Appendices to Mortgage Borrowing and the Boom-Bust Cycle in Consumption and Residential Investment

A Robustness of MSA-level evidence

Table A1: Robustness checks and sub-sample estimates

Panel I. House price shocks

	Unit measure	p.c. measure	Alt. HPI	1999-2007	2008-2015
Consumption		0.070***	0.079***	0.069***	0.071***
		(0.014)	(0.015)	(0.020)	(0.024)
Residential investment	1.058***	0.967***	0.707***	2.321***	0.931***
	(0.169)	(0.161)	(0.173)	(0.310)	(0.217)

Panel II. Mortgage rate shocks

	Unit measure	p.c. measure	add. controls	1999-2007	2008-2015
Consumption		0.006	0.001	0.007	0.036***
		(0.009)	(0.008)	(0.014)	(0.013)
Residential investment	0.506***	0.475***	0.470***	0.558***	0.501***
	(0.085)	(0.088)	(0.088)	0.100)	(0.188)

Panel III. Credit supply shocks

	Unit measure	p.c. measure	add. controls	1999-2006
Consumption		0.023	0.027	0.009
		(0.050)	(0.045)	(0.045)
Residential investment	0.555*	1.074***	1.642***	1.658***
	(0.308)	(0.342)	(0.306)	(0.268)

Notes: House price shocks (panel I) are identified using the GMNS instrumental-variable approach. Mortgage rate shocks (panel II) are measured by $frac > 0$. Credit supply shocks (panel III) are identified using the LS instruments. Column (1) shows the responses of residential investment measured by annual growth of building permit units. Column (2) shows the responses of residential investment measured by annual growth of building permit valuation per capita. In column (3) of panel I, the FHFA house price indices are used. In column (3) of panel II, additional controls are included (the interaction between Guren et al.'s sensitivity measure and national house price growth, and the differential sensitivity of retail employment to regional retail employment and to Gilchrist and Zakrajsek (2012) excess bond premia). In column (3) of panel III, additional controls are included (the interaction between Guren et al.'s sensitivity measure and national house price growth and the differential sensitivity of retail employment to regional retail employment and to the 30-year fixed mortgage rate). The last two columns present sub-sample estimates from the preferred specifications.

B PSID Data and Additional Empirical Results

The PSID main family data 1999-2015 are used to provide household-level evidence in Section 6. The data are representative of the U.S. population and contain detailed information on wealth, income, and expenditures of a panel of approximately 7,000 households, making it more suitable than other U.S. household surveys to study consumer borrowing and spending patterns.[29]

I applied the following sample selection criteria. First, I focus on households of working age (i.e., the heads of the household between age 26 and 65). Second, I focus on existing homeowners, because they have the ability to use their homes as collateral to borrow.[30] I also exclude first-time home buyers, because the increase in their mortgage debt (from zero) is mechanically used to finance their housing investment. Including them in the sample will reinforce my results. Third, I exclude households owning farms or businesses, because their borrowing may be related to their business investment, rather than consumer spending. Fourth, I exclude households having negative total income or a home value below $5,000 to reduce possible errors in the survey data. Below I describe the definition of the key variables in the empirical analysis. See Table B1 for the summary statistics of selected key variables.

- Indicator for increasing one's mortgage debt: A homeowner's total mortgage balance increases by at least 5% between two survey periods, and the increase exceeds $1,000 (as used in Bhutta and Keys (2016)). Note that total mortgage balance refers to the first and second liens on the primary residence, as the PSID does not collect information on mortgages secured by non-primary residence.
- Indicator for home upgrading: A homeowner sells the old home and moves to a more expensive new home within the same period. For robustness, I also use alternative definitions based on the number of main rooms (see Table B4).
- Expenditures on home upgrading: The difference between the market price of the current home and the price at which the old home was sold (all in 2009 dollars). This

[29] The Survey of Consumer Finance (SCF), for example, collects data on household wealth but not on expenditures. In addition, SCF data are cross-sectional with the exception of the 2007-09 panel that was designed to study the impact of the Great Recession. The Consumer Expenditure Survey (CE) collects detailed expenditure data over a four-quarter panel but has limited information on wealth and income. In particular, it does not reflect the change in outstanding mortgage balances, making it impossible to distinguish, for example, between cash-out refinancing and rate refinancing. Moreover, it stops tracking households who move to another place during the interview period.

[30] This selection is also motivated by the empirical observation in Mian and Sufi (2011) and Bhutta (2015) that household debt dynamics in the 2000s were mainly driven by existing homeowners.

definition is used to match the concept of housing investment in the theoretical model, i.e., $p_t\left[h_{i,t} - h_{i,t-1}(1-\delta)\right]$.

- Indicator for home improvement: A homeowner makes any additions, remodeling or improvements that exceed \$10,000 (not including general maintenance or upkeep).[31]
- Expenditures on home improvement: Expenditures reported by the homeowner making home improvements.
- Consumption expenditures include: (i) non-durable goods: food (at home, delivered, and eaten out), gasoline, and clothing (available since 2005); (ii) durable goods: automobiles, furniture (available since 2005), and trips and recreation (available since 2005); (iii) services: utilities (heating, electricity, water, and other kinds of utilities), education, health (hospital bills, doctor visits, prescription drugs, and health insurance), child care, vehicle lease (lease payment and fees), public transportation (bus, train, taxi, and other transportation services), parking, vehicle repair, vehicle insurance, homeowner insurance, property tax, telephone (available since 2005), internet (available since 2005), and home repair services (available since 2005).
- Total household income: taxable income, transfer income and social security income of the head of household and of the spouse in the previous year.
- Wealth: (i) net liquid assets: sum of safe assets (checking and savings accounts, money market funds, certificates of deposit, government savings bonds, and treasury bills) and risky assets (stock shares) net of non-mortgage debt (credit cards, student loans, medical or legal bills, and loans from relatives); (ii) net illiquid assets: sum of home equity, net value of real estate owned by the household, private annuities and individual retirement accounts, net value of other assets, and the value of farms or businesses. Note that this definition is used when wealth is included as a control variable in a regression. When comparing the calibrated model with the data (Figure 2), wealth is defined as the sum of liquid assets and home equity.

[31] In the PSID survey, home improvement expenditures are reported when exceeding \$10,000, which leads to a truncated-variable problem. Since I estimate the change in expenditure growth associated with debt increases, this problem cannot be addressed by estimating the Tobit model. Note that, since the 2005 survey, home maintenance expenditures (often less than \$10,000) are reported without truncation. I conduct robustness checks that impute the home maintenance expenditures of households prior to the 2005 survey by matching their characteristics to households after the 2005 survey. I then redefine home improvements as the sum of the reported improvements and the imputed maintenance expenditures. The estimates based on this measure exhibit patterns similar to the baseline estimation.

Table B1: Summary statistics, PSID 1999-2015

Year	# Households	Home value ($,000)	Mortgage balance ($,000)	Deb increasers (% of h.h.)	Amount increased ($,000)	Housing investment ($,000) non-increasers	Housing investment ($,000) Increasers	Consumption ($,000) non-increasers	Consumption ($,000) Increasers
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
99-01	1,890	146.5	85.3	27.7	40.0	4.6	22.8	82.9	84.4
01-03	2,022	170.5	99.2	33.4	40.7	5.1	23.4	81.0	93.6
03-05	2,148	219.1	119.0	32.3	54.4	4.4	34.8	84.8	92.6
05-07	2,167	248.5	137.5	31.4	64.7	6.4	35.4	83.2	89.6
07-09	2,215	217.5	141.6	23.5	51.3	4.1	15.7	81.0	88.8
09-11	2,250	205.6	145.2	19.1	49.0	2.6	15.1	79.7	82.8
11-13	2,254	207.4	146.2	15.6	49.2	2.7	14.5	71.0	75.5
13-15	2,151	224.5	145.1	16.4	61.7	3.6	28.3	72.5	78.9
Average		206.2	128.4	24.7	51.4	4.1	25.0	79.2	87.4

Notes: Statistics in columns (1) to (8) are reported as household average. Mortgage balances in column (2) are conditional on households having mortgages. The amount borrowed in column (4) is conditional on households who increased their mortgage debt. Housing investment and consumption expenditures in columns (5)-(8) are converted to 2009 dollars using the CPI.

Table B2: Effects of house price shocks: Evidence from PSID data

	All homeowners	Age group			
		26-35	36-45	46-55	56-65
Panel I. Consumption					
HP growth	0.086***	0.010	0.138**	0.062*	0.113***
	(0.016)	(0.042)	(0.056)	(0.037)	(0.035)
# Obs.	16,050	2,537	4,338	5,227	3,948
Panel II. Likelihood of making housing investment					
HP growth	0.151***	0.239***	0.178***	0.124***	0.082***
	(0.009)	(0.023)	(0.018)	(0.014)	(0.018)
# Obs.	16,050	2,537	4,338	5,227	3,948
By investment type: (i) Home upgrading					
HP growth	0.082***	0.196***	0.103***	0.051***	0.033***
	(0.005)	(0.018)	(0.011)	(0.006)	(0.006)
# Obs.	16,050	2,537	4,338	5,227	3,948
(ii) Home improvement					
HP growth	0.056***	0.040***	0.063***	0.067***	0.046***
	(0.007)	(0.013)	(0.013)	(0.012)	(0.016)
# Obs.	16,050	2,537	4,338	5,227	3,948
By borrowing status: (i) Those who increased mortgage debt					
HP growth	0.218***	0.243***	0.258***	0.209***	0.148***
	(0.019)	(0.039)	(0.034)	(0.037)	(0.037)
# Obs.	3,996	735	1,234	1,282	745
(ii) Those who did not increase mortgage debt					
HP growth	0.059***	0.084***	0.066***	0.065***	0.042**
	(0.010)	(0.028)	(0.021)	(0.014)	(0.021)
# Obs.	12,054	1,802	3,104	3,945	3,203
Panel III. Likelihood of increasing mortgage debt					
HP growth	0.263***	0.471***	0.315***	0.182***	0.147***
	(0.013)	(0.033)	(0.029)	(0.020)	(0.020)
# Obs.	16,050	2,537	4,338	5,227	3,948

Notes: Responses to a 1% increase in home value. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively. Standard errors are clustered at the household level. All regressions control for household demographics, financial conditions in the previous period, changes in income and mortgage rates, and household and year fixed effects.

Table B3: Change in expenditures and mortgage debt increase

	Total expenditures	Consumption	Housing investment
Panel I. Expenditure growth associated with debt increase			
Microdata	0.161***	-0.025	0.186***
	(0.029)	(0.025)	(0.016)
# Obs.	16,050	16,050	16,050
Model	0.164***	0.006***	0.158***
	(0.002)	(0.001)	(0.002)
# Obs.	140,400	140,400	140,400
Panel II. Expenditures associated with a $1 debt increase			
Microdata	0.319***	-0.005	0.324***
	(0.045)	(0.015)	(0.042)
# Obs.	16,050	16,050	16,050
Model	0.395***	0.009***	0.386***
	(0.007)	(0.001)	(0.006)
# Obs.	140,400	140,400	140,400

Notes: Panels I and II show the estimates of β_1 in equations (13) and (14), respectively, using the PSID data and simulated data from the model. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

Table B4: Alternative measures of home upgrading in PSID

	All homeowners	Age group			
		26-35	36-45	46-55	56-65
Baseline: moving to a more expensive home					
Change in likelihood	0.064***	0.138***	0.087***	0.039***	0.025***
	(0.003)	(0.012)	(0.007)	(0.005)	(0.004)
Change in exp. growth	0.162***	0.339***	0.172***	0.097***	0.077**
	(0.013)	(0.047)	(0.028)	(0.016)	(0.032)
Change in exp. amount	0.307***	0.643***	0.475***	0.190***	0.089
	(0.040)	(0.093)	(0.092)	(0.044)	(0.125)
Alt. 1: moving to a more expensive home with at least same # of main rooms					
Change in likelihood	0.053***	0.128***	0.077***	0.027***	0.017***
	(0.003)	(0.013)	(0.008)	(0.004)	(0.004)
Change in exp. growth	0.102***	0.194***	0.128***	0.055***	0.036
	(0.017)	(0.058)	(0.029)	(0.014)	(0.057)
Change in exp. amount	0.190***	0.404***	0.319***	0.155***	0.012
	(0.045)	(0.125)	(0.072)	(0.050)	(0.152)
Alt. 2: moving to a home with at least one more main room					
Change in likelihood	0.041***	0.109***	0.061***	0.018***	0.011***
	(0.003)	(0.012)	(0.007)	(0.004)	(0.003)
Change in exp. growth	0.072***	0.149***	0.101***	0.031**	0.007
	(0.018)	(0.053)	(0.035)	(0.013)	(0.056)
Change in exp. amount	0.165***	0.339***	0.287***	0.127***	0.010
	(0.043)	(0.127)	(0.064)	(0.042)	(0.148)
Alt. 3: moving to a more expensive home with at least one more main room					
Change in likelihood	0.042***	0.113***	0.064***	0.018***	0.010***
	(0.003)	(0.013)	(0.008)	(0.004)	(0.003)
Change in exp. growth	0.075***	0.149***	0.103***	0.032***	0.008
	(0.017)	(0.053)	(0.028)	(0.012)	(0.055)
Change in exp. amount	0.155***	0.339***	0.276***	0.109***	0.008
	(0.042)	(0.127)	(0.064)	(0.039)	(0.148)

Notes: Change in likelihood refers to the estimates of β_1 in equation (12). Change in exp. growth refers to the estimates of β_1 in equation (13). Change in exp. amount refers to the estimates of β_1 in equation (14).

C Numerical Solution Methods

I use a two-step numerical procedure to solve the stochastic equilibrium of the model. In the first step, I solve the value functions indexed by j over a fixed-grid state space characterized by (h, b, a, y). I choose 20 grids for h, 18 grids for b, and 8 grids for a. For the stochastic income component, z, I use the Tauchen (1986) method to discretize an AR(1) process to 5 states. The Tauchen method chooses grid points and computes the corresponding transitional probability matrix. The following backward-induction algorithm is used to solve the value functions (step 1):

1. The value function of the last period, V_J, is determined by the bequest function.
2. For a given state (j, h, b, a, y), I compute $V_j^R(h, b, a, y)$ and $V_j^N(h, b, a, y)$ separately. To obtain $V_j^R(h, b, a, y)$, I construct a choice set $\left\{h_R^{'}(h, b, a, y), b_R^{'}(h, b, a, y), a_R^{'}(h, b, a, y), c_R(h, b, a, y)\right\}$ that takes into account all constraints and may vary across states.
3. I then compute the value of the objective function for each choice. To compute the continuation value, I use the linear interpolation if the choice is not one of the grid points.
4. I set $V_j^R(h, b, a, y)$ to the maximum value of the objective function after evaluating all choices.
5. A similar procedure is used to obtain $V_j^N(h, b, a, y)$. Then, the value function for age j is set to $V_j(h, b, a, y) = \max\{V_j^R(h, b, a, y), V_j^N(h, b, a, y)\}$.

In the second step, given V_j's obtained in the first step and a realized state (j, h, b, a, y), I solve the optimal choices, $(h_R^{'}, b_R^{'}, a_R^{'}, c_R)$ and $(h_N^{'}, a_N^{'}, c_N)$, over a finer choice set that has four times as many as the choices for each variable. The optimization algorithm is run similarly as in 2-5 above. This procedure allows me to find the solution more accurately.

To obtain the impact responses to a permanent aggregate shock, I first solve the set of value functions with the realization of the new aggregate state (i.e., step 1). I then set individual-specific states at the beginning of the shock period to those under the original stochastic equilibrium, and solve the optimal choices with the realization of the new aggregate state and the value functions obtained in step 1.

D A Canonical Model with One Type of Housing Investment

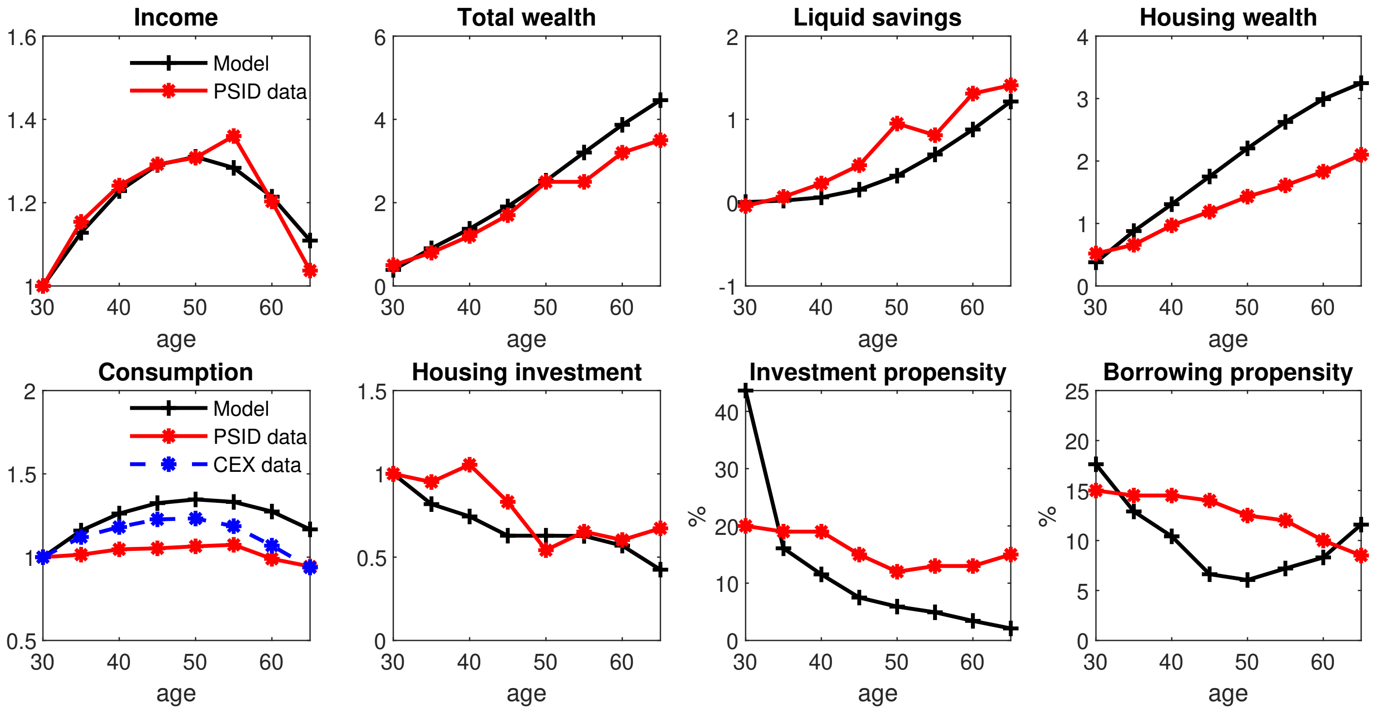
This section calibrates a life-cycle model that is identical to the model in Section 4, except that there is no distinction between home upgrading and home improvements. Specifically, households pay a transaction cost if the new home size (after an investment) relative to the current home size exceeds a certain threshold. The transaction cost is set to the middle point of the transaction cost of upgrading and of improvement, i.e., 0.015. The threshold is calibrated to match the annual investment rate (the frequency of upgrading or making an improvement), which is 12%.

Figure D1 shows key life-cycle profiles of the average household simulated from the model compared to household survey data. The model matches well these profiles in the data, with the exception of the investment propensity. The model implies a much higher investment rate for young homeowners and a much lower investment rate for old households. Changing the parameters to dampen the investment rate for the young would result in even lower investment rates for the old, and vice versa. The model in Section 4, in contrast, imposes differential investment parameters for home upgrading, which helps to limit young households' investment frequency.

Figure D2 plots the impact responses of borrowing and spending to each of the shocks in Section 7. These responses are similar to those in Figures 4 to 6, indicating that the model with two investment types captures the predictions in the canonical model about the overall spending and borrowing responses.

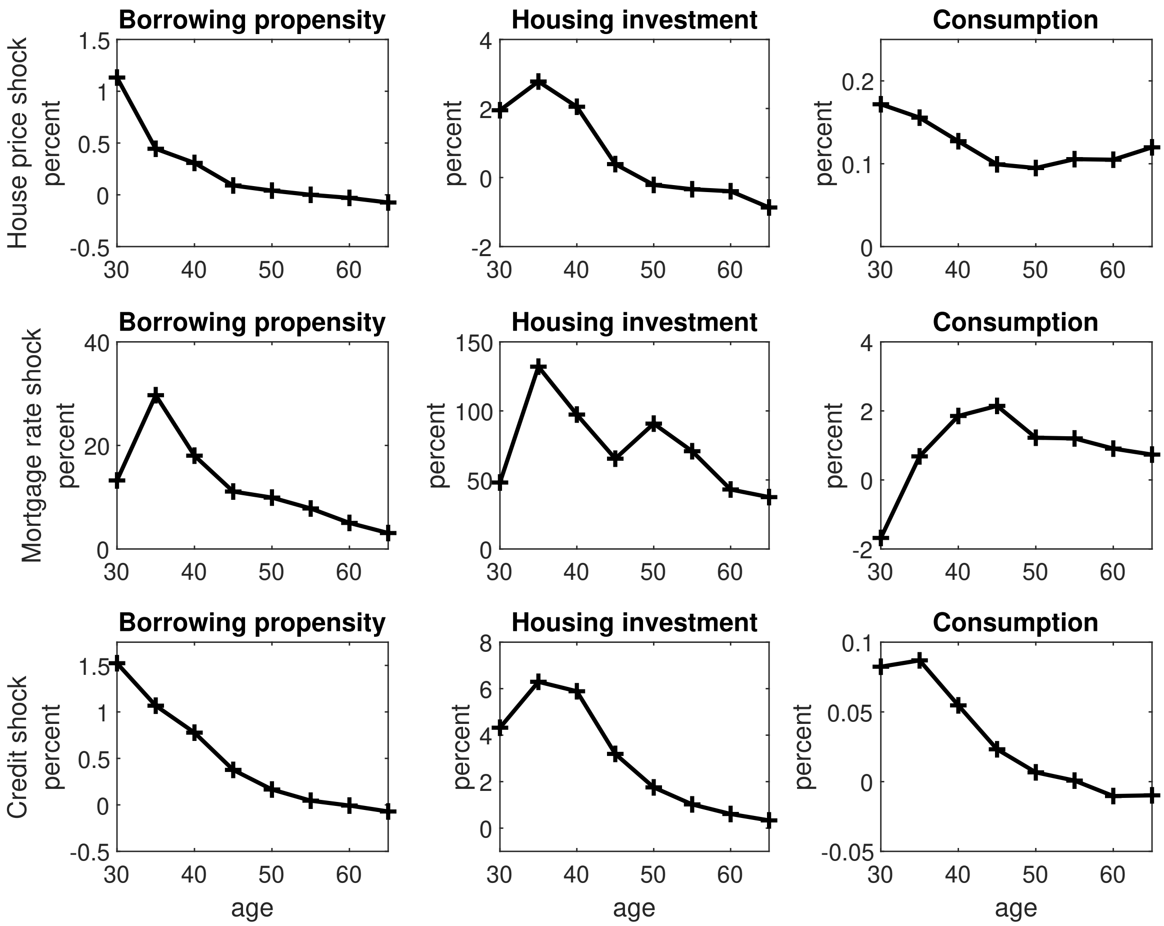
To summarize, it is hard to match the investment aspect of the canonical model directly with microdata, because different types of investment do exist, with moving and improvements most commonly seen. Previous studies have used statistics about moving to calibrate the investment parameters, but this approach leaves home improvements unexplained. The model in Section 4 adds realism to the canonical life-cycle framework. It also shows that, although home improvements account for an important share of housing investment and are performed frequently, they are not the main component that responds to shocks (see Section 6.2 for the mechanisms). Moreover, I show that the prediction of my model about borrowing, consumption, and overall housing investment are consistent with the canonical life-cycle model.

Figure D1: Life-cycle profiles: Canonical model and microdata



Notes: Simulations are from the model with one investment type. See notes in Figure 2 for detailed variable description.

Figure D2: Impact responses in the canonical model



Notes: Simulations from the model with one investment type. The size of each shock is the same as in Figures 4 to 6.

E Impulse Responses: Life-Cycle Model and DSGE Model

This section presents the impulse responses of key aggregate variables from the structural life-cycle model of Section 4 and compares them with the two-agent DSGE model of Iacoviello and Neri (2010) (henceforth the IN model). I choose the IN model for comparison because it embeds a housing sector and constrained households into the mainstream DSGE framework (see Christiano et al. (2005) and Smets and Wouters (2007)). The IN model fits the U.S. data quantitatively well and has become the workhorse DSGE model for studying the interaction between housing and the macroeconomy. The objective is to see whether the structural life-cycle model can generate aggregate responses consistent with DSGE models featuring housing and household heterogeneity.

Both models share a common transmission channel: Shocks to the housing market affect some households' borrowing capacity and hence their spending. On the other hand, the key difference is that the life-cycle model is partial-equilibrium and does not incorporate (i) the responses of other sectors to a shock, (ii) the redistribution between constrained and unconstrained households, and (iii) the feedback effects of (i) and (ii) on household expenditures. For example, fluctuations in house prices and mortgage rates are exogenous in the life-cycle model but are endogenously determined in the IN model with feedback effects on each other. Despite this difference, however, as I show below, the two models generate qualitatively similar responses. In particular, the responses of young households in the life-cycle model are similar to the constrained households in the IN model.

Credit supply shocks. Figure E1 shows the impulse responses of aggregate borrowing, consumption and residential investment to a 1% credit supply shock in the IN model (left) and in the life-cycle model (right).[32] This shock has the same interpretation across the two models, making the comparison straightforward. An expansion in credit increases household borrowing, consumption and residential investment in both models. In particular, consumption and residential investment of young/constrained households are more responsive than old/unconstrained households.

Mortgage rate shocks. Since the mortgage rate is endogenously determined in the IN model, to facilitate the comparison, I consider a monetary policy shock in the IN model that lowers the

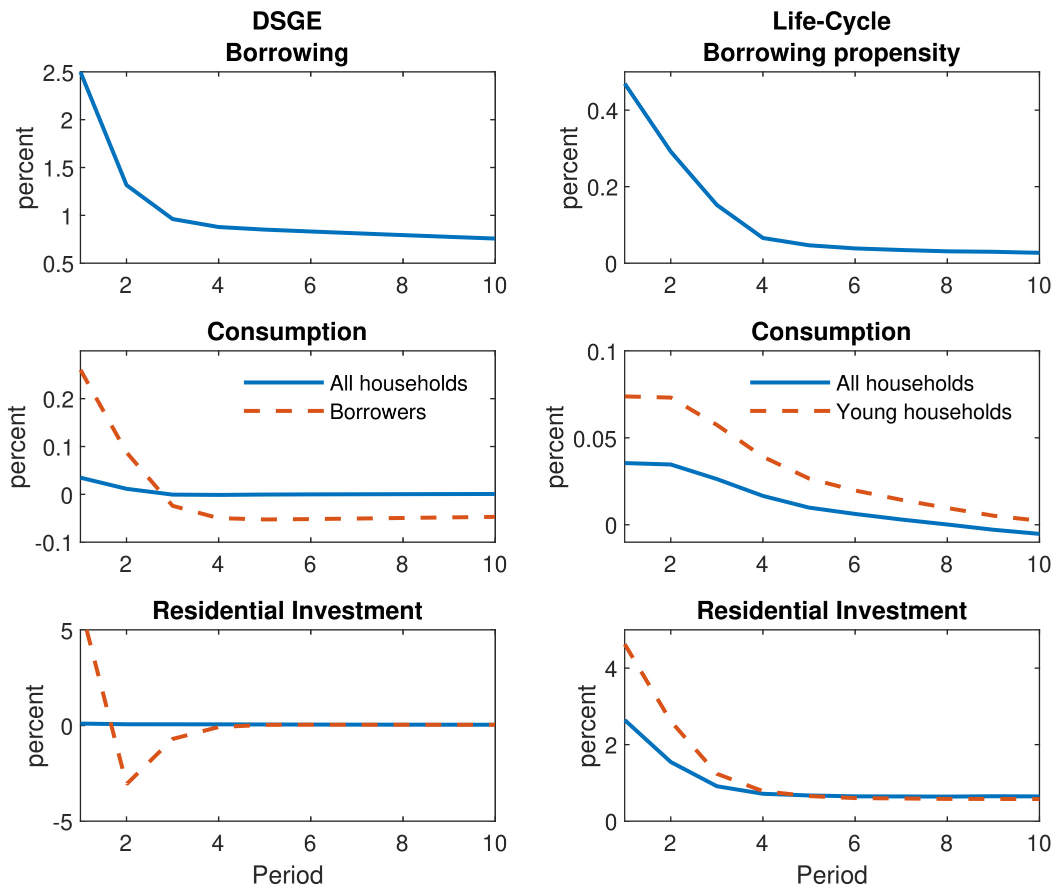
[32]The quarterly impulse responses from the IN model are averaged to obtain annual responses for the comparison with the life-cycle models. The residential investment responses of borrowers from the IN model are scaled by their labor income share to make the magnitudes of aggregate residential investment visible. The responses of residential investment in the life-cycle model refer to the responses of home upgrading and home improvements, consistent with the impact responses of housing investment in Section 7.

mortgage rate by 1 pp in the first year. Figure E2 shows the impulse responses from the two models. A lower mortgage rate stimulates borrowing, consumption and residential investment in both models, especially for young/constrained households. One difference is that consumption increases more in the IN model, whereas residential investment increases more in the life-cycle model. This is driven by the endogenous response of house prices in the IN model. As the mortgage rate falls, house prices increase, stimulating consumption (due to the collateral effect and the substitution effect), while dampening housing investment to some extent.

House price shocks. Since house prices are endogenously determined in the IN model, to facilitate the comparison, I consider a housing technology (supply) shock in the IN model that raises the real house price by 1% in the first year.[33] Figure E3 shows the impulse responses from the two models. Higher house prices stimulate household borrowing and consumption, especially for young/constrained households. Residential investment falls in the IN model, mainly because unconstrained households cut back on such spending, although constrained households see a rise immediately after the shock. Aggregate housing investment in the life-cycle model shows almost no change, but it increases for young households after the shock, which can be explained by life-cycle demand for housing and the collateral effect.

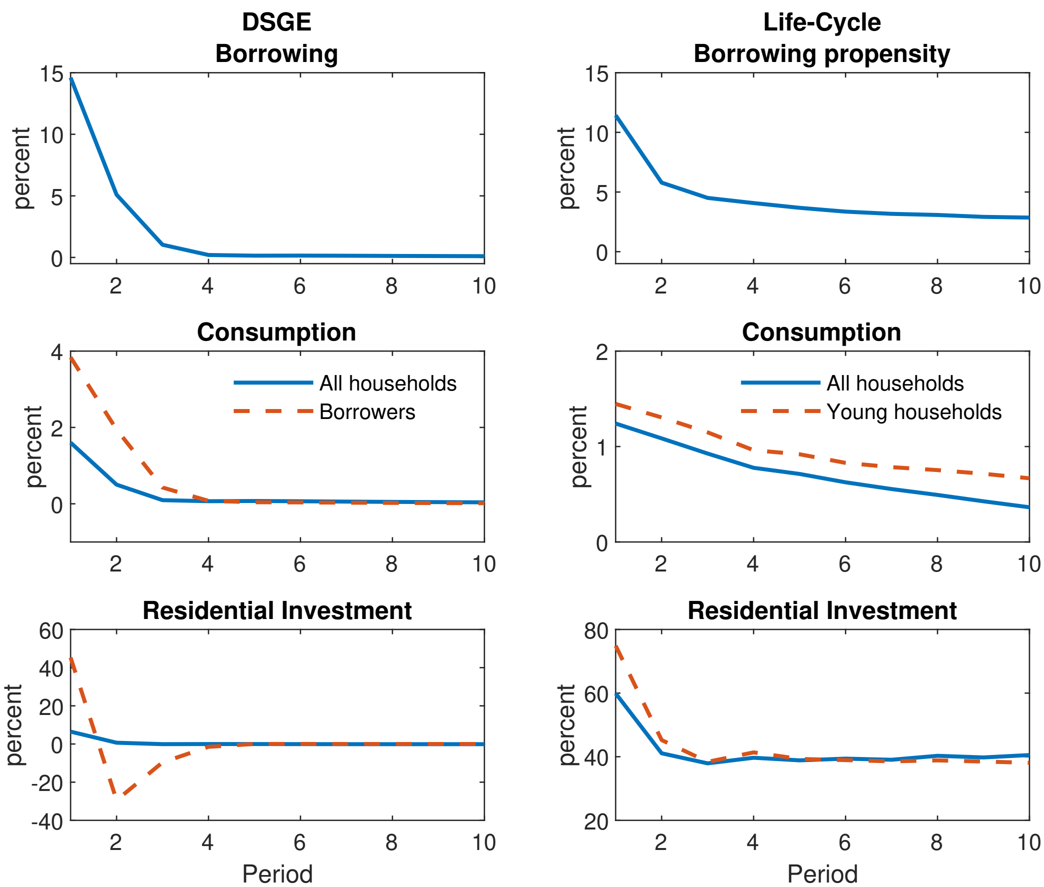
[33] House price fluctuations can also be driven by housing preference (demand) shocks in the IN model. A positive housing demand shock raises house prices, borrowing, consumption and residential investment, especially for constrained households.

Figure E1: Impulse responses to a credit supply shock



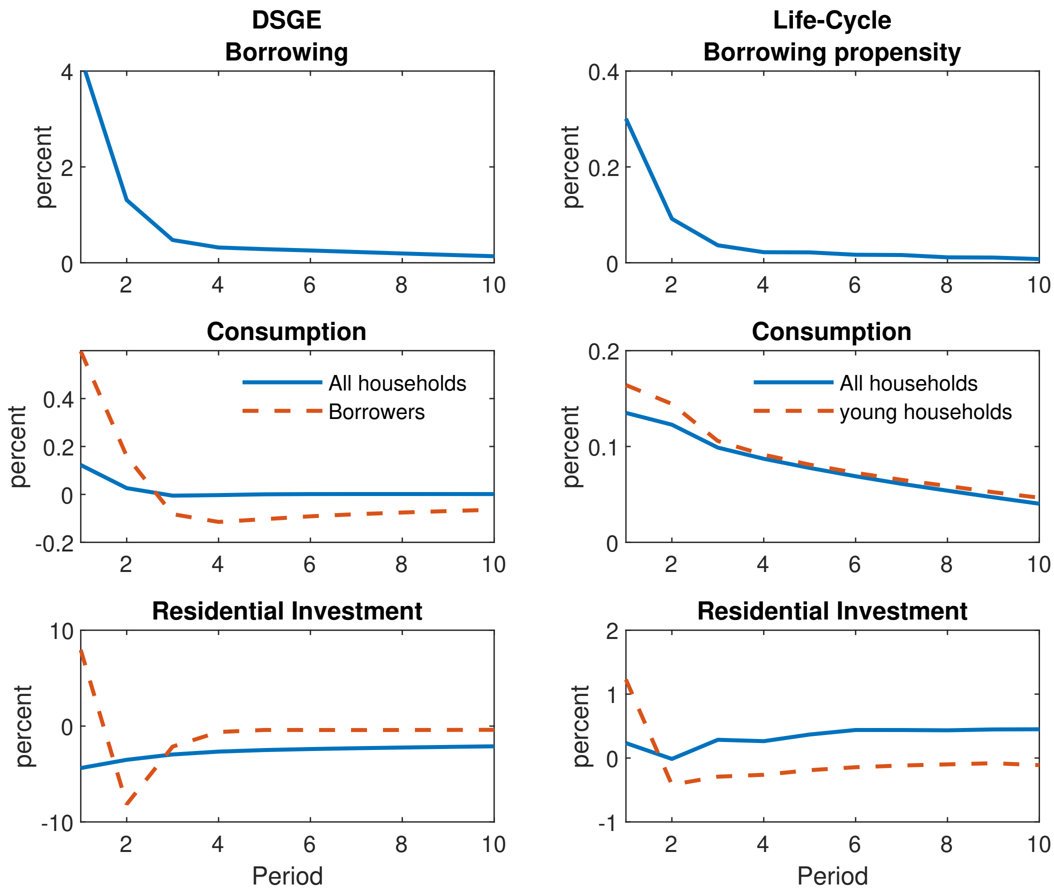
Notes: The left column shows the impulse responses to a 1% credit supply shock in the DSGE model of Iacoviello and Neri (2010). The right column shows the impulse responses to a 1% credit supply shock in the life-cycle model of Section 4.

Figure E2: Impulse responses to a mortgage rate shock



Notes: The left column shows the impulse responses to a monetary policy shock that lowers the mortgage rate by 1 pp in the first year in the DSGE model of Iacoviello and Neri (2010). The right column shows the impulse responses to a 1 pp reduction in the mortgage rate in the life-cycle model of Section 4.

Figure E3: Impulse responses to a house price shock



Notes: The left column shows the impulse responses to a housing technology shock that raises the real house price by 1% in the first year in the DSGE model of Iacoviello and Neri (2010). The right column shows the impulse responses to a 1% increase in the house price in the life-cycle model of Section 4.

F Accounting for House Price Changes Driven by Demand Shocks

This section complements the analysis in Section 7 by allowing mortgage rate and credit supply shocks to affect house prices. As a consequence, consumption and residential investment respond directly to a change in the mortgage rate or the credit condition, and indirectly through the change in the house price.

To calibrate the change in house prices to these shock, I use MSA-level data and the empirical strategies in Section 3 to estimate the causal responses. Specifically, for the mortgage rate shock, I estimate a 2SLS specification as in question (5) fitting the log annual change in the MSA-level house price. The regression using pre-crisis data gives $\hat{\beta}_1 = 0.16$ (with t-statistics of 6.39). This means that a 1 pp decline in the mortgage rate increases the house price by 16%. For the credit supply shock, I estimate a 2SLS specification as in equation (6) with the log annual change in MSA-level house prices as the dependent variable, which gives $\hat{\beta}_1 = 0.14$ (with t-statistics of 1.98), implying that a 1% increase in credit raises house prices by 0.14%.

Figure F1 shows the responses to a 1 pp decline in the mortgage rate and a simultaneous increase in house prices of 16%. These responses are similar to Figure 5 with three noticeable differences: (i) the higher borrowing propensity due to increased home equity, especially for young homeowners, (ii) slightly lower housing investment, especially for middle-age and old homeowners on home improvements, due to the higher cost of investing, and (iii) higher consumption due to increased home equity for all homeowners.

Figure F2 shows the responses to a 1% increase in the collateral value and a simultaneous increase in house prices of 0.14%. These responses are similar to those in Figure 6 with two noticeable differences. One is lower housing investment, especially for middle-age and old homeowners on home improvements, because of the higher cost of investing. The other is higher consumption for young homeowners due to increased home equity. Overall, these responses are similar to those presented in Sections 7.2 and 7.3 and the differences mainly reflect the responses to house price changes, as in Section 7.1.

Figure F1: Responses to mortgage rate shocks that also trigger increases in house prices

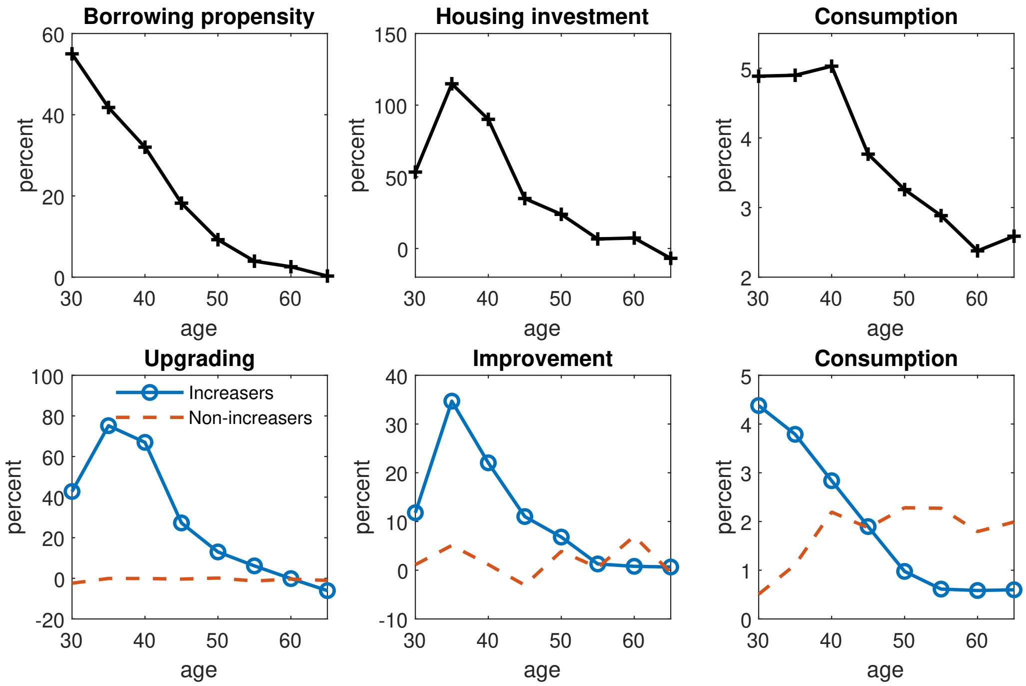
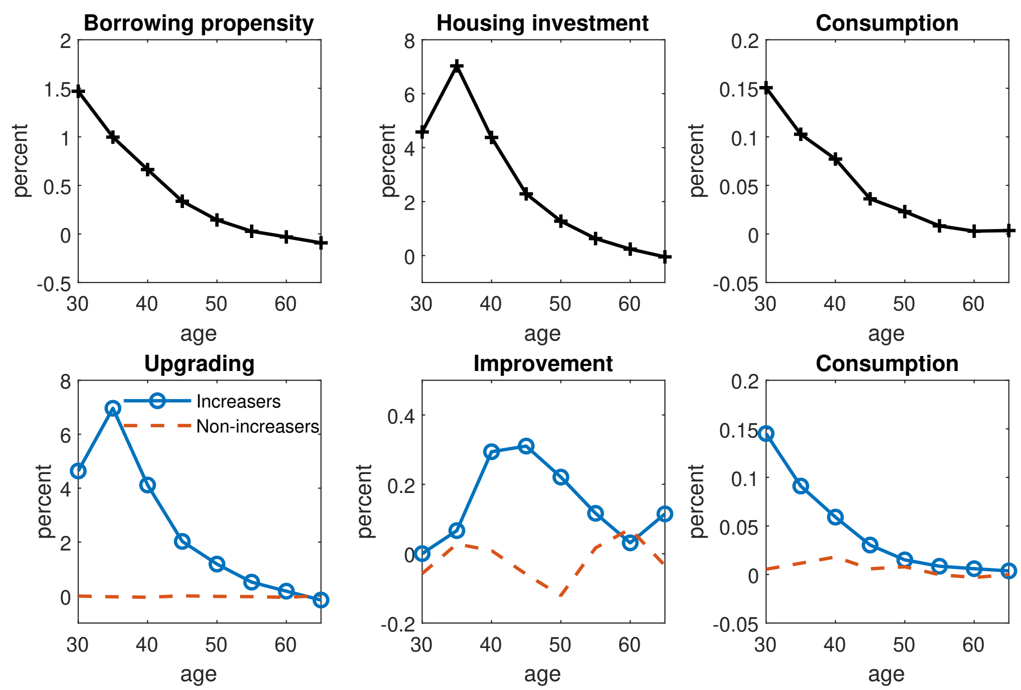


Figure F2: Responses to credit supply shocks that also trigger increases in house prices



G The Role of Expectations

The recent literature has stressed the role of beliefs about future house prices in driving household spending decisions (see Kaplan et al. (2020) and Bailey et al. (2019)). Intuitively, when households expect future house prices to grow, owning a home becomes more attractive, which stimulates housing investment. This optimism may be triggered by current house price increases. In this section, I extend the model to incorporate the expectations channel.

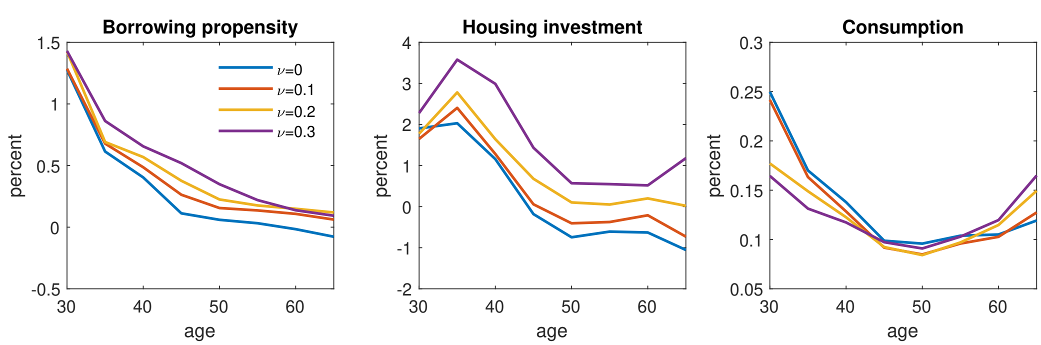
Suppose a shock in period t increases the house price relative to the steady state, i.e., $\frac{p_t - p_{t-1}}{p_{t-1}} \equiv g_p > 0$. In Section 7.1, households expect future house prices to stay at the current level, i.e., $\mathbb{E}_t p_{t+k} = p_t$, $k = 1, 2, ...$. To model the expectations channel, I assume that expected future house prices evolve according to

$$\mathbb{E}_t p_{t+k} = (1 + g_p \nu^k) \mathbb{E}_t p_{t+k-1}, \quad k = 1, 2, ..., \tag{15}$$

where ν is the parameter governing the extent to which households form their expectations based on current house price growth. $\nu = 0$ corresponds to a "flat" path of expected future house prices as in Section 7.1, whereas $\nu = 1$ corresponds to the case of exponential growth.

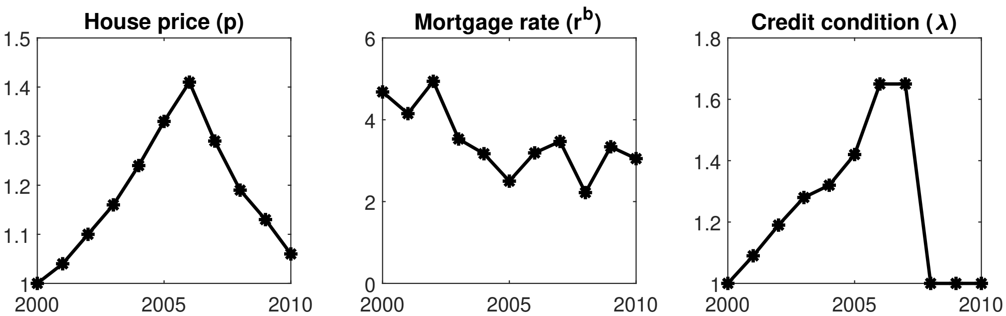
Figure G1 shows the responses for different values of ν. Compared to $\nu = 0$ (Section 7.1), allowing a rising path of expected house prices increases the borrowing propensity and housing investment. The average consumption response, in contrast, stays roughly the same, because the cut back of young households is compensated by higher consumption of old households. The analysis confirms that expected growth in house prices stimulates housing investment. As long as ν is relatively small, the responses are similar to the baseline expectation scenario.

Figure G1: Responses to a 1% increase in house price



H Additional Figures

Figure H1: Time series fed into the model



Notes: The real house price is constructed by deflating the FHFA house price index by the CPI. The real mortgage rate is constructed by subtracting the inflation from the average 30-year fixed mortgage rate. The credit condition from 2000 to 2007 is measured by the change in the single-family conforming loan limit.