu securities for nondurable consumption and housing services, λ'_{mt} will be related to the regional price of housing services in terms of nondurable consumption goods.[1] Equation (A-12) suggests that any idiosyncratic variable D_{it} net of the nationwide average (as well as its interaction with the regional house-price growth net of aggregate house-price growth) independent of

[1]It can be shown that a decentralized competitive equilibrium with time-0 Arrow-Debreu claims to nondurable consumption and housing services is a particular Pareto optimal allocation with $q^0(s^t) = \theta(s^t)$, and $hp^0_m(s^t) = \lambda_m(s^t)$ where $q^0(s^t)$ is the time 0 Arrow-Debreu price of one unit of nondurable consumption in terms of time 0 nondurable goods to be delivered if state s^t is realized at time t, and $hp_m(s^t)$ is the time 0 price of one unit of housing services in terms of time 0 nondurable goods to be delivered if state s^t is realized at time t.

taste shocks and measurement error in nondurable consumption growth should not enter significantly the regression (A-9). Under the null of full risk sharing of housing services and nondurable consumption β, ξ, and ζ are all equal to zero, while under the null of full risk sharing of nondurable consumption but regional risk sharing of housing services ξ and ζ are equal to zero while β is not equal to zero.

Appendix B Data

The PSID started in 1968 with a representative sample of about 3,000 households (the core sample) and a sample of low-income households (the SEO sample) that comprised about 2,000 families. In 1990 the PSID added the Latino sample and in 1997—the Immigrant sample. The PSID follows families over time, including young adults as they split off from the original family units. We use the core and SEO samples in our analysis, dropping the Latino and Immigrant samples. In 1997, the PSID changed from interviewing annually to interviewing biennially.

Our sample selection is as follows. We start with the individual file that contains information on age, sex, education, employment and headship status, and individual year of birth for years 1968–2007. We drop those who are never heads of household during the survey years. Individual age is reported with noise in the PSID: first, interviews may be conducted in different months of a year and, as a result, age may change or jump by more than one year in consecutive surveys; second, age can be recorded with error by interviewers. We utilize the data on year of birth from the individual file to construct a cleaner measure of age: age is defined as the difference between the survey year and year of birth. For those heads with no information on year of birth, we utilize the first record on age when an individual becomes a head to construct a consistent age series.

We further add the data on marital status, family composition change, family size, head's and wife's labor and transfer income, displacement and disability status, homeownership status, moving, self-reported house value and food from the family files of the PSID. We keep households whose heads are of ages 25 to 65, drop those with no information on food at home, homeownership status, and region of residence during the survey years. In the PSID, a small number of households report being neither owners nor renters in any survey year. We label those households owners if they report a positive house value; otherwise, we label them renters. Our results are robust to dropping those households. We set homeownership status to missing if households report being owners and zero house value. We also set top-coded observations on income, house value, food at home, food away, and family size to missing.

Food consumption consists of food consumed at home and away from home (excluding food purchased at work or school). The PSID reported annual food costs until 1993, but has reported costs at the daily, weekly, biweekly, monthly, or annual frequency since 1994. For the years 1994–2005, we use household food consumption reported at the monthly or weekly frequency and convert those records to annual amounts.[2] For household income, the sum of real labor and transfer income of head and wife before taxes is used. Food consumption at home and away from home and household income are deflated by the all-items-less-housing consumer price index (CPI) from the Bureau of Labor Statistics.

The timing of several variables is not fully synchronized. For example, the income record in a survey year t refers to income earned in period $t-1$—the same holds for displacement status. Since most households are interviewed in the first quarter of the year, we assume that food consumption and limiting status records in a survey year t refer to the food consumption and limiting status effective in period $t-1$. Similarly, demographic variables such as age and family size are assumed to correspond to the head's

[2]We lose a low number of observations for households reporting food consumption at other frequencies. We do not include them in our sample because some, when converted to annual amounts, are clear outliers.

age and family size in period $t-1$.[3] The house-price index in year t is the house-price index for the previous year.

Further sample selection criteria are as follows. For each year, observations with zero or missing records of food consumption at home are dropped. To hedge against outliers, observations above the 99th percentile and below the 1st percentile of the annual food-at-home distributions are dropped and records of food away from home above the 99th percentile of each annual distribution are set to missing.[4] We then add up real food at home and food away from home to obtain a measure of total food consumption. We drop observations with a ratio of total food consumption to income above the 99th percentile or below the 1st percentile of the annual distributions for the ratio. We also drop observations above the 99th percentile and below the 1st percentile of the four-year consumption growth distributions. We restrict our analysis to family-year pairs with stable composition (same head and wife during the four-year span) and families for which we have information on housing status. The sample is also restricted to households that reside in the same metropolitan area during a given four-year period so four-year MSA house-price changes can be meaningfully assigned.

Appendix C House-price appreciation across MSAs

Figure A-1 shows the distribution of real house-price appreciation (four-year growth rates to match our empirical specification) over the period. As is evident from the distribution, our sample includes both house-price appreciation and house-price depreciation episodes.

[3] This is necessary to enable us to keep observations after 1997, when the PSID switched to biennial data collection.

[4] We do not drop observations with zero records of food away from home. In the Consumer Expenditures Survey, which provides reliable information on the spending patterns of U.S. consumers, virtually everyone reports non-zero records of food at home, while a substantial fraction of respondents reports zero expenditures on food away from home (excluding food at work).

Figure A-2, panel (a) reveals significant cross-sectional variation of house-prices while panel (b) shows a clear difference in the intertemporal patterns of house-price appreciation for selected MSAs. Overall, this figure demonstrates the large variation in the panel of house prices which allows us to obtain statistically significant estimates of their impact on nondurable consumption.

Appendix D The Household Problem and Calibration

The household problem

The problem solved by a newborn at time 0 can be written as:

$$\max_{\{C_t, F_t, H_t, A_t, M_t, x_t\}_{t=0}^{T}} E_0 \sum_{t=0}^{T} \frac{1}{(1+\rho)^t} \zeta_t U \left(C_t, \underbrace{(1-x_t) F_t + x_t H_t}_{=J_t} \right), \tag{A-13}$$

subject to

$$C_t \geq 0,\ F_t \geq 0,\ H_t \geq 0,\ A_t \geq 0,\ M_t \geq 0,\ x_t \in \{0,1\},\ z_t \in \{0,1\},\ \forall t = 0, \ldots, T, \tag{A-14}$$

$$\begin{aligned} C_t + (1-x_t)\, r_t^f F_t + A_t - M_t + x_t (1 + I\,\kappa)\, q_t H_t + x_{t-1} I\, \chi q_t (1-\delta_h) H_{t-1} + \tau_y Y_t^{\tau} \leq \\ W_t + (1+r^a) A_{t-1} - (1+r^m)\ M_{t-1} + x_{t-1} q_t (1-\delta_h) H_{t-1},\ \forall t = 0, \ldots, T, \end{aligned} \tag{A-15}$$

$$W_t = P_t \nu_t \phi_t, \quad P_t = P_{t-1} \gamma_t \epsilon_t \varsigma_t, \quad \forall t \leq R. \quad W_t = b P_R, \ \forall t > R,$$

$$\varsigma_t = \begin{cases} \lambda_t < 1, & p_\varsigma, \\ 1 & 1 - p_\varsigma. \end{cases} \text{ and } \phi_t = \begin{cases} \mu < 1, & p_\phi, \\ 1 & 1 - p_\phi, \end{cases} \tag{A-16}$$

$$Y_t^\tau = W_t + r^a A_{t-1} - \tau_m r^m M_{t-1}, \ \forall t = 0, \ldots, T, \tag{A-17}$$

$$\begin{aligned} &M_t \leq (1-\theta) q_t H_t \text{ or} \\ &\quad M_t < M_{t-1} \ \text{ if } M_t > (1-\theta) q_t H_t \text{ and } \left(|H_t/H_{t-1} - 1| < 0.05, z_t = 0 \right), \\ &\qquad \forall t = 0, \ldots, T-1; \ M_T = 0, \end{aligned} \tag{A-18}$$

$$q_{t+1} = (1 + \varrho_{t+1}) q_t, \ \forall t = 0, \ldots, T. \tag{A-19}$$

Equation (A-14) contains non-negativity constraints, and states that households cannot be renters and homeowners at the same time (x_t is an indicator of ownership in period t and F_t are housing services acquired through the rental market), and face moving shocks. Equation (A-15) is the budget constraint, where I is an indicator function equal to 1 if the household is moving and 0 otherwise. Equation (A-16) describes labor income for working-age households, and the pension benefit for retirees. Equation (A-17) spells out taxable income. Equation (A-18) is the collateralized debt constraint, which says that the maximum loan-to-value ratio for new mortgages and equity lines of credit is $1 - \theta$, allowing for an exception for non-movers (when prices go down) who can simply pay their mortgage. Finally, equation (A-19) captures the dynamics of housing prices.

Under these assumptions, households prefer equity to debt financing of their houses (i.e., they pay their mortgages before accumulating deposits), as long as the after-tax rate on mortgages, $(1 - \tau_m \tau_y) r^m$, is higher than the after-tax return on deposits, $(1 - \tau_y) r^a$. For details on the solution method, see Díaz and Luengo-Prado (2010).

Calibration Details

Preferences, endowments and demography

For computational reasons, one period is two years. Households are born at age 24 ($t = 1$), and die at the maximum age of 85 ($t = 31$). The retirement age is 66 ($t = 22$). Survival probabilities are taken from the latest U.S. Vital Statistics (for females in 2003), published by the National Center for Health Statistics. The implied fraction of working-age households is 75.6 percent—slightly lower than the fraction in the PSID, 78.6 percent. Most parameters are quoted in annual terms, but are adjusted to a biennial frequency in our computations.

For preferences regarding consumption of nondurable goods and housing services, we choose the non-separable Cobb-Douglas utility function:

$$U(C, J) = \frac{(C^{\alpha} J^{1-\alpha})^{1-\sigma}}{1-\sigma}. \tag{A-20}$$

The curvature of the utility function is $\sigma = 2$.

We follow Cocco, Gomes and Maenhout (2005) in our labor earnings calibration. Using data from the PSID, those authors estimate the life-cycle profile of income, as well as the variance of permanent and transitory shocks for three different educational groups: no high school, high school, and college. We choose these authors' estimates of the variance of permanent and transitory shocks for households whose head has a high school degree—

the typical median household (0.01, and 0.073, respectively). These values are typical in the literature—Storesletten, Telmer and Yaron (2004). For consistency, we also use the estimated growth rate of the non-stochastic life-cycle component of earnings for a household with a high school degree from Cocco et al. (2005).

To calibrate the displacement shock, we follow the evidence in Stephens (2001). The literature on job displacement finds that annual earnings fall 25–40 percent in the year of displacement, while earnings fall by roughly 15 percent after a disability shock. Annual earnings are well below expected levels six years after the initial shock in both cases. We model displacement as a combination of permanent and transitory shocks. We set the income loss from the permanent shock to the lower end of his findings for the young, 25 percent, and to the upper end, 40 percent, for the old (young is under 46, old is 46-64 so λ_{young}=0.75 and λ_{old}=0.60). The probability of the permanent displacement shock is 3 percent, a bit below the 5–15 percent found using datasets such as the PSID. (Numbers vary depending on the specific definitions of displacement and disability.) Cocco et al. (2005) do not allow for a displacement shock, so σ_{ε}^2 is adjusted so that the overall variance of the permanent shocks inclusive of this bad shock is equal to their estimate, 0.01. The transitory displacement shock is calibrated to produce a loss of income of 40 percent for just one period with a 5 percent probability. As with the permanent shocks, σ_{ν}^2 is adjusted so that the overall variance of the transitory shocks is 0.073 as in Cocco et al. (2005). This combination of permanent and transitory bad shocks reproduces the mean and standard deviation of the bad news variable constructed from PSID data and used in our regressions. In our model, retirees face no income uncertainty. Their pension is set at 50 percent of permanent income in the last period of working life. That figure is between the 42 percent estimated in Munnell and Soto (2005) as the median replacement rate for newly retired workers, according to both the Health Retirement Survey and Social

Security Administration data, and the 68 percent in Cocco et al. (2005), calculated as a ratio of average income for retirees and average income in the last working year before retirement (PSID data). The moving shock is calibrated to match the four-year moving rate for owners in PSID data which is 19 percent. We need an annual moving probability of 1.5 percent to get this rate in our model. Only working-age individuals are affected by the moving shock.

In our setup, there is no age limit on credit availability and, in the event of death, houses are liquidated at the price in the previous period to avoid most negative accidental bequests. A negative bequest is still possible for a homeowner who dies at a young age after a period of house-price depreciation. We assume the government takes the loss in this case.

Market arrangements

The minimum down payment is 20 percent, slightly below the 25 percent average down payment for the period 1963–2001 reported by the Federal Housing Finance Board. We set the selling cost equal to 6 percent, a typical realtor fee, and the buying cost to 2 percent. The interest rate on deposits, r^a, is set to 4 percent in annual terms (the average real rate for 1967–2005, as calculated in Díaz and Luengo-Prado 2010), while the interest rate on mortgages is set to 4.5 percent.

Taxes

To calibrate the income tax rate, τ_y, we use data on personal income and personal taxes from the National Income and Product Accounts of the Bureau of Economic Analysis, as well as information from TAXSIM, the NBER tax calculator.[5] For the period 1989–

[5] The TAXSIM data is available at `http://www.nber.org/taxsim`.

2004, personal taxes represent 12.47 percent of personal income in NIPA. As in Prescott (2004), we multiply this number by 1.6 to reflect the fact that marginal income tax rates are usually higher than average rates. The 1.6 number is the mean ratio of marginal income tax rates to average tax rates, based on TAXSIM (for details, see Feenberg and Coutts 1993). The final number is 19.96 percent, which we approximate using $\tau_y = 0.20$. We assume mortgage payments are fully deductible, $\tau_m = 1$.

House prices

Housing prices follow the process $q_t = q_{t-1}(1 + \varrho_t)$, where $\varrho_t \sim N(\mu_\varrho, \sigma_\varrho^2)$. $\mu_\varrho = 0$ and $\sigma_\varrho^2 = .0132$—as in Li and Yao (2007). We assume ϱ_t is serially uncorrelated and uncorrelated with the income shocks. The housing depreciation/maintenance cost rate, δ^h, is set to 1.5 percent, as estimated in Harding, Rosenthal and Sirmans (2007).

The rental price is proportional to house prices. In particular:

$$r_t^f = \frac{q_t - E_t\left[\frac{1}{1+(1-\tau_y)r^a}\, q_{t+1}\left(1-\delta^h\right)\right]}{1-\tau_y} = q_t\,\frac{(1-\tau_y)r^a + \delta_h}{(1-\tau_y)(1+(1-\tau_y)r^a)}, \tag{A-21}$$

which can be interpreted as the user cost for a landlord who is not liquidity constrained, not subject to adjustment costs, and who pays income taxes on rental income. This calibration choice is consistent with the estimates in Sinai and Souleles (2005), who find the house-price-to-rent ratio capitalizes expected future rents, as any other asset (for more details see Díaz and Luengo-Prado 2010). For our benchmark calibration, r_t^f/q_t is roughly 5.7 percent annually.

Patterns of homeownership and wealth

Figure A-3 depicts the evolution of some key variables throughout the life cycle in our baseline calibration. All series are normalized by mean earnings. Panel *(a)* shows mean labor income (earnings for workers and pensions for retirees) and nondurable consumption. For working-age households, the life-cycle profile for earnings is calibrated to the profile estimated by Cocco et al. (2005) for households with a high school degree. Earnings peak at age 47. For retirees, the pension-replacement ratio is calibrated to be 50 percent of permanent earnings in the last working period. Our model produces a hump-shaped nondurable consumption profile with a peak around age 60.

Panel *(b)* in Figure A-3 depicts mean wealth and its different components throughout the life cycle. Total wealth is hump-shaped and peaks at ages 60–63, with a value about 2.96 times mean earnings in the economy, declining rapidly afterward. Because we do not allow for altruism in the model, total wealth is zero for those who reach the oldest-possible age (not depicted). Housing wealth (including collateralized debt) increases until age 52–55, then stays fairly constant until it begins to decrease at age 72, when the homeownership rate starts to decline. Financial assets become negative at age 72 as retirees take advantage of reverse mortgages.

The targets of our calibration are the overall homeownership rate in the United States, the median wealth-to-earnings ratio for working-age households, and the median ratio of house value to total wealth for homeowners. Figure A-4 plots the life-cycle patterns of these three variables against the data.[6] The median wealth-to-earnings ratio in the model—see panel *(a)*—follows the ratio in the data very closely until age 59, and diverges significantly thereafter, probably because we are not allowing for heterogeneity in retirement ages. In our model, gross housing wealth is a higher (lower) fraction of total wealth than in the data for the oldest (youngest) cohorts. The fact that we are abstracting from intergenerational altruism (that is, older cohorts exhaust their assets as they age) may

[6]We use data from the Survey of Consumer Finances (averages from 1989 to 2004) instead of the PSID for these graphs, because the SCF has somewhat better information on wealth and the sample sizes are larger.

account for the divergence for the oldest households. Other possibilities are limited availability of reverse mortgages in real life or uncertainty about health expenses in old age which may result in higher liquid savings. The timing of accidental bequests (received early in life in the form of liquid wealth) could explain the divergence for the youngest cohorts.

Panel *(b)* in Figure A-4 depicts the life-cycle profile of homeownership rates in our benchmark calibration and in the data. Although we can reproduce the average U.S. homeownership rate, our model underestimates homeownership for ages 24 to 40, and overestimates homeownership rates for older cohorts, with the exception of the oldest. In our benchmark calibration, the oldest cohort turns to renting in the last period of life in order to free up forced housing equity.

It seems we would need further heterogeneity and/or additional assumptions to exactly replicate homeownership patterns and other profiles by age. However, this is not the focus of our paper. Our aim is to determine if our empirical findings are consistent with a story in which housing equity is used to alleviate liquidity constraints. To this end, we study the quantitative predictions of this model (with the key features of endogenous tenure choice and a collateral role for housing) regarding the effect of house-price changes on risk sharing.

Appendix E Alternative model specifications

Correlation between income shocks and house-price shocks

To allow for a possible correlation between income shocks and house-price shocks, we modify the income process by introducing a regional permanent shock, g_t, common to all residents of the region. Thus, $P_t = P_{t-1} g_t \gamma_t \epsilon_t \varsigma_t$, where $\log g_t \sim N\left(-\sigma_g^2/2, \sigma_g^2\right)$. To calibrate σ_g, we use the evidence in Luengo-Prado and Sørensen (2008). We save on state variables by assuming that the regional income shock and the house-price shock are perfectly correlated. This case can be seen as the opposite extreme from our baseline calibration in terms of income/house-price correlation. With this correlation, young households delay homeownership and the overall homeownership would be lower if the model was not recalibrated to match the same aggregates. See Figure A-5.

A bequest motive

We consider warm-glow altruism. The utility derived from bequeathing wealth, X_t, is:

$$v(X_t) = b\frac{X_t\left(\alpha^{\alpha}[(1-\alpha)/r_t^f]^{1-\alpha}\right)^{1-\sigma}}{1-\sigma},$$

where b measures the strength of the bequest motive, and terminal wealth equals the value of the housing stock, after depreciation takes place and adjustment costs are paid, plus financial assets: $X_t = q_t H_t(1-\delta^h)(1-\chi) + A_t$.

The Cobb-Douglas utility assumption we use as our benchmark would result in the inheritor's expenditure on nondurable consumption, C, and housing services, $r_t^f F_t$, in fixed proportions $\alpha/(1-\alpha)$. We consider bequests with and without correlation between income and house-price shocks. In this case, we have one additional calibration parameter, the strength of the bequest motive, so we add one additional target, the mean bequest-to-income ratio, set to 2.5 consistent with the evidence in Hendricks (2001).

Adding a bequest motive changes the results just slightly from the baseline regression—the direct effect of house prices is slightly larger reflecting that homeowners hold on to their house longer rather than selling it in order to spend down life-cycle savings late in life (this makes the present value of adjustment costs lower)—see Figure A-5, panel (b) and Table A-4. One important difference is a significantly lower MPC out of income for renters when a bequest motive is at play. This is intuitive because, in the absence of a bequest motive, poor consumers (typically renters) would spend a higher fraction of increases in income. Importantly, our house-price interaction terms are consistently significant for owners, with a sign indicating risk sharing, while that is not the case for renters.

CES utility

We report results for a different utility function. In particular, we use the findings in Li, Liu and Yao (2009) and consider a CES utility function with an intra-temporal elasticity of substitution between housing and nondurable consumption of 0.33 (i.e., housing and nondurables are complements).

In this case, the expenditure shares on housing and nondurables for renters are not independent of the relative price of the two goods, as in the Cobb-Douglas case. The parameter that controls the expenditure share on housing and nondurables, the discount rate, and the minimum house size are recalibrated to reproduce the same homeownership rate, wealth-to-income ratio, and ratio of house value to total wealth as in the case with a Cobb-Douglas utility function. The estimated coefficients using our simulated data are not very sensitive to this change. Most importantly, the house-price interaction term is positively significant for owners, indicating additional risk sharing, and not for renters—see Table A-4.

Appendix F Robustness to sampling frequency

We explore robustness of our results to the sampling frequency and report results in Table A-5. In the data, we find a somewhat stronger direct effect of house prices at the two-year frequency—especially for renters—and insignificant interaction terms. At longer frequencies the direct effect of house prices is fairly stable for owners and less so for renters although the effect remains significant. The direct effect of bad news does not vary much with the frequency indicating that disability and displacement indeed are persistent events. The interaction term is significant for 3-year and 6-year frequencies reaching its highest level of significance at the four-year frequency, the baseline. Our prior was that low frequencies would have low signal to noise ratios and the results bear this out but are otherwise robust.

In the model, results are fairly robust to the sampling frequency except for the interaction term which becomes smaller as the sampling frequency increases. At long frequencies, people may be more likely to move anyway making the interaction effect smaller—the direct effects do not change with the sampling frequency as in the data.

Table A-1: Summary Statistics of Empirical Data

Variable	Mean	SD	Min	Max
$c_{it} - \bar{c}_t$	0.00	0.46	–1.84	1.69
$y_{it} - \bar{y}_t$	0.00	0.42	–2.22	2.04
$hp_{mt} - \overline{hp}_t$	0.00	0.13	–0.57	0.55
D_{it}	0.12	0.32	0.00	1.00
$(D_{it} - \bar{D}_t) \times (hp_{mt} - \overline{hp}_t)$	0.00	0.05	–0.47	0.46
L_{it}	0.02	0.28	–1.00	1.00
$(L_{it} - \bar{L}_t) \times (hp_{mt} - \overline{hp}_t)$	0.00	0.04	–0.55	0.55
BN_{it}	0.15	0.36	0.00	1.00
$(BN_{it} - \overline{BN}_t) \times (hp_{mt} - \overline{hp}_t)$	0.00	0.05	–0.44	0.43
Owner	0.60	0.49	0.00	1.00
Age	45.18	9.95	29.00	65.00

Notes: Variable definitions as follows: c_{it} is the (four-year) log difference of consumption for individual i in year t, y_{it} is the log difference of current income, and $\bar{c}_t$ ($\bar{y}_t$) is the mean log consumption (income) difference in period t. hp_{mt} is the log difference in house prices in the region where individual i lives, while $\overline{hp}_t$ is the mean log difference in house prices for all regions in period t. D_{it} is the displacement shock indicator; L_{it} is the limiting condition indicator; and BN_{it} is the "bad news" indicator.

Table A-2: Summary Statistics of Simulated Data

Variable	Mean	SD	Min	Max
$c_{it} - \bar{c}_t$	0.00	0.22	–1.31	1.66
$y_{it} - \bar{y}_t$	0.00	0.58	–2.97	2.01
$hp_{mt} - \overline{hp}_t$	0.00	0.29	–0.37	0.35
D_{it}	0.15	0.36	0.00	1.00
$(D_{it} - \bar{D}_t) \times (hp_{mt} - \overline{hp}_t)$	0.00	0.10	–0.31	0.30
Owner	0.59	0.49	0.00	1.00
Age	45.65	11.07	28	64

Notes: Variable definitions as follows: c_{it} is the (four-year) log difference of consumption for individual i in year t, y_{it} (p_{it}) is the log difference of current (permanent) income, and $\bar{c}_t$ ($\bar{y}_t, \bar{p}_t$) is the mean log consumption (income) difference in period t. hp_{mt} is the log difference in house prices in the region where individual i lives, while $\overline{hp}_t$ is the mean log difference in house prices for all regions in period t. D_{it} is the displacement shock indicator.

Table A-3: IV Regression of Food on Nondurable Expenditures. CEX Data: 1980–2002

Log nondurable cons.	0.730***	Log nondurable cons. × HS	0.023
	(15.84)		(1.03)
Log nondurable cons. × 1980	0.122***	Log nondurable cons. × coll.	0.089***
	(9.45)		(3.72)
Log nondurable cons. × 1981	0.103***	Log regional food CPI	0.643***
	(9.09)		(3.88)
Log nondurable cons. × 1982	0.094***	Log regional fuel-util. CPI	–0.113***
	(8.87)		(–2.75)
Log nondurable cons. × 1983	0.089***	White	0.047***
	(8.78)		(6.91)
Log nondurable cons. × 1984	0.083***	Family size	0.055***
	(8.77)		(17.34)
Log nondurable cons. × 1985	0.081***	High school	–0.252
	(8.97)		(–1.22)
Log nondurable cons. × 1986	0.076***	College	–0.924***
	(8.95)		(–4.10)
Log nondurable cons. × 1987	0.070***	Male head	0.082***
	(9.03)		(15.41)
Log nondurable cons. × 1988	0.067***	Married	–0.030**
	(9.55)		(–2.42)
Log nondurable cons. × 1989	0.061***	Age	0.012***
	(10.07)		(4.49)
Log nondurable cons. × 1990	0.051***	Age sq./100	–0.011***
	(10.05)		(–4.13)
Log nondurable cons. × 1991	0.043***	Born 1924–1932	–0.017*
	(9.51)		(–1.67)
Log nondurable cons. × 1992	0.041***	Born 1933–1941	–0.012
	(9.56)		(–0.90)
Log nondurable cons. × 1993	0.038***	Born 1942–1950	–0.004
	(9.52)		(–0.24)
Log nondurable cons. × 1994	0.034***	Born 1951–1959	0.001
	(9.64)		(0.06)
Log nondurable cons. × 1995	0.030***	Born 1960–1968	0.019
	(9.51)		(0.80)
Log nondurable cons. × 1996	0.023***	Born 1969–1978	0.029
	(8.92)		(1.02)
Log nondurable cons. × 1997	0.020***	Northeast	–0.013**
	(9.47)		(–2.33)
Log nondurable cons. × 1998	0.017***	Midwest	–0.061***
	(9.64)		(–11.48)
Log nondurable cons. × 1999	0.013***	South	–0.037***
	(8.57)		(–7.06)
Log nondurable cons. × 2000	0.011***	Constant	0.085
	(9.59)		(0.24)
Log nondurable cons. × 2001	0.006***	Adj. R sq.	0.721
	(7.58)		
N	40,630	F	1264.1

Notes: t-statistics in parentheses. Instruments for log nondurable consumption (and its interaction with year and education dummies) are the averages of log head's wages specific to cohort, education, and head's sex in a given year (and their interactions with year and education dummies). *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

Table A-4: Risk sharing regressions–Model. Alternative Calibrations

	Owner		Renter	
Baseline				
Income growth	0.12***	(158.59)	0.30***	(186.42)
House price growth	0.27***	(180.72)	0.01	(1.60)
Bad news	–0.10***	(–82.99)	–0.08***	(–36.33)
Bad news × House price gr.	0.07***	(17.32)	–0.02**	(–2.10)
No. of obs.		151,150		62,126
Bequest motive				
Income growth	0.12***	(188.10)	0.21***	(188.35)
House price growth	0.29***	(169.01)	0.01**	(2.68)
Bad news	–0.10***	(–82.72)	–0.09***	(–46.63)
Bad news × house price gr.	0.08***	(19.62)	–0.00	(–0.28)
No. of obs.		142,923		66,002
Bequest and income/house price correlation				
Income growth	0.12***	(170.73)	0.20***	(141.65)
House price growth	0.39***	(301.98)	0.14***	(54.28)
Bad news	–0.10***	(–77.24)	–0.09***	(–45.77)
Bad news × house price gr.	0.06***	(15.34)	–0.00	(–0.60)
No. of obs.		140,264		73,633
CES utility				
Income growth	0.10***	(87.48)	0.31***	(177.74)
House price growth	0.28***	(146.37)	0.01	(1.33)
Bad news	–0.10***	(–88.93)	–0.08***	(–30.07)
Bad news × house price gr.	0.06***	(18.04)	–0.02***	(–2.89)
No. of obs.		151,866		53,955

Notes: We run the following regression: $c_{it} - \bar{c}_t = \mu + \beta\ (hp_{mt} - \overline{hp}_t) + \xi\ (D_{it} - \bar{D}_t) + \zeta\ (D_{it} - \bar{D}_t) \times (hp_{mt} - \overline{hp}_t) + (X_{it} - \bar{X}_t)'\delta + \alpha(y_{it} - \bar{y}_t)\varepsilon_{it}$. We report the estimated coefficients $\hat{\alpha}$, $\hat{\beta}$, $\hat{\xi}$, and $\hat{\zeta}$. We control for age and age sq. in the regressions. All models recalibrated to match the same targets as benchmark. Serial correlation in the regression errors is corrected using the Prais-Winsten transformation; robust standard errors in the regressions clustered by region. t-statistics in parentheses. ***(**)[*] significant at the 1(5)[10]% level.

Table A-5: Risk sharing regressions–Data and Model. Different frequencies

	Owner		Renter	
Data				
Baseline				
House price growth	0.135***	(5.92)	0.213***	(4.86)
Bad news	–0.047***	(–4.66)	–0.070***	(–4.09)
Bad news × house price gr.	0.184***	(2.61)	0.012	(0.11)
No. of obs.		19,228		8,776
2-year frequency				
House price growth	0.162***	(6.04)	0.199***	(3.61)
Bad news	–0.036***	(–3.28)	–0.052***	(–3.66)
Bad news × house price gr.	0.094	(0.98)	0.096	(0.54)
No. of obs.		26,672		14,852
3-year frequency				
House price growth	0.134***	(5.09)	0.110*	(1.87)
Bad news	–0.040***	(–3.84)	–0.082***	(–5.18)
Bad news × house price gr.	0.182***	(2.87)	–0.077	(–0.61)
No. of obs.		18,254		9,935
6-year frequency				
House price growth	0.127***	(4.85)	0.239***	(4.41)
Bad news	–0.047***	(–4.20)	–0.059***	(–3.47)
Bad news × house price gr.	0.116*	(1.89)	–0.027	(–0.27)
No. of obs.		13,804		5,626
Model				
Baseline				
House price growth	0.27***	(140.39)	0.01	(1.56)
Bad news	–0.17***	(–120.89)	–0.21***	(–69.05)
Bad news × house price gr.	0.08***	(16.69)	–0.01	(–0.91)
No. of obs.		151,150		62,126
2-year frequency				
House price growth	0.28***	(158.45)	0.01**	(2.57)
Bad news	–0.16***	(–146.20)	–0.24***	(–77.83)
Bad news × house price gr.	0.14***	(18.24)	–0.07***	(–3.13)
No. of obs.		151,150		62,126
6-year frequency				
House price growth	0.27***	(147.14)	0.01*	(1.72)
Bad news	–0.16***	(–76.69)	–0.18***	(–47.70)
Bad news × house price gr.	0.06***	(11.36)	–0.00	(–0.04)
No. of obs.		151,150		62,126

Notes: We run the following regression: $c_{it} - \bar{c}_t = \mu + \beta\ (hp_{mt} - \overline{hp}_t) + \xi\ (D_{it} - \bar{D}_t) + \zeta\ (D_{it} - \bar{D}_t) \times (hp_{mt} - \overline{hp}_t) + (X_{it} - \bar{X}_t)'\delta + \varepsilon_{it}$. We report the estimated coefficients $\hat{\beta}$, $\hat{\xi}$, and $\hat{\zeta}$. We control for age and age sq. (and family size growth in PSID data) in the regressions. Serial correlation in the regression errors is corrected using the Prais-Winsten transformation; robust standard errors in the regressions clustered by region. t-statistics in parentheses. ***(**)[*] significant at the 1(5)[10]% level.

Figure A-1: MSA house-price appreciation (four-year growth rates)

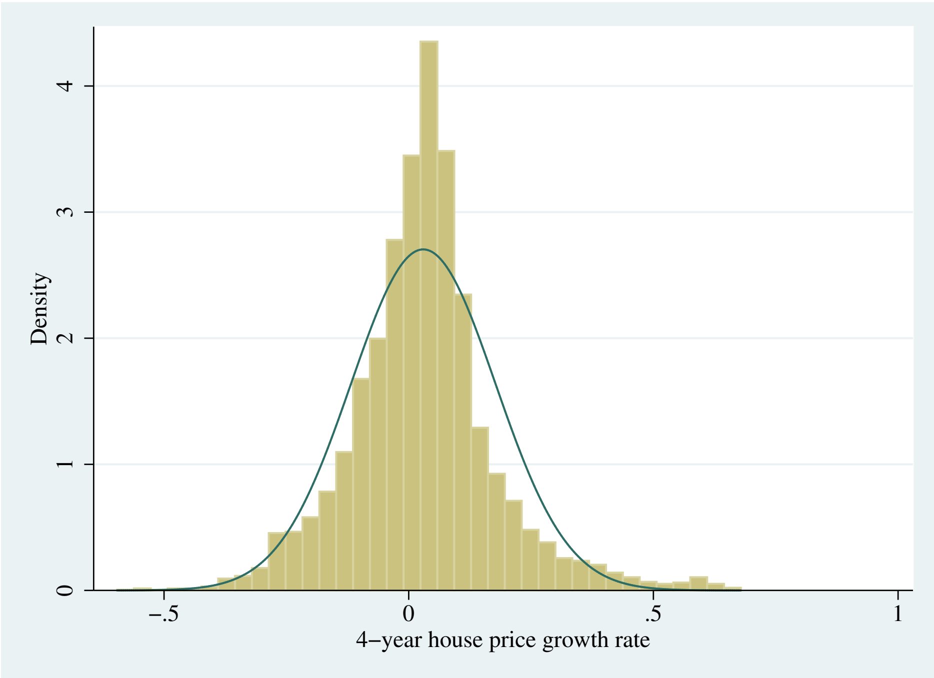
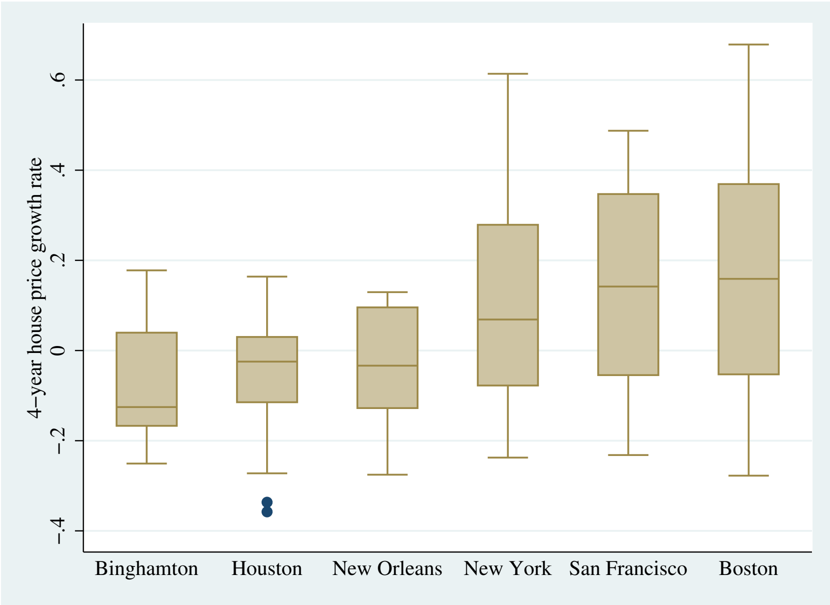
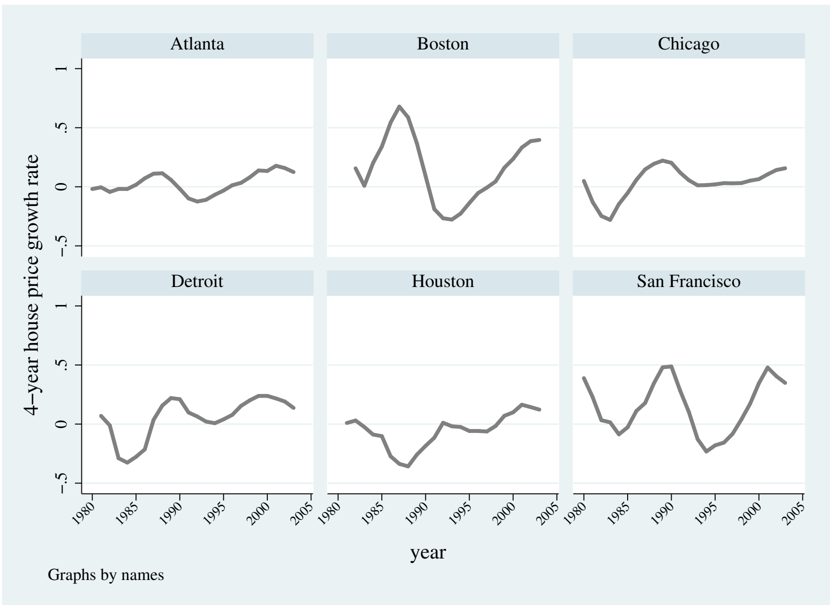


Figure A-2: MSA house-price appreciation. Selected MSAs



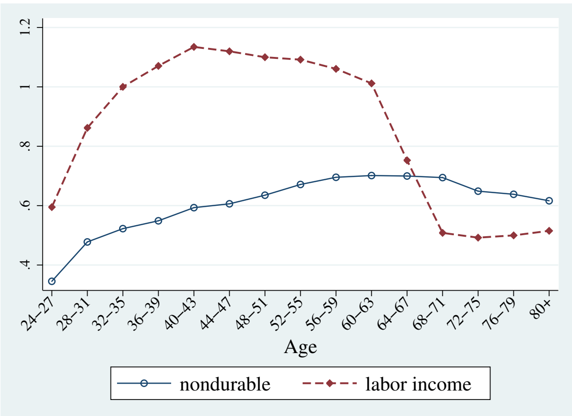
(a) Low vs. High

On each box, the central mark is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually.

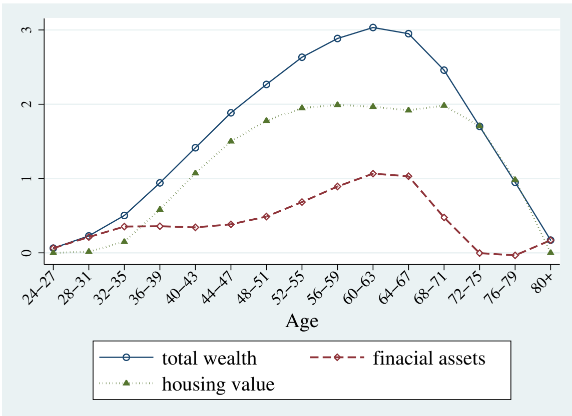


(b) Over Time

Figure A-3: Life-cycle Profiles. The Benchmark Case

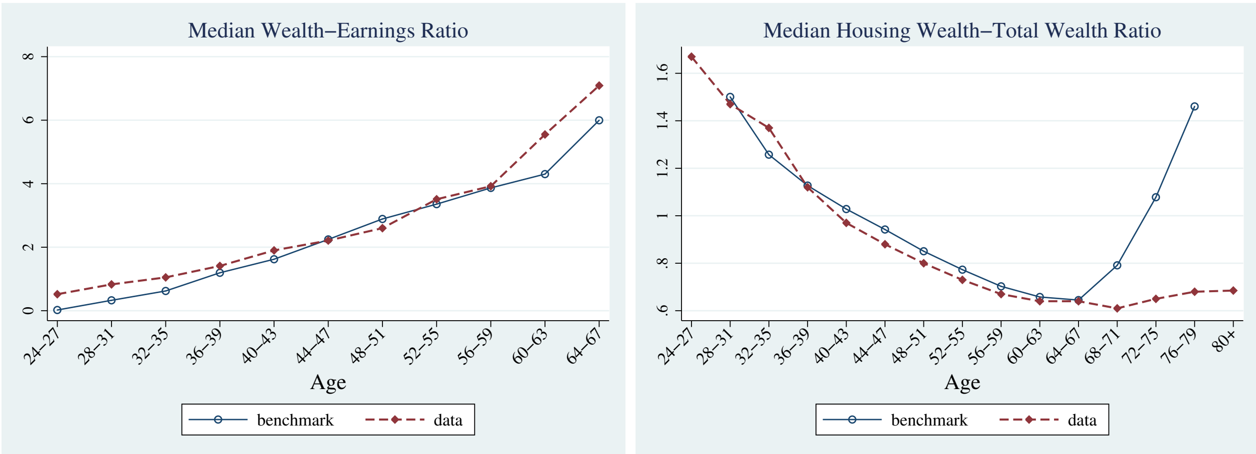


(a) Income and Consumption

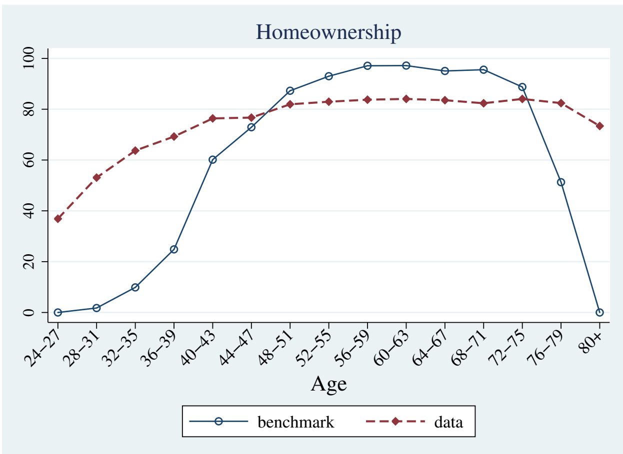


(b) Wealth

Figure A-4: The Benchmark and the Data



(a) Wealth and Earnings



(b) Home ownership

FIGURE A-5: Home ownership under Different Assumptions

(a) Accidental Bequests

(b) Bequest Motive

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