CHAPTER 12

Housing, Finance, and the Macroeconomy

Morris A. Davis*, Stijn Van Nieuwerburgh†
*Department of Finance and Economics, Rutgers Business School, Rutgers University, Newark, NJ, USA
†Department of Finance, Stern School of Business, New York University, NY, USA

Contents

Handbook of Regional and Urban Economics, Volume 5B
ISSN 1574-0080, http://dx.doi.org/10.1016/B978-0-444-59531-7.00012-0

Abstract

In this chapter, we review and discuss the large body of research that has developed over the past 10-plus years that explores the interconnection of macroeconomics, finance, and housing. We focus on three major topics—housing and the business cycle, housing and portfolio choice, and housing and asset returns—and then review the recent literature that studies housing and the macroeconomy during the great housing boom and bust of 2000–2010. Our emphasis is on calibrated models that can be compared with data. In each section, we discuss the important questions, the typical set of tools used, and the insights that result from influential articles. Although great progress has been made in understanding the impact of housing outcomes on macroeconomic aggregates and vice versa, work remains. For example, economists recognize the importance of changing credit-market conditions in amplifying the volatility of house prices, but cannot explain the timing of these changes. At the end of the chapter, we discuss a new literature that assesses the macroeconomic effects and welfare implications of housing policies.

Keywords

Housing, Housing and macroeconomics, Housing and portfolio choice, Housing and asset pricing, Real estate boom and bust, Financial crisis, Housing crisis, Housing cycle, Real estate and business cycle

JEL Classification Codes

R00, R20, R31, D14, D31, D91, E21, E32, E44, E69

12.1. INTRODUCTION

Like disco and bell-bottomed pants, the study of housing has become fashionable among economists again. The tremendous boom (2000–2006) and bust (2006–2010) of housing markets and the subsequent financial crisis precipitated by an unforeseen surge in mortgage defaults have left many economists asking: What happened, why did it happen, and will it happen again? With this context in mind, the purpose of this chapter is to document what has been studied so far, what we think as economists we understand, and what we think we do not understand. Prior to the dramatic events of the past decade, economists investigated the interplay of housing and the macroeconomy for the obvious reasons that housing accounts for a large percentage of wealth and investment in housing accounts for a large fraction of overall economic activity. In addition, housing has some unique features that distinguish it from other assets. Specifically, (a) housing is infrequently traded and trades are subject to search frictions and large transaction costs, (b) the dividends that housing provide are unique to housing in the sense that only a structure can provide shelter and in the case of owner occupancy are hard to quantify, (c) the value of the asset class is enormous, and (d) the federal government interferes significantly in housing and mortgage markets. The sheer size of the housing and mortgage markets suggests that these peculiarities might affect macroeconomic outcomes and all other asset prices.

Many excellent articles have been produced on these topics, and it is impossible to cover all ground in one chapter. The articles and topics we write about almost all focus on the data and experiences in the United States and reflect our tastes in research. Our goal is to document the methods and explain the results of recent quantitative, mostly calibrated models produced by researchers in the fields of macroeconomics and finance. To this end, the chapter has eight sections. We start by highlighting key facts about housing in the United States. These facts typically serve as calibration or estimation targets; or, in some cases, they are the focus of specific research questions. Then, in order, we cover the topics of business cycles and housing; housing and portfolio choice in partial equilibrium models; and housing and asset prices. After this, we review a recent set of articles that aim to jointly explain business cycle facts, life-cycle portfolio facts, and equilibrium asset prices during the great housing boom and bust of the 2000–2010 decade. We distinguish between articles that fix house prices or take them as given and articles where house prices are determined endogenously inside the model. The penultimate section of the chapter describes the results of a small set of articles studying the impact and implications of US housing policy, with specific emphasis on the preferential tax treatment of owner-occupied housing and recent foreclosure relief efforts.

While we include quite a lot in this chapter, we do not cover everything. For example, we omit discussion of search frictions in housing markets[1]; the relationship of housing and long-run demographic projections and the impact of housing on the long-run growth rates of output and consumption[2]; and articles with results that rely on agents having different expectations about the path of house prices.[3] We also omit discussion of the active empirical literature that investigates the causes and consequences of the subprime mortgage crisis using techniques from applied microeconomics[4] and articles investigating the role of mortgage finance in amplifying the housing boom and bust.[5] Finally, this chapter is largely focused on the US experience. Home ownership rates and mortgage financing patterns differ across countries, and more research is needed to explain why these differences occur and how they may affect macroeconomic outcomes.[6]

[1] Several macroeconomists have contributed to this area. A small set of examples include Albrecht et al. (2007, 2010), Head et al. (2011), Wong and Wright (2011), Head and Lloyd-Ellis (2012), He et al. (2013), Hedlund (2014), Landvoigt et al. (2013a), Ngai and Tenreyro (2014), and Piazzesi et al. (2013).

[2] See, for example, Mankiw and Weil (1989) and Davis et al. (2014).

[3] See, for example, Piazzesi and Schneider (2009) and Burnside et al. (2011).

[4] Examples are Mian and Sufi (2009, 2011, 2012, 2014), Mian et al. (2010, 2013, 2014), and the references therein.

[5] See, for example, Keys et al. (2009, 2010, 2012), Piskorski et al. (2010), and the review article by Keys et al. (2013).

[6] For articles describing experiences of OECD countries, see Catte et al. (2004) and Hirata et al. (2013). Aruoba et al. (2014) note that source data on house prices for many countries are simply unavailable prior to 1990, hindering empirical analysis.

12.2. STYLIZED FACTS

12.2.1 Levels of aggregates

In this section, we highlight a set of stylized facts from US data that models of housing and the macroeconomy appropriate to explain outcomes in the United States should match. We begin by defining a set of first moments, or level variables, that are key to identifying parameters related to preferences and technology. Figure 12.1 shows the ratios of aggregate housing wealth to GDP and housing structures to GDP. Housing wealth is defined as the sum of housing structures and the market value of land, so the gap between the two series plotted in Figure 12.1 is equal to the ratio of the market value of land to GDP. These data are taken from Davis and Heathcote (2007), but similar data can be constructed from the Federal Reserve Board's Flow of Funds Accounts tables.[7] According to these data, over the 1975–2013 period the average ratio of housing wealth to GDP is

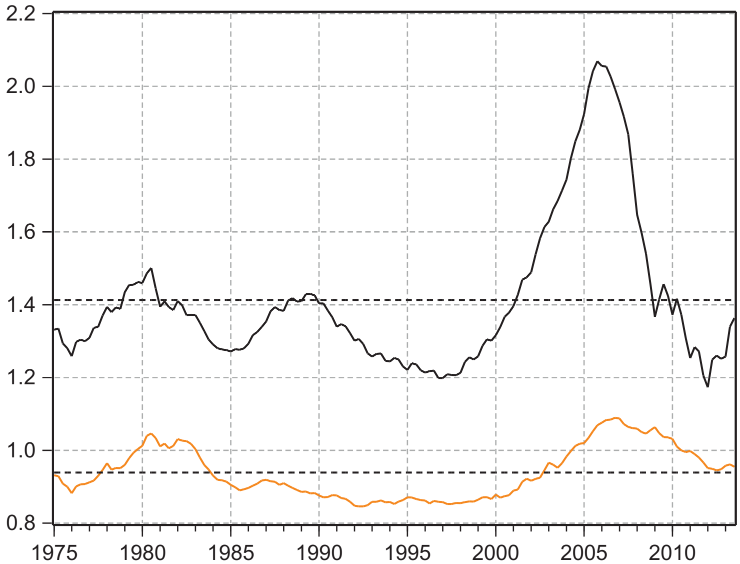


Figure 12.1 The figure plots the nominal value of housing (black), inclusive of land and structures, and the nominal value of structures (orange (light gray in the print version)), both relative to nominal GDP from the first quarter of 1975 to the third quarter of 2013. The housing and structures data are from Davis and Heathcote (2007) and are available for downloading at http://www.lincolninst.edu/subcenters/land-values/price-and-quantity.asp and the nominal GDP data are from the National Income and Product Accounts.

[7] The data from Davis and Heathcote (2007) enforce that the capital gains from housing line up with changes in the Case–Shiller–Weiss price indices. This is not the case with the Flow of Funds data. The Davis and Heathcote (2007) data are available for downloading at http://www.lincolninst.edu/subcenters/land-values/price-and-quantity.asp.

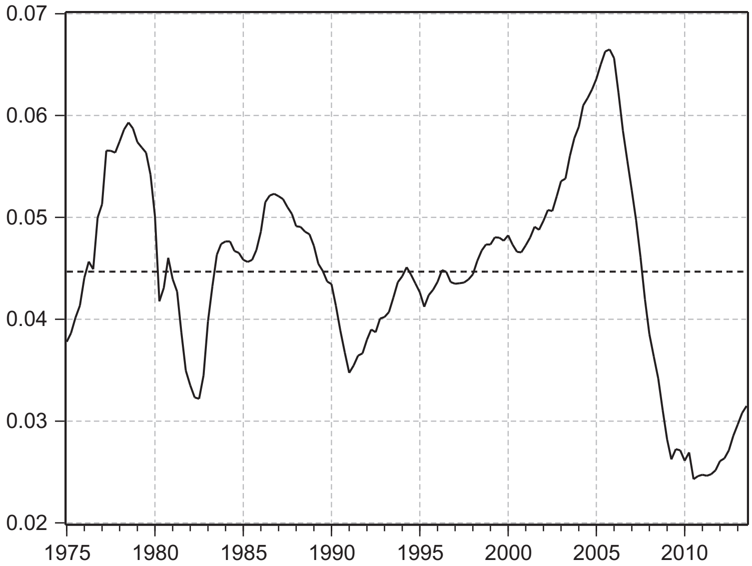


Figure 12.2 This figure plots the ratio of residential investment to GDP from the first quarter of 1975 to third quarter of 2013. These data are derived from Table 1.1.5 of the National Income and Product Accounts.

about 1.4 and the average ratio of the replacement cost of housing structures to GDP is 0.94. On average, the market value of land is roughly 45% of GDP, but the land share is volatile: At the height of the housing boom, the value of land was equal to 100% of GDP.

Figure 12.2 shows the ratio of residential investment to GDP over the same time period.[8] The average value of this ratio is 4.5%. In most models, knowledge of the average value of the ratio of structures to GDP and residential investment to GDP is sufficient to pin down the implied rate of depreciation on residential structures. To see this, note that a capital accumulation equation for the real stock of structures implies

$$K_{t+1} = K_t(1-\delta_K) + I_t.$$

If we assume a zero inflation rate and no trend to the relative price of structures, we can divide both sides by GDP at time t, Y_t, to uncover

$$\left(\frac{K_{t+1}}{Y_{t+1}}\right)\left(\frac{Y_{t+1}}{Y_t}\right) = \left(\frac{K_t}{Y_t}\right)(1-\delta_K) + \frac{I_t}{Y_t}.$$

[8] These data are derived from National Income and Product Accounts (NIPA) Table 1.1.5. Residential investment in the NIPA includes payments of brokers' commissions on the sale of homes. Although we do not do it here, authors occasionally remove these commissions from residential investment and adjust the estimate of the stock of structures accordingly.

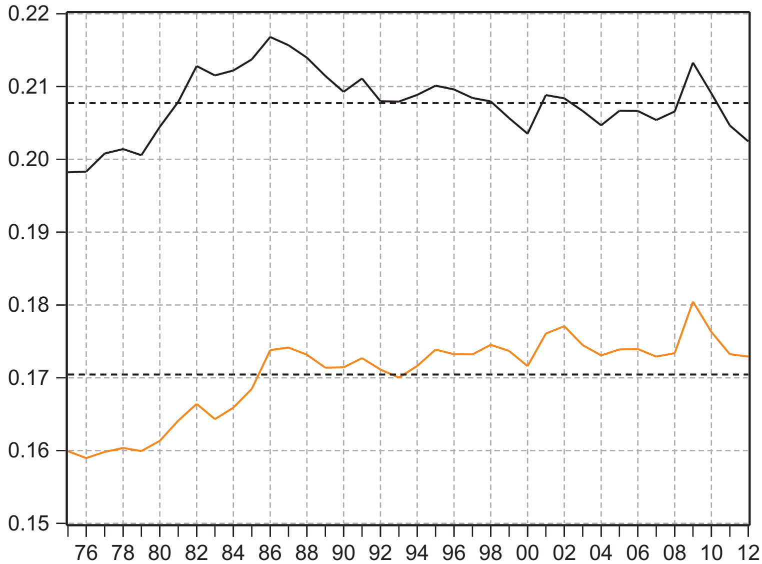


Figure 12.3 This figure plots the ratios of total spending on housing and utilities (black line) and housing (orange (light gray in the print version) line) to consumption expenditures on nondurable goods and services, from the first quarter of 1975 to third quarter of 2013. These data are derived from Table 2.4.5 of the National Income and Product Accounts.

Denote the steady-state ratios of structures to GDP, residential investment to GDP, and the growth rate of real GDP ($Y_{t+1}/Y_t - 1$) as K/Y, I/Y, and g_y, respectively. The model-implied rate of depreciation δ_K can be written as

$$g_y + \delta_K = \frac{I/Y}{K/Y}.$$

Taking I/Y as 0.045 and K/Y as 0.95, $g_y + \delta_K$ is 0.047. If we think the growth rate of real GDP inclusive of population growth is 3% per year, then this gives an estimate for δ_K of 1.7%. Most studies use a number in the vicinity of this estimate.

Some other first moments help to pin down parameters related to preferences. Figure 12.3 shows the aggregate ratio of expenditures on housing rents and utilities (black line) and housing rents (orange (light gray in the print version) line) to total consumption expenditures on nondurable goods and services.[9] About 21% of aggregate consumption is accounted for by housing and utilities, 4% by utilities alone, and this percentage has remained constant despite real increases in consumption and rental prices over time. One typical objection to this evidence notes that, on average after 1975, more than 60% of measured aggregate spending on housing rents and utilities is imputed as rents

[9] These data are derived from NIPA Table 2.4.5.

accruing to homeowners. Davis and Ortalo-Magné (2011) use microdata on renting households from the 1980, 1990, and 2000 Decennial Censuses of Housing to show that, across metropolitan areas and over time, the median ratio for renters of rental expenditures and utilities to household income is nearly constant at 24%. Although these results are not without controversy, researchers use the combination of evidence from Figure 12.3 and from Davis and Ortalo-Magné (2011) to justify preferences for housing and consumption that deliver constant expenditure shares on housing rents in the absence of borrowing constraints and frictions.

Finally, many researchers use data on price–rent ratios to help calibrate discount factors and to understand expectations about the future growth rate of rents and prices. An example of an estimate of aggregate price–rent ratios taken from Davis et al. (2008) is shown in Figure 12.4.[10] This figure shows a slightly increasing ratio of prices to rents prior to 2000, a massive surge (2000–2006) and collapse in the ratio (2006–2010) during the housing boom and bust, and a return to trend after 2010. Of course, rents must be imputed to homeowners and therefore the reported level can vary from study to study depending on the imputation procedure. Therefore, Figure 12.5 plots five additional

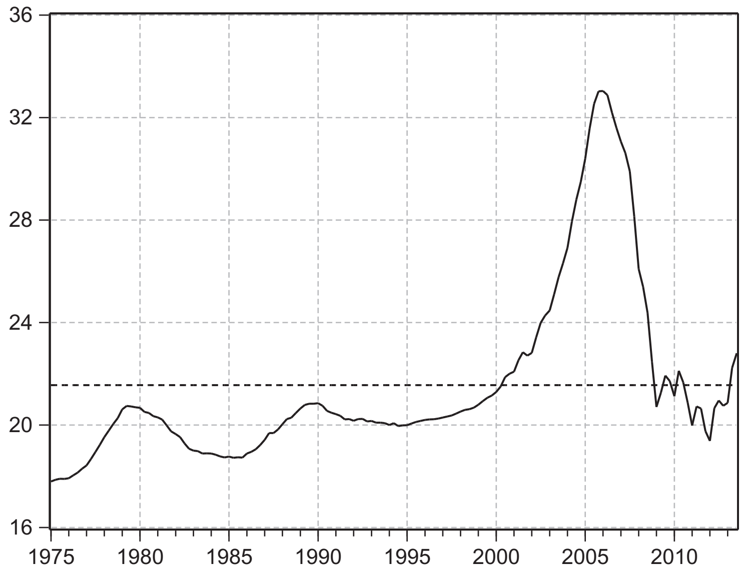


Figure 12.4 This figure plots the price–rent ratio for homeowners as derived by Davis et al. (2008) from the first quarter of 1975 to third quarter of 2013. These data are available for downloading at http://www.lincolninst.edu/subcenters/land-values/rent-price-ratio.asp.

[10] These data are available at http://www.lincolninst.edu/subcenters/land-values/rent-price-ratio.asp.

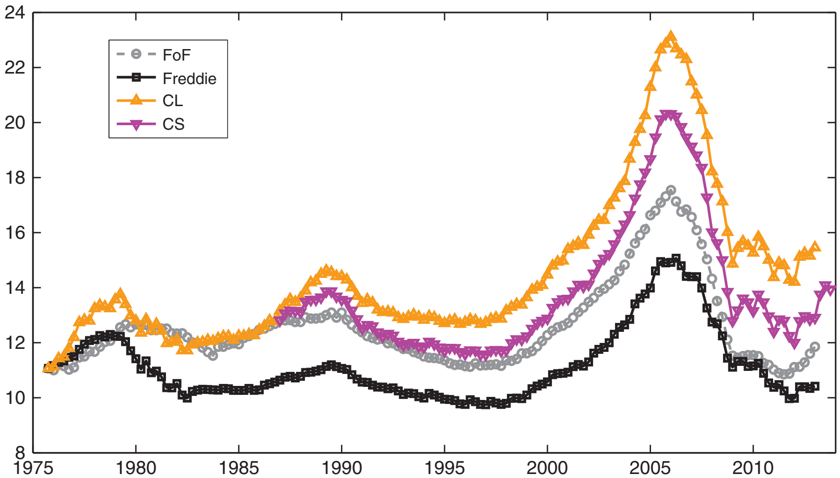


Figure 12.5 The figure compares five estimates of price–rent ratios from the fourth quarter of 1975 to the fourth quarter of 2013. "Flow of Funds" is the ratio of residential real estate wealth of the household sector from the Flow of Funds to aggregate housing services consumption from the National Income and Product Accounts. "Freddie Mac" is the ratio of the Freddie Mac Conventional Mortgage Home Price Index for purchases to the Bureau of Labor Statistics' price index of shelter (which measures rent of renters and imputed rent of owners). "CoreLogic" is the ratio of the CoreLogic national house price index to the Bureau of Labor Statistics's price index of shelter. "Case–Shiller" is the ratio of the Case–Shiller national house price index to the Bureau of Labor Statistics's price index of shelter. The data are quarterly from the fourth quarter of 1975 or whenever first available until the fourth quarter of 2013.

estimates of the national price–rent ratio. The first one (circle markers) uses the ratio of aggregate housing wealth from the Flow of Funds divided by aggregate housing consumption from NIPA, and the next three series combine three different repeat-sales house price indices (the Freddie Mac index, squares; the CoreLogic index, up triangles; and the national Case–Shiller House Price Index, down triangles) with the shelter component of the Consumer Price Index of the Bureau of Labor Statistics.[11] All series display a similar pattern. The Flow of Funds ("FoF" in Figure 12.5) series and the Freddie Mac series ("Freddie" in Figure 12.5) display the least overall volatility, while the Case–Shiller series ("CS" in Figure 12.5) and the CoreLogic series ("CL" in Figure 12.5) display the largest boom and bust.

[11] Since both price and rental series are indices, we set the first observation (fourth quarter of 1975) of the price–rent ratio for each of these three series equal to the corresponding quarter's observation for the Flow of Funds series. Since the Case–Shiller series only starts in the first quarter of 1987, we initialize this series at the first quarter of 1987 value for the Flow of Funds series. For an in-depth discussion of the properties of house price indices and repeat-sales methodology, see Ghysels et al. (2013).

12.2.2 Cross-sectional facts

Understanding differences across households with respect to choices and outcomes is often a goal of researchers in macroeconomics and finance. In this section, we discuss differences and disparities across households as they pertain to housing-related variables. Perhaps the most important dimension of heterogeneity in models of housing involves renting and owning. Figure 12.6 shows the path of the home ownership rate since 1975. In lockstep with the changes to house prices over the 2000–2010 period, the home ownership rate displays a pronounced boom and bust: a four percentage point increase and a four percentage point decline. Each percentage point represents the experiences of approximately one million households.[12]

A second source of heterogeneity involves saving and lending: some households borrow to finance a home purchase and other households, some abroad, lend those funds. The aggregate quantity of US mortgage debt has increased significantly over time. The value of mortgages was equal to 20% of housing wealth in the 1950s, 30% by the mid-1970s, and 40% by the mid-1990s. Aggregate "loan to value" ratios remained constant during the housing boom. After house prices crashed, mortgage debt relative to housing wealth achieved its peak value of 62% in 2009. Household deleveraging (including defaults) alongside recovering property values has pushed the mortgage debt to housing wealth ratio back down to 50%. Figure 12.7 also shows the ratio of mortgage debt to

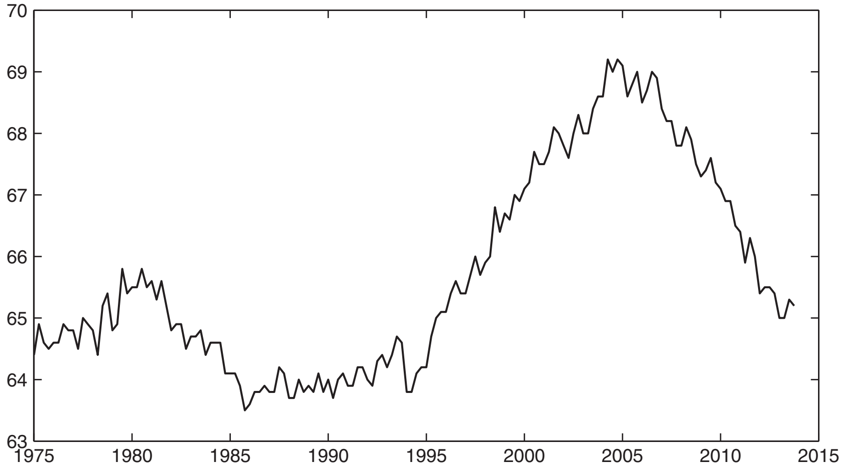


Figure 12.6 The figure plots the quarterly home ownership rate from the first quarter of 1975 to the fourth quarter of 2013. The data are from the US Department of Commerce: Census Bureau (FRED series ID RHORUSQ156N).

[12] As an aside, the home ownership rate increased dramatically between 1940, when it was in the low 40% range, and 1960, when it was in the low 60% range (see Garriga et al., 2014).

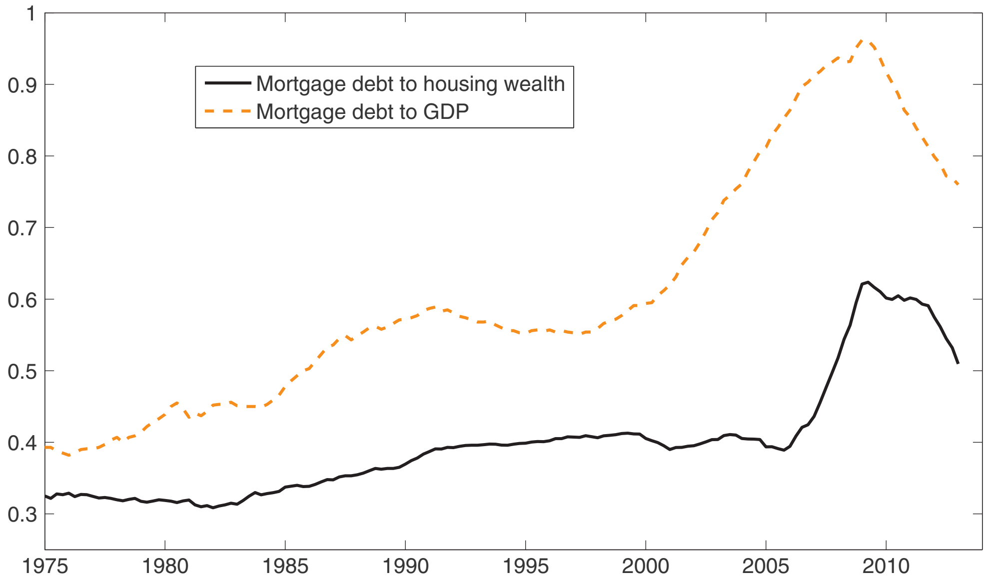


Figure 12.7 The figure plots mortgage debt relative to real estate wealth of the household sector (solid line) and mortgage debt of the household sector relative to GDP (dashed line) in the United States from the first quarter of 1975 to the first quarter of 2013. The data are from the Federal Reserve Board's Flow of Funds Accounts Tables B100.d and B103.d. Household real estate wealth excludes the real estate wealth of nonprofits, but includes the value of rental housing owned by the household sector (listed in Table 103.d but included in private business wealth in Table B100.d). Similarly, household mortgage debt includes the mortgage debt of the nonfinancial noncorporate sector. The GDP data are from the Bureau of Economic Analysis National Income and Products Accounts.

GDP. It tracks the ratio of mortgage debt to household wealth during the housing boom but shows a stronger deleveraging effect during the bust. Over the last 4 years, mortgage debt has fallen from 96% to 76% of GDP.

Next, we document a few important stylized facts about household portfolios using data from the Survey of Consumer Finances (SCF). Figure 12.8 reports the home ownership rate by age for three different waves of the SCF: 2003, 2007, and 2010. In each SCF wave, home ownership rates rise with age until age 50 years and then stay flat until age 80 years. Figure 12.8 also shows that home ownership rates fell at almost every age between 2007 and 2010, indicating that changes in the aggregate home ownership rate between 2007 and 2010 reflect changes across much of the population.

Figure 12.9 shows the average household's net worth, defined as household assets less household liabilities, by age for homeowners and for renters. All data in this figure are in constant 2010 dollars. Clearly, average wealth is much higher for homeowners than for renters. In addition, homeowner wealth profiles have a clear "hump" shape over the life cycle, while wealth for renters is low and relatively constant with age. Combined with

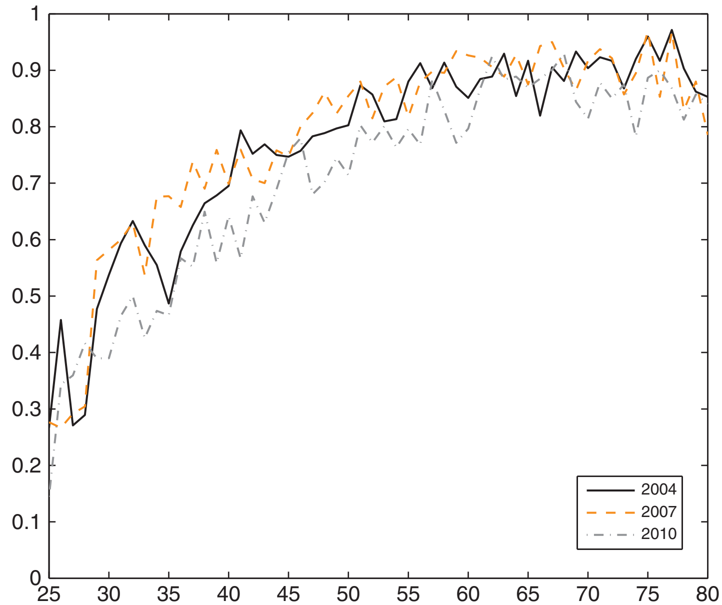


Figure 12.8 The figure plots the home ownership rate by age for the 2003, 2007, and 2010 waves of the Survey of Consumer Finances.

the previous graph, this figure suggests that homeowners decumulate financial wealth but not housing wealth late in life. This graph also suggests that homeowners and renters have quite different life experiences.

Figure 12.10 plots portfolio shares for major classes of assets by age using data from the 2010 SCF. The left panels show data for homeowners and the right panels show the data for renters.[13] The top panels look at the share of housing, stocks, bonds, and retirement assets in total assets.[14] The bottom panels plot home equity, stocks, bonds net of unsecured debt, and retirement assets as a share of net worth.[15] The top-left panel shows that housing wealth accounts for most (90%) of the assets of homeowners early in life. Because most young homeowners take out a substantial amount of mortgage debt, home equity accounts for a somewhat smaller but still very large fraction of net worth (bottom left).

[13] Homeowners are identified as households having positive housing wealth.

[14] Retirement assets are difficult to split into stocks and bonds and so we leave them as a separate category. We include bank accounts with bonds and mutual fund holdings with stocks. The four shares sum to 1; for the calculation of these shares, we disregard the asset categories of vehicles, "other" financial assets, and business wealth.

[15] Bonds are defined as the sum of bonds and bank accounts less credit card debt plus other financial assets less other unsecured debt. Home equity is defined as the sum of the values of "primary housing" and "other housing" less all mortgage debt. Stocks and retirement accounts are defined as before. By construction, the graphed shares sum to 1.

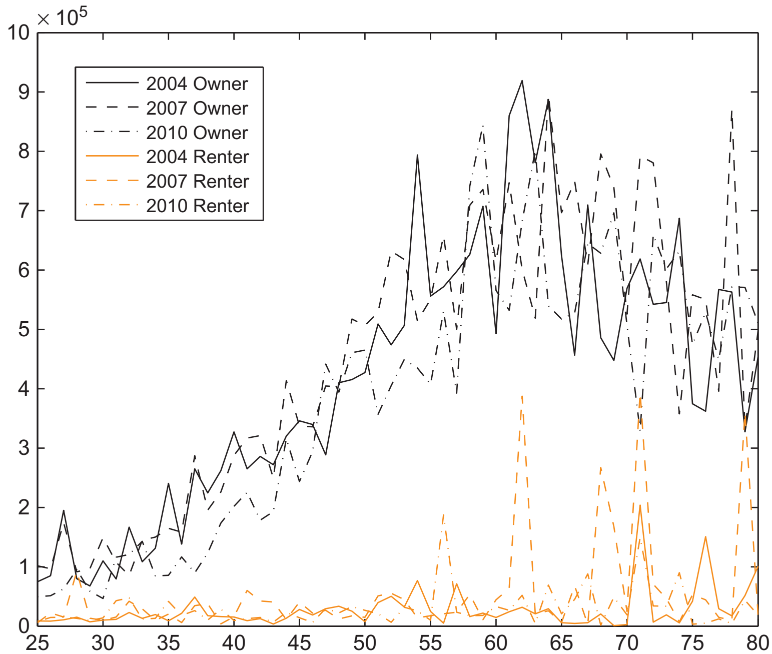


Figure 12.9 This figure plots average net worth by age for the 2003, 2007 and 2010 Survey of Consumer Finances. All nominal wealth estimates are deflated by the Consumer Price Index (base year 2010) published by the Bureau of Labor Statistics. Household wealth is expressed on a *per capita* basis by dividing by the number of adult members of the household. Wealth is computed as the sum of all assets minus the sum of all liabilities. Assets are pension assets, bank accounts, IRAs, bond holdings, mutual fund holdings, stock holdings, the value of the primary residence if owned, other housing wealth, business wealth, other financial wealth, and vehicles. Liabilities are credit card debt, mortgage debt for the primary residence, debt for other property, and other debt.

As homeowners age, housing falls to about 50% of total assets by age 60 years, and financial wealth becomes a larger share of assets and net worth. Late in life, retirement assets are depleted, and stocks, bonds, and housing all account for a significant fraction of wealth. In contrast, renters have little stock market wealth; most of their wealth is in retirement assets and in bonds.

12.2.3 Volatilities and correlations

Macroeconomic researchers studying the properties of business cycle models typically force the models to match key first moments, such as the first moments we discussed earlier in the chapter, and then informally evaluate model performance by judging how well the model can replicate important second moments. This procedure is in the spirit of Kydland and Prescott (1982), who ask if a macroeconomic model can simultaneously be consistent with the long-run growth facts of Kaldor (1957) and match the business cycle facts of

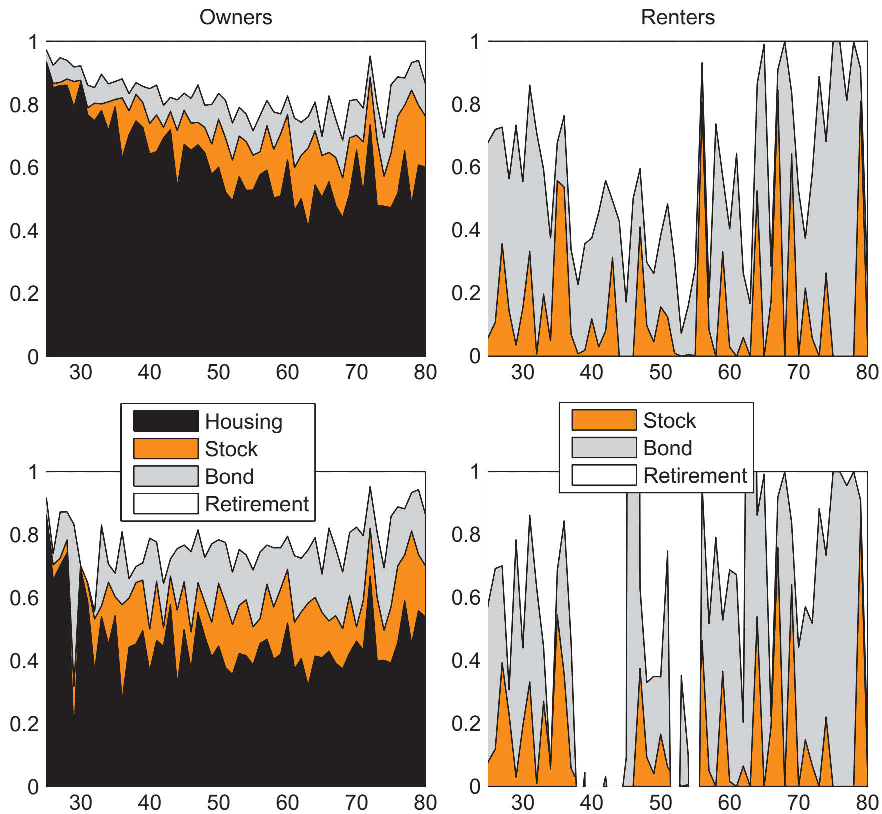


Figure 12.10 The figure plots portfolio shares by age for homeowners (left panels) and renters (right panels) for the 2010 Survey of Consumer Finances wave. The top panel plots the share of four asset categories: housing, stocks, bonds, and retirement accounts. Retirement assets are difficult to split into stocks and bonds, and so we leave them as a separate category. We include bank accounts as bonds and mutual fund holdings with stocks. The four shares sum to 1. That is, for the calculation of these shares, we disregard the remaining asset categories of vehicles, other financial assets, and business wealth. The bottom panels plot home equity, stocks, bonds net of unsecured debt, and retirement assets as a share of net worth. In these panels, bonds are defined as the sum of bonds and bank accounts less credit card debt plus other financial assets less other unsecured debt. Home equity is defined as the sum of the value of all housing owned less the amount of all mortgage debt owed. Stocks and retirement accounts are defined as in the top panels, and the four shares sum to 1.

Burns and Mitchell (1946).[16] Through the appropriate choice of functional forms for production and utility functions, many macro models will, by definition, be consistent with first moments; this implies model evaluation should focus on second moments. Table 12.1

[16] For example, the ratios of consumption, investment, and capital to output are stable, on average over many years, but are all positively correlated over the business cycle.

Table 12.1 Properties of selected detrended US macroeconomic data, first quarter of 1955 to third quarter of 2013

	Variable X	Standard deviation	Relative standard deviation	Correlation of variable X_s and GDP_t						
				$s = t - 3$	$t - 2$	$t - 1$	t	$t + 1$	$t + 2$	$t + 3$
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(a)	GDP	1.54	1.00	0.40	0.64	0.86	1.00	0.86	0.65	0.42
(b)	Consumption	0.85	0.55	0.49	0.67	0.81	0.84	0.75	0.59	0.41
(c)	Nonresidential investment	4.74	3.07	0.13	0.36	0.61	0.81	0.87	0.82	0.70
(d)	Residential investment	9.98	6.47	0.67	0.75	0.76	0.66	0.45	0.21	−0.02
(e)	House prices[a]	4.16	2.70	0.47	0.53	0.55	0.52	0.46	0.41	0.35
(f)	Durables quantities	4.49	2.91	0.51	0.67	0.79	0.82	0.65	0.44	0.21
(g)	Durables prices	0.93	0.60	0.13	0.05	−0.04	−0.15	−0.24	−0.30	−0.35

[a]Data begin in the first quarter of 1975.

Data are quarterly. All data except the house price data are from the National Income and Product Accounts (NIPA) as produced by the Bureau of Economic Analysis. The house price data combine data from the Federal Home Finance Agency House Price Index (1975–1986) and the Case–Shiller–Weiss index as made available by Macromarkets (1987–2013). All variables have been logged and Hodrick–Prescott-filtered with smoothing parameter $\lambda = 1600$. Real house and durable prices are computed as the nominal price index divided by the price index for consumption of nondurable goods and services.

shows some of these second moments for US data—standard deviations and correlations—that researchers try to match. Generating these moments requires, as a first step, removing trends in the data. The typical procedure to remove those trends has been to use the Hodrick–Prescott filter.[17]

Inspection of Table 12.1 yields several important stylized facts. First, consumption, nonresidential investment, residential investment, and spending on durable consumption goods are all positively contemporaneously correlated with GDP (column 6). The positive correlation of these major macroeconomic variables is considered a key property of business cycles. Second, consumption is about half as volatile as GDP (cell b2 of the table); nonresidential investment is three times more volatile than GDP (c2); residential investment is more than twice as volatile as nonresidential investment (d2); and house prices are more than 2.5 times as volatile as GDP (e2).[18] Finally, the highest correlation of nonresidential investment and GDP occurs when GDP is lagged once relative to nonresidential investment (c7); and the highest correlation of residential investment and GDP occurs when residential investment is lagged by one or two quarters (d4 and d5).[19] Thus, residential investment leads business investment by about two quarters.

12.3. HOUSING AND THE BUSINESS CYCLE

The cyclical nature of housing has been a topic of interest for decades, and many economists have written on the topic. An active empirical literature studies the lead–lag relationship of housing with other macroeconomic aggregates (e.g., Green, 1997; Leamer, 2007; Ghent and Owyang, 2010), and the relationship of house prices and housing wealth to consumption (e.g., Muellbauer and Murphy, 1997; Davis and Palumbo, 2001; Case et al., 2005).[20] In this section, we focus on one specific branch of the literature: equilibrium aggregate models in the spirit of Kydland and Prescott (1982)—that is, "real business cycle" (RBC) models, where housing prices and quantities are endogenously determined inside the model alongside aggregate consumption, investment, and output, and aggregate market clearing conditions are defined as part of the equilibrium.[21] We focus on these models because they reflect our tastes and research experience, but also because many macroeconomists currently studying housing use a similar framework.

[17] The Hodrick–Prescott filter removes a stochastic trend (see Hodrick and Prescott, 1997 for details).

[18] Almost identical results are obtained for every statistic when real house prices are replaced with the price–rent ratio (not shown).

[19] Residential investment does not lead GDP in all countries (see Kydland et al., 2012).

[20] See Cooper and Dynan (2013) for a recent summary of that literature.

[21] For example, we would not consider the models of Topel and Rosen (1988) and Grenadier (1995) to be part of this literature, since in both of those models many aggregate variables are determined outside the model and aggregate market clearing conditions for all variables are not specified.

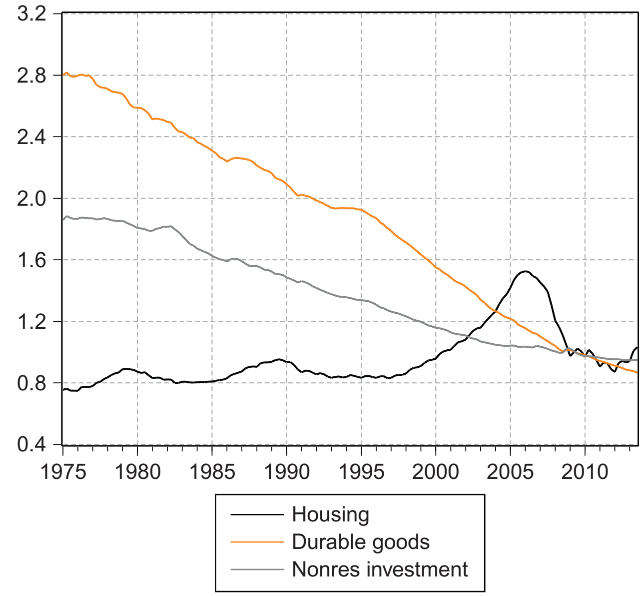
The first class of RBC models where housing variables entered as objects of interest were models with home production (Benhabib et al., 1991; Greenwood and Hercowitz, 1991). Those models are two-sector extensions of the canonical RBC model of Kydland and Prescott (1982). The key extension of these models relative to the original RBC model is that households are assumed have three uses of time: market work and leisure, as in the standard model, and work at home. Households combine work at home with a stock of home capital, subject to a productivity shock to home output, to produce a good called "home consumption," which is complementary in utility with leisure and with consumption purchased in the market. A justification for this approach (see McGrattan et al., 1997) is that in time-use surveys, households on average spend about 25% of discretionary time on activities that can be classified as home work. When authors in this literature calibrate their models, they set the stock of home capital equal to the sum of the stock of residential structures (housing less land) and the stock of durable goods and set gross investment in home capital equal to investment in residential structures and spending on consumer durables (see Greenwood et al., 1995; McGrattan et al., 1997).

In the home production literature, it is typically assumed that home capital and market capital have the same price per unit (except for adjustment costs), and that home capital can be modeled as a simple aggregate of durable goods and residential structures. Figure 12.11, which graphs real house prices, durable goods prices, and the price of nonresidential fixed investment over the 1975–2013 period, shows that these assumptions are at odds with the data.[22] The top panel of the figure plots the raw data, while the bottom panel shows the logged, Hodrick–Prescott-filtered data. The top panel shows that the real price of durable goods and business investment has been falling rapidly, while the real price of housing has been rising slowly. The bottom panel shows that cyclical durable goods prices and nonresidential investment prices are highly correlated, but the cyclical price of housing is more volatile than and is not correlated with either series.

These price data suggest that the productivity shocks affecting the production of housing may be quite different from shocks affecting production in other sectors of the economy.[23] To see this, consider the following simple two-sector economy. In the first sector (subscript c), a general good is produced that can be used for consumption or business investment. In the second sector (subscript h), residential structures used for housing are produced. Firms in each sector rent capital K and labor L from households to produce output Y according to the functions below:

[22] All prices have been converted to real using the NIPA price index for consumption of nondurable goods and services.

[23] "Productivity shocks" allow the level of output to vary even when the quantity of inputs is held fixed. These shocks capture, in a reduced-form sense, changes to the methods by which firms manage and organize inputs (e.g., logistics, management structure) to more efficiently make output.



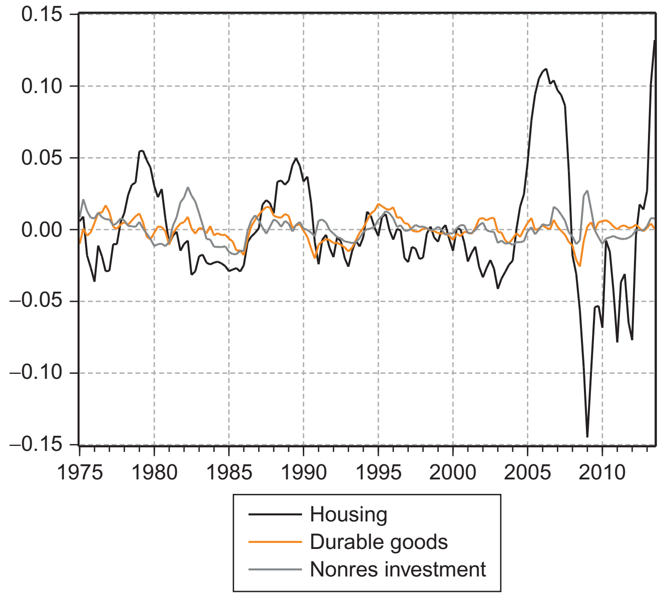


Figure 12.11 Relative prices (2009 prices correspond to 1.0), first quarter of 1975 to third quarter of 2013. The price index for durable goods and that for nonresidential investment are from the National Index and Product Accounts. The house-price data combine data from the Federal Home Finance Agency House Price Index (1975–1986) and the Case–Shiller–Weiss index as made available by Macromarkets (1987–2013). All prices have been converted to real prices by deflating them using the National Index and Product Accounts price index for consumption of nondurable goods and services. The top panel shows the raw data and the bottom panel shows the data after taking logarithms and applying the Hodrick–Prescott filter.

$$Y_c = z_c K_c^{\alpha} L_c^{1-\alpha},$$
$$Y_h = z_h K_h^{\alpha} L_h^{1-\alpha},$$

where z_c and z_h are sector-specific productivity shocks. Normalize the price of consumption to 1 and denote the price of one unit of residential investment as p_h, the price of one unit of capital as r, and the price of one unit of labor as w. The profit maximization problems for the firms in each sector are

$$\max_{K_c, L_c} \quad z_c K_c^{\alpha} L_c^{1-\alpha} - rK_c - wL_c,$$
$$\max_{K_h, L_h} \quad p_h z_h K_h^{\alpha} L_h^{1-\alpha} - rK_h - wL_h,$$

implying first-order conditions for optimal capital and labor utilization for firms in each sector of

$$r = z_c \alpha \left(\frac{K_c}{L_c}\right)^{\alpha-1} = p_h z_h \alpha \left(\frac{K_h}{L_h}\right)^{\alpha-1},$$
$$w = z_c (1-\alpha) \left(\frac{K_c}{L_c}\right)^{\alpha} = p_h z_h (1-\alpha) \left(\frac{K_h}{L_h}\right)^{\alpha}.$$

These two equations imply that we can solve for the relative price of residential structures in equilibrium as

$$p_h = \frac{z_c}{z_h}. \tag{12.1}$$

In this simple two-sector model, where we have assumed the capital share of production is the same in both sectors, the relative price of residential structures is equal to the ratio of the two productivity shocks.[24] This result is the reason why authors interested in the cyclical behavior of residential investment and house prices have modeled the production of housing in some detail inside a business-cycle model.

The first article to model shocks affecting the production of housing is by Davis and Heathcote (2005). The model of Davis and Heathcote is similar in spirit to the simple two-sector model described above. The key difference is that Davis and Heathcote design the production side of the model such that all the inputs and key parameters are identifiable using available data. Other articles that have adopted a similar specification for housing production are those of Kahn (2008), Iacoviello and Neri (2010), Kiyotaki et al. (2011), and Dorofeenko et al. (2014) to name just a few recent examples.

In Davis and Heathcote (2005), one set of firms produces "intermediate goods" (similarly to what is done in the article by Hornstein and Praschnik, 1997) and a second set of firms transforms these intermediate goods into final goods. There are three types of firms

[24] Adjustment costs can introduce a wedge between the price producers receive as computed in (12.1) and the price households pay for additional installed unit of capital (see Fisher, 1997 for more details).

producing intermediate goods—a first type produces construction output (subscript b), a second type produces manufacturing output (subscript m), and a third type produces services output (subscript s). Call each of these types of firms "industries." Output x from each industry is made from capital K and labor N rented from households and is subject to an industry-specific productivity shock z according to

$$x_{it} = z_{it} K_{it}^{\theta_i} N_{it}^{1-\theta_i} \quad \text{for} \quad i = \{\text{b}, \text{m}, \text{s}\}.$$

Notice that the capital share θ_i is allowed to vary by industry. Davis and Heathcote (2005) identify θ_i for each industry and then use data on K_i and N_i from the Bureau of Economic Analysis to estimate the time-series values of z_{it} for each industry. These z_{it} are the only shocks in the Davis and Heathcote model.

Continuing, Davis and Heathcote assume three types of firms that produce final goods. The first type of firm produces a good (subscript c) that can be used by households for either consumption or business investment. The second type of firm produces residential investment (subscript d). The third type, discussed below, produces housing (subscript h). The first two types of firms that produce final goods use construction, manufacturing, and services goods as inputs. These firms produce their output (y) according to

$$y_{jt} = b_{jt}^{B_j} m_{jt}^{M_j} s_{jt}^{S_j} \quad \text{for} \quad j = \{\text{c}, \text{d}\}.$$

B_j, M_j, and S_j are the shares of construction, manufacturing, and services value-add for residential investment ($j = \text{d}$) and consumption and business investment ($j = \text{c}$).

Davis and Heathcote identify the production-function parameters B_j, M_j, and S_j using data from the Input–Output tables of the NIPA. Since all three intermediate goods are used in both types of final goods, shocks to all three industries affect the production of both types of final goods. To the extent that residential investment is more construction intensive than consumption and business investment, $B_\text{d} > B_\text{c}$, the shocks affecting the construction sector will be relatively more important for determining residential investment. Thus, residential investment will have a price different from that of other goods depending on the properties of the z_{it} terms and the values of B_j, M_j, and S_j for $j = \text{c, d}$.

The third type of firm that produces final goods combines residential investment and new land to make housing. Denote x_d and x_l as residential investment and land that the housing-producing firms buy. The amount of new housing produced y_h is given by

$$y_{\text{h}t} = x_{\text{l}t}^{\vartheta} x_{\text{d}t}^{1-\vartheta}. \tag{12.2}$$

Davis and Heathcote assume that the amount of new land available in the economy is fixed at 1 each period. This assumption makes possible a closed-form solution for the total quantity of housing in the economy as a function of past investments in structures

Table 12.2 Business cycle properties of the Davis and Heathcote (2005) model

	Variable	Data	Davis and Heathcote model
Standard deviations relative to GDP			
(a)	Hours worked	1.01	0.41
(b)	Nonresidential investment	2.30	3.21
(c)	Residential investment	5.04	6.12
(d)	House prices	1.37	0.40
Period *t* correlations			
(e)	Residential and nonresidential investment	0.25	0.15
(f)	Residential investment and house prices	0.34	− 0.20

All results and data in this table are taken from Table 10 in Davis and Heathcote (2005). The standard deviations and correlations in this table do not exactly match those in Table 12.1. Davis and Heathcote (2005) use annual data over a different sample range (1948–2001); they filter the data using the Hodrick–Prescott filter with smoothing parameter $\lambda = 100$; and they use different source data for house prices.

after accounting for depreciation and land accumulation. The inability to produce new land acts like an adjustment cost to the production of new housing.[25]

For the household side of the model, the Davis and Heathcote model assumes a representative agent who receives utility from market consumption c_t, leisure $1 - L_t$, and housing H_t of the form

$$\frac{\left(c_t^{\mu_c} H_t^{\mu_h} (1 - L_t)^{1-\mu_c-\mu_h}\right)^{1-\sigma}}{1-\sigma}.$$

In this expression, total hours worked L_t is the sum of the hours worked in the construction, manufacturing, and services sectors.

Table 12.2 compares some key moments from the data and from simulations of the Davis and Heathcote model. Row (a) shows that the model underpredicts the volatility of hours worked. This finding is not surprising. Despite the fact that Davis and Heathcote model three productivity shocks, all activity in the model occurs in the market, so the three productivity shocks once aggregated should have, roughly speaking, the same properties as the one productivity shock of the canonical RBC model, and that model systematically underpredicts the volatility of hours worked. Rows (b) and (c) show the relative standard deviations of nonresidential and residential investment. Relative to the classic results from the home-production literature such as Gomme et al. (2001), the model has great success replicating the fact that residential investment is about twice as volatile as nonresidential investment. Additionally, the model replicates the positive contemporaneous correlation of nonresidential and residential investment (row (e)). This result arises from the fact that land acts as an adjustment cost to building new housing

[25] While the assumption of one unit of land available for development in each period is convenient, it is not clear what this quantity should be. Ultimately, the quantity of new land available for development determines the aggregate elasticity of supply of housing. More research is needed on this topic.

rapidly. As noted by Fisher (1997), these kinds of adjustment costs are necessary to generate positive co-movement of residential and nonresidential investment.

The model fails to match the housing data along three dimensions. First, residential investment tends to lead GDP and nonresidential investment tends to lag GDP. The model fails to replicate this finding. Second, the model underpredicts the volatility of house prices (row (d)).[26] Third, the model predicts a negative correlation of residential investment and house prices, whereas in the data the correlation is positive (row (f)).

The fact that the model predicts that house prices and residential investment are negatively correlated is likely due to the nature of shocks hitting the model.[27] Consider again the result of the simple two-sector model without adjustment costs, $p_{\mathrm{h}} = z_{\mathrm{c}}/z_{\mathrm{h}}$. When residential investment has relatively high productivity and z_{h} is relatively high, house prices fall. But when z_{h} is high, it is a productive time to build housing. A simpler way to say this is that people should build housing when it is cheap to do so. Ultimately, there are two offsetting effects in the model of Davis and Heathcote making the analysis more complicated. First, land acts as an adjustment cost, and the fixity of new land available for new housing boosts house prices when building activity is high. Second, income effects can offset price effects. Referring again to the simple model, we find when z_{c} is high and house prices are relatively high, income is also high (since z_{c} is used to produce consumption and business investment, most of GDP). When income is high, households want more of everything, including housing.

Some progress has been made on fixing the three counterfactual findings of Davis and Heathcote (2005), but more work needs to be done. Fisher (2007) shows that when housing is included as a separate capital stock in the market production function, the lead–lag properties of the model are improved. Dorofeenko et al. (2014) show that the inclusion of "risk shocks" to the production of housing can help boost the volatility of house prices, but at the expense of other model statistics. Kydland et al. (2012) demonstrate that properties of the pricing of fixed-rate mortgages (FRMs) may be critical to understanding why residential investment leads GDP. Favilukis et al. (2011), whose work is discussed in more detail later in this chapter, generate considerably more volatile house prices in a heterogeneous-agent equilibrium model with collateral constraints. It also improves on the lead–lag relationship between residential investment and GDP and generates a positive correlation between residential investment and house prices.

12.4. HOUSING OVER THE LIFE CYCLE AND IN THE PORTFOLIO

A substantial literature researches the role of housing in households' portfolios of assets. On average over 1952–2013, housing wealth accounted for 35% of household assets and

[26] The relative volatility of house prices is much lower in Table 12.2 than in Table 12.1 owing to differences in sample periods and source data. See the notes to Table 12.2 for details.

[27] The model of Fisher (1997) also predicts a negative correlation of house prices and residential investment.

40% of household net worth (assets minus liabilities), while home equity (housing wealth minus mortgage debt) accounted for 23% of assets and 26% of net worth.[28] As shown in Figures 12.6, 12.8, and 12.10, two-thirds of households in the United States own their home, and for most home-owning households, housing accounts for a substantial portion of total wealth.

Housing is not only an important asset in the portfolio, it also has several features that make it different from investments in financial assets. First, it is illiquid in the sense that changing the quantity of housing may take time and/or requires incurring substantial transaction costs. Second, it is indivisible: a limited assortment of types and sizes are available for purchase at any time (including a minimum size). Third, home ownership and housing consumption are typically intimately linked. Most households own only one home and live in the house they own. Fourth, housing represents the main source of pledgeable capital against which households can borrow. Investment in housing is much more leveraged than investments in other financial assets, and the value of owned housing limits the amount of leverage in households' portfolios. Fifth, housing is tied to a particular labor market: people usually live near where they work.

For the past 15 years or so, researchers have developed relatively simple life-cycle decision models with rational, forward-looking, optimizing agents able to reproduce systematic differences in the data on the home ownership, housing, and portfolio choices of various groups of households—sorted by tenant status (owner vs. renter), age, income, and net worth. With this in mind, we proceed by describing a model environment representative of many of the models studied in this literature and describe the typical calibration of key parameters and processes. Finally, we discuss in some detail the setup and results of many key articles in this now mature literature.

12.4.1 A typical model

12.4.1.1 Utility

Most authors assume that finite-lived households receive utility from nonhousing consumption c, the quantity of housing services h, and whether or not those services are acquired through owning $o=1$ or renting $o=0$, such that per-period utility can be written as $u(c,h,o)$. In each period, households act to maximize the present discounted value of remaining expected utility subject to constraints we discuss later. That is, if the household dies with certainty in T periods, in the current period $t=0$ households maximize

[28] The data are from the Flow of Funds for the first quarter of 1952 until the first quarter of 2013, Table B100. The calculations reassign the portion of private business wealth in the household table that reflects households' ownership of real estate available for rent. The same is done for the corresponding mortgages. This reclassification is done on the basis of information in Table B103.

$$\sum_{t=0}^{T} \beta^t \pi(t) E_0[u(c, h, o)]. \tag{12.3}$$

In the equation above, β is the rate at which households discount future utility, $0 < \pi(t) < 1$ is the age-dependent probability of survival to period t, and E_0 denotes an expectation taken in the current period. Occasionally, authors assume that households have a bequest motive in which they or their offspring receive utility if they die with positive wealth. In that case, the net present discounted value of utility has one additional term equal to some payoff from wealth remaining at death.

The functional form for per-period utility can be generalized as a constant relative risk aversion utility over a joint consumption bundle with risk aversion parameter $\sigma \geq 1$, and where the consumption bundle is a constant elasticity of substitution (CES) aggregate over housing and nonhousing consumption, with intratemporal elasticity parameter $-\infty < \rho < 1$ and budget share parameter α:

$$u(c, h, o) = \frac{(\alpha c^\rho + (1-\alpha)\xi_o h^\rho)^{\frac{1-\sigma}{\rho}}}{1-\sigma}. \tag{12.4}$$

The parameter ξ captures the extra utility from housing services that are owned rather than rented: $\xi_1 > \xi_0$.

12.4.1.2 Choices

In each period of the model, households make a set of continuous choices and one discrete choice. The continuous choices are related to consumption, the quantity of financial assets, and the quantity of housing services. Studies differ in the treatment of financial assets. Some authors lump together all financial assets into a net position; others allow for one positive financial asset and one negative financial asset, typically a mortgage; others allow for a set of positive financial assets such as stocks and bonds; and finally some studies allow households to choose among multiple types of mortgages—for example, FRMs or adjustable-rate mortgages (ARMs). The discrete choice is whether or not to receive housing services by owning or renting.

12.4.1.3 Constraints

Each period, households are subject to a basic budget constraint, a net worth or home equity constraint, and one or more constraints about housing choices. Below, we consider the case of renters remaining renters and homeowners remaining homeowners. When homeowners in $t-1$ become renters in t and renters in $t-1$ become homeowners in t, constraints change in the expected ways.

Denote labor income as w_t, financial assets (consolidated for convenience) as a_t, the rate of return on financial assets as r_t, and the rental price per unit of housing as q_t. In all studies income varies over time. In most studies, house prices vary over time. The basic budget and net worth constraints for households that were renters in the previous period $o_{t-1} = 0$ and choose to rent in the current period have the intuitive forms

$$c_t + q_t h_t + \tau_t + a_t = w_t + a_{t-1}(1 + r_{t-1}), \tag{12.5}$$

$$a_t \geq \underline{a}_{t,} \tag{12.6}$$

$$h_t \leq \overline{h}. \tag{12.7}$$

The first equation is simple accounting—out of available resources, whatever is not spent on consumption, taxes τ_t, or rental housing is saved. For renters, taxes paid is usually a simple function of age, income, and assets. The second equation imposes some discipline on spending. Consider what would happen in the period before death, $T-1$, without a constraint like this: each household would spend as much as possible on consumption and housing. In many articles, $\underline{a}_{t,}$ is set to 0 in each period, and in a few articles, $\underline{a}_{t,}$ is determined endogenously such that the household can repay any debt with probability 1. The final constraint is that rental housing cannot be too large.

The budget and net worth constraints for households that owned their home in the previous period and choose to own their home in the current period are more complicated. The simpler models tend to have the form

$$c_t + p_t h_t + \tau_t + mc + a_t = w_t + a_{t-1}(1 + r_{t-1}) + p_t (1 - \delta) h_{t-1}, \tag{12.8}$$

$$mc = \zeta p_t h_{t-1} \quad \text{if } h_t \neq h_{t-1}, \text{ 0 otherwise}, \tag{12.9}$$

$$h_t \geq \underline{\mathrm{h}}, \tag{12.10}$$

$$a_t \geq -(1 - \phi)\, p_t h_t. \tag{12.11}$$

The first equation is accounting. It states that out of available resources (income, financial assets, and housing wealth after accounting for depreciation δh), whatever is not spent on consumption, taxes, or housing is saved. The amount spent on housing is the value of the house bought plus moving costs mc. As shown in Equation (12.9), moving costs, typically assumed to be a fixed percentage ζ of the value of the house being sold, are incurred if the size of the owned house changes between periods—that is, $h_t \neq h_{t-1}$. Some authors include a fixed component in the moving cost. The moving costs allow models to capture the fact that households move infrequently.

The term $r_{t-1}a_{t-1}$ reflects net interest received or paid (if negative) by households. The embedded assumption is that homeowners can borrow and lend at the same rate r, so a is the value of all savings net of any debt owed. In this stylized budget constraint, there are no costs to adjusting the quantity of debt or assets, so households can vary their mortgage or other financial assets costlessly over time as long as their debt level is not too high. Some authors relax this assumption and allow for participation costs or other costs when households change the size of their mortgage (refinance) or adjust their portfolio between stocks and bonds. A sizeable literature studies costs households pay to participate in stock markets (e.g., Vissing-Jorgensen, 2002).

Equation (12.10) specifies that owned housing cannot be too small. Equation (12.11) is a key constraint which governs maximum homeowner debt. Homeowners can borrow up to $1 - \phi$ fraction of their house value; ϕ is sometimes called the down-payment fraction. The down-payment constraint (or, transformed, the loan-to-value constraint) and the minimum-sized owned housing constraint allow models to match low home ownership rates for the young: the young need to save to afford the down payment on their first house. Models of this class usually rule out default.[29]

The budget constraints for homeowners, taxes paid, and laws of motion for wealth and debt can be more complicated in studies of how different mortgage types affect the demand for housing. Some authors assume that homeowners cannot borrow and save at the same rate, and cannot add to their mortgage debt without incurring a cost. In these articles, the constraint regarding the maximum quantity of mortgage debt is typically considered only for first-time home buyers, or for homeowners moving to a different house. That is, homeowners are (usually) not forced to move if the value of their house unexpectedly declines and their loan-to-value ratio increases. The simple model also assumes that mortgage debt has one-period maturity, resembling ARMs. Some authors explicitly allow for long-term mortgages, usually modeled as perpetuities whose coupon payments are set to match the average duration of FRMs. Authors who study mortgage design also separately model interest and principal repayment schedules, and mortgage interest on debt is assumed to be tax deductible. Finally, some authors add debt-to-income constraints in addition to loan-to-value constraints.

12.4.1.4 Expectations for wages and prices

Earnings in these models are almost always stochastic around a known age-specific hump-shaped profile. Households are assumed to know the process for wages, but not the future realizations of the shocks. Assumptions about house prices vary. Sometimes house prices are fixed or grow at a predetermined rate, but most of the time they are stochastic. If they are random, typically the level is assumed to be persistent, either a random walk (possibly with time-varying drift as in Corradin et al., 2014), or a first-order autoregressive process with a value for the autoregressive coefficient near 1. In models where house prices are not determined endogenously, the process for calibrating the covariance of shocks to income and shocks to house prices varies across authors. Households in these models are forward-looking with rational expectations.

[29] We discuss models that allow for default later in the chapter. In these models, the down-payment constraint limits the likelihood of default, but does not rule it out.

12.4.2 Calibration and estimation

These models are estimated or calibrated using a two-step approach. The discount factor β and the coefficient of relative risk aversion σ are set using standard values: $\beta = 0.96$ and $\sigma \in [2,6]$.[30] When there is only one financial asset, the rate of return on this asset, r, is typically set to 4%. Survival probabilities by age are exogenous and come from life tables. Tax rates are also set exogenously, around 40% for nonretirees and 0% for households that are retired. Some parameter values related to housing are also set outside the model—specifically, the transaction cost of selling a house ζ is usually set somewhere between 5% and 10%,[31] and the down-payment constraint for home buyers ϕ is set to 5%, 10%, or 20%.[32]

The depreciation rate on owned houses is set between 1% and 3%, on the basis of evidence from the Bureau of Economic Analysis. The remaining parameters—given σ, the parameter determining the elasticity of substitution between consumption and housing ρ, the expenditure share on consumption as compared with housing α, the home ownership premium to utility, the maximum sized rental house $\overline{h}$, the rental price per unit q, and the bequest function—are estimated or calibrated to match a set of facts about housing and capital in the aggregate or over the life cycle. Most authors add parameters or tweak their model specification until they decide the model fits the data along the margins they feel are most important.

The life-cycle profile and stochastic process for earnings are taken directly from the Panel Study of Income Dynamics (PSID) or from studies that use PSID data.[33] For example, earnings from the PSID in logarithmic form are regressed on age, age squared, marital status, household composition, and family fixed effects to obtain the deterministic life-cycle component. The residuals of this regression can be used to recover the stochastic component of labor income. Earning processes are estimated separately for different educational attainment groups, and earnings in retirement are the average of observed income in each education group.

The treatment of the process for house prices differs widely. Sometimes house prices are fixed; sometimes house prices follow some exogenous process set outside the model; and sometimes house prices are endogenously determined inside the model. When the path for house prices is set outside the model, many authors specify a process that

[30] Chambers et al. (2009a,c) and Fisher and Gervais (2011) depart from the utility function we describe and consider utility of the form $\left(\frac{\alpha}{1-\rho_1}\right)c^{1-\rho_1} + \left(\frac{1-\alpha}{1-\rho_2}\right)c^{1-\rho_2}$. Chambers et al. (2009a,c) set $\rho_1 = 3$ and $\rho_2 = 1$. They argue that this is necessary to match the income elasticity of owned housing in their data. Fisher and Gervais (2011) set $\rho_1 = 1$ and $\rho_2 = 2$ to ensure that expenditures on housing rise with the price of housing.

[31] The widely cited article for this estimate is Gruber and Martin (2003). Some authors calibrate ζ to capture both monetary and nonpecuniary moving costs.

[32] Occasionally this value is estimated on the basis of data on loan-to-value ratios of first-time home buyers.

[33] Storesletten et al. (2004), Cocco et al. (2005), and Heathcote et al. (2010) are standard references.

replicates the autocorrelation and variance of house price indices such as the Federal Housing Finance Authority or Case–Shiller–Weiss indices. Other authors try to replicate the patterns for house prices that can be derived from PSID data.[34] The benefit of the PSID approach is that it can deliver an estimate of the variance of prices of individual housing units. For example, Flavin and Yamashita (2002) construct real, annual housing returns using self-reported housing values from the PSID in adjacent years from 1968 to 1992. They estimate that the mean return to housing (including imputed rents net of maintenance) is 6.6%, with a standard deviation of 14.2%, and show the correlation of housing returns with stock, bond, and T-bill returns is almost zero.[35] It seems fair to say that the literature still lacks high-quality data to pin down the return correlation matrix between stocks, bonds, and individual houses.[36]

The correlation of shocks to income and shocks to house prices plays a key role in portfolio decisions in many of these models. Many authors assume that there is zero correlation between individual house price returns and individual income realizations. On the basis of 1970–1992 PSID data, Cocco (2005) finds a 55% correlation between average house prices and the common part of household income. In his model, he assumes that house prices are perfectly positively correlated with the aggregate component of income and positively but imperfectly correlated with temporary labor income shocks. Using Swedish data for 2000–2007, Vestman (2012) estimates a correlation of 63% between the common component of income growth and national house price growth. The overall correlation with individual income growth is 14%. As a summary of commonly held views, (a) individual housing returns contain modest but important metropolitan-level and national components in addition to a large idiosyncratic component and (b) the national components of house prices and income are correlated with each other and with stock prices. We suspect that local labor income and local house prices are also positively correlated at a fine level of geography, such as the level of census tracts or ZIP codes, but the micro evidence is lacking.

[34] The literature has recognized that the PSID sample is small and that self-reported home values are noisy and possibly upward biased. For example, an increase is self-reported house prices across time may be due to quality improvements or pure appreciation. Nevertheless, some have argued that homeowners, on average, can guess the value of their house within a few percentage points. See Goodman and Ittner (1992), Bucks and Pence (2008), Benitez-Silva et al. (2010), and Davis and Quintin (2014).

[35] The imputed rent, or dividend, on housing is set equal to a proportion of the house value, where the proportion is equal to the real interest rate and the property tax rate multiplied by the marginal income tax rate. The short-term interest rate is fixed to 5%.

[36] Other studies measuring housing returns using microdata are those of Piazzesi et al. (2007), who improve on the method of Flavin and Yamashita (2002), and Landvoigt et al. (2013b), who estimate high-quality housing price appreciation rates for San Diego. Favilukis et al. (2011) discuss measurement issues and compare several approaches.

12.4.3 Major findings in the portfolio literature

The ultimate aim of the portfolio choice literature is to produce a model that can match life-cycle profiles for the incidence of home ownership, the incidence of stock market participation, total wealth, and the percentage of total wealth accounted for by housing, stock, and bond market wealth—that is, portfolio shares. The literature also increasingly seeks to match systematic differences in portfolio shares across groups of households, sorted by tenant status (owner vs. renter), age, income, and net worth. In the remainder of this section, we discuss the major findings in three strands of the literature: housing and consumption over the life cycle, the interplay of optimal housing holdings and optimal financial asset decisions, and mortgage choice. In this section, we study models that (a) assume house prices are constant, or are stochastic but determined outside the model—we call these models "partial equilibrium models"—and (b) do not explicitly study how government policy affects housing decisions. In Section 12.6, we discuss similar models that endogenize house prices, while in Section 12.7 we study the impact of tax and other policies on housing outcomes.

12.4.3.1 Housing and consumption patterns over the life cycle

12.4.3.1.1 Home ownership over the life cycle

An early body of literature studies how various segments of the housing market are connected in simple life-cycle models where housing comes in discrete and fixed sizes (Stein, 1995; Ortalo-Magné and Rady, 2006). In such models, people move "up" the housing ladder—that is, they buy more expensive housing—as they age or become richer. These models do not try to match the life-cycle data to the same degree as the models we discuss in this section; rather, they are designed to study equilibrium differences in house prices across various segments of the housing market. We discuss these models in more detail in Section 12.6.3.

The work of Fernández-Villaverde and Krueger (2011) is one of the earlier articles in the literature: although the article was published in 2011, it was last revised in 2001. Fernández-Villaverde and Krueger ask if a partial equilibrium life-cycle model with housing and idiosyncratic income and mortality risk can fit the life-cycle profiles of consumption spending (hump shaped), spending on durable goods (hump shaped), and housing and financial wealth. They treat durable goods and housing interchangeably. Durable goods provide service flows and act as the sole source of borrowing constraints. The main finding is that the interaction of borrowing constraints (our Equation 12.11) and consumer durables produces young agents who accumulate durables early in life and increase nondurable spending and financial asset positions later in life.

Yang (2009) revisits the work of Fernández-Villaverde and Krueger (2011) and argues that consumption of housing first increases over the life cycle but fails to decline in old age, unlike nondurable spending (recall Figure 12.8). She adds housing transaction costs to the framework of Fernández-Villaverde and Krueger (2011). Borrowing constraints are needed to explain the accumulation of housing early, and transaction costs are necessary to explain the slow downsizing of housing later in life.

In related work, Nakajima and Telyukova (2012) study the standard model's predictions for retired households. They show that retired homeowners spend down their wealth more slowly than renters. This arises in their model because retired homeowners cannot easily borrow against their house and because they want to stay in their current house as long as possible, rather than sell and move. Relative to the standard model, Nakajima and Telyukova model medical expenses explicitly in the budget constraint and allow for a consumption floor in the event of a large medical expense shock, as in Hubbard et al. (1995) and Ameriks et al. (2010).

Halket and Vasudev (2014) study the life-cycle patterns of home ownership and mobility across metropolitan statistical areas (MSAs). They show that the standard model, modified to allow for Lucas–Prescott-style job mobility (Lucas and Prescott, 1974), can account for the increase in home ownership, increase in wealth, and decline in mobility over the life cycle. The young move more frequently than the old because they rent. Uncertainty about family size can also affect the decision to move.

On the topic of home ownership over the life cycle, Fisher and Gervais (2011) ask why home ownership rates for young people declined substantially from 1980 through 2000. They show that the trend toward marrying later and the increase in income risk can account for almost the entirety of the decline. Unlike most of the articles in this literature, they allow for only three ages in their model (young, middle aged, old) and households transition stochastically between ages.

12.4.3.1.2 Housing collateral to smooth consumption

Hurst and Stafford (2004) and subsequent researchers study how households use home equity to smooth consumption. In their model, housing does not enter utility. They show that a combination of low liquid asset holdings and a bad income realization predicts borrowing against home equity, and the borrowing allows better consumption smoothing. They use PSID data to demonstrate that the mechanism they describe is present in the data.

In related work using Danish household panel data, Ejarque and Leth-Petersen (2008) demonstrate that new first-time home buyers, who have depleted their financial assets and have borrowed as much as possible to purchase their house, respond to income shocks by reducing consumption. They show that a relatively standard model, such as the one described earlier, can replicate this fact.

Providing further empirical evidence on the housing collateral channel, Hryshko et al. (2010) use data from the PSID linked to MSA geography to show that, after becoming disabled or losing a job, households tap into home equity to smooth consumption when home prices are rising. When house prices are falling, after disability or job loss households reduce consumption. The study authors predict how the empirical results would change if down-payment constraints, adjustment costs, or the correlation of income and price growth were to change.

A related body of literature studies the response of consumption to house prices using microdata. Campbell and Cocco (2007) use UK Family Expenditure Survey data to estimate an elasticity of new consumption spending to exogenous changes in wealth as large as 1.7 for old households that own their home, but close to zero for young households that rent, after controlling for interest rates, household income, and demographics. Consumption responds to predictable changes in house prices, which is consistent with a housing collateral effect. Since it is predictable changes in aggregate and not regional house prices that seem to matter, the collateral effect operates at the aggregate level. This evidence is consistent with the results of Lustig and Van Nieuwerburgh (2010), discussed later, who find evidence for an aggregate housing collateral effect in US MSA-level consumption data.

Li and Yao (2007) also study the differential impact of exogenous changes to house prices on various groups of agents in the economy. An unanticipated positive increase in house prices benefits old homeowners because their remaining life span is short and they can afford more consumption. Despite earning a capital gain, young homeowners are worse off because they have a longer horizon and face higher borrowing costs for their housing. Renting households are strictly worse off after the shock. Li and Yao (2007) also show that the relationship between the uncertainty and volatility of house prices and the probability of home ownership is ambiguous and depends on the degree of household risk aversion.

Bajari et al. (2013) estimate the parameters of the standard life-cycle model presented earlier in this section using PSID data along with auxiliary data on mortgage interest rates and house prices. They simulate the model and compare simulated household responses to a negative house price shock and, separately, a negative income shock. They show that in response to a negative shock to house prices, households accumulate more housing later in life but do not change the basic shape of their life-cycle patterns of spending and saving. In contrast, in response to a negative and unanticipated income shock, households reduce both their housing demand and their consumption.

Attanasio et al. (2011) study the aggregate implications of the life-cycle model described earlier. They show that an unanticipated increase in the level of house prices leads to smaller housing units but not a decline in the home ownership rate, an increase in consumption of the old, and a decrease in consumption of the young. Relative to Li and Yao (2007), Attanasio et al. (2011) add the restriction that the home equity constraint only binds at the time of the purchase, such that households can have negative equity if house prices decline. The model is calibrated to English data.

Finally, Kaplan and Violante (2014) point out that the illiquidity of housing affects the propensity to consume out of fiscal stimulus payments. Many households have substantial illiquid housing wealth but limited liquid wealth. A fiscal transfer, which is an increase in liquid wealth, increases aggregate consumption by a much larger amount than would be predicted from a model economy in which housing and liquid assets are aggregated together and are both considered to be liquid.

12.4.3.1.3 House price risk and demand for housing

Han (2008) studies housing demand when house prices are uncertain and volatile and housing incurs transaction costs. Han emphasizes that although housing is risky, driving down demand, current housing is a hedge against future housing demand shocks since price changes of housing units in the same market are correlated. A related argument was made by Sinai and Souleles (2005). Han uses a variant of the life-cycle framework to determine when, given (a) life-cycle profiles for income and tastes for housing, (b) the probability of moving to a new market with a different level for house prices, and (c) the inherent volatility of house prices in every market, the hedging demand for housing dominates its inherent risk. Han (2008) concludes that the impact of uncertainty of house prices depends on households' future plans. When households expect to increase their holdings of housing in the future, they buy a bigger home today in response to an increase in house price uncertainty. If, instead, households expect to downsize in the future, they reduce their holdings of housing today in response to an increase in house price uncertainty.

Halket and Amior (2013) study the relationship of housing risk and home ownership. They document that house price volatility is negatively correlated with home ownership rates and low loan-to-value ratios at the MSA level. They also show that house price volatility is high where house prices are high, because these areas are areas where land's share of home value is high. They find that a relatively standard model of housing predicts that home ownership rates are low in high house price areas. The model can also explain why loan-to-value ratios are low in areas where house prices are volatile.

12.4.3.2 The role of housing in the financial portfolio

The work of Flavin and Yamashita (2002) is among the first articles in the housing and portfolio-choice literature; it considers a simple mean-variance framework without labor income risk. In addition to their data-based contribution discussed earlier, Flavin and Yamashita (2002) highlight that young households who own housing have a highly levered position that should incentivize them to take less risk in the rest of their portfolio. This intuition qualitatively explains why young households hold fewer stocks. The article also proposes a resolution to an asset allocation puzzle. Standard portfolio theory prescribes that households combine the risk-free assets with the efficient portfolio of all risky assets and vary the holdings of each to suit their level of risk aversion. Financial planners, in contrast, advise clients to vary the proportion of risky stocks and bonds. In Flavin and Yamashita (2002), the latter is optimal since households are at a corner of zero in terms of their risk-free rate holdings.

Unlike Flavin and Yamashita (2002), who consider only the optimal portfolio of owner-occupiers and do not explicitly model life-cycle income and savings decisions of households, Yao and Zhang (2004) study how households optimally choose their portfolio of financial assets using a life-cycle model like the one described earlier where households in the model choose whether to rent or own housing in each period. Agents in their model face the following trade-off: house prices are uncertain and volatile, leading households to want to have fewer stocks, but homeowners can use home equity as a buffer against income shocks, leading households to want to have more stocks. They show that renters and owners choose substantially different portfolios of financial assets, highlighting that conclusions drawn about optimal portfolio allocations over the life cycle from models that do not include a rental/own housing choice may be misleading. For example, when a household transitions from renting to owning in the model, the share of stocks in total wealth falls, but the share of stocks in liquid wealth increases. The reason is that the low correlation of stock and housing returns and the high equity risk premium make holding stocks relatively attractive.

The work of Cocco (2005) is similar to that of Yao and Zhang (2004), and some of the insights—for example, about what drives changes to equity participation over the life cycle—are similar. Cocco (2005) does not allow for a housing tenure decision (everyone owns housing), but includes a fixed cost of stock market participation. The model results in the finding that younger and lower-wealth home-owning households do not participate in the stock market because of the fixed cost of participation. Rather, their portfolios are heavily tilted toward real estate and are highly levered, similarly to the data. The large and risky housing investment makes participation in risky stock markets relatively unattractive in the model. Cocco (2005) shows that a small fixed participation cost in equity markets generates substantial rates of nonparticipation. As households age, leverage declines, stock market participation rates increase, and the share of liquid assets held as stocks rises, just like in the data. Thus, the article shows that stock market participation patterns in the data are less puzzling once the impact of housing is considered.

Like Yao and Zhang (2004), Vestman (2012) studies stock market participation rates for homeowners and renters, but unlike the existing literature, he considers Epstein–Zin preferences, such that the intertemporal elasticity of substitution is governed by a different parameter than the degree of risk aversion. Vestman (2012) also allows these preference parameters to vary across households. His model matches the hump-shaped life-cycle profile of home ownership in the data and generates a flatter and more accurate life-cycle profile of stock market participation than Cocco (2005). Vestman (2012) shows that households with low-risk aversion and high elasticity of intertemporal substitution save less, invest less of those savings in equity, are more likely to not participate in the stock market and are more likely to rent. Using panel data from Sweden, Vestman (2012) documents that stock market participation drops by one-fifth in the year of home purchase, and his model generates a similar sized decline.

12.4.3.2.1 Introducing geography

One important feature of housing most of the literature abstracts from is its spatial aspect. A household's two largest assets, human wealth and housing wealth, are intimately tied to the fortunes of the location where that household lives and works. A large body of literature in urban economics, discussed elsewhere in this handbook, centers around issues of geography. For our purposes, we highlight a few articles that integrate spatial considerations into the financial portfolio choice literature. In Ortalo-Magné and Prat (2013) and Hizmo (2012), households choose where to live once at the beginning of life, and then in each subsequent period they decide on the portfolio composition.[37] For tractability, preferences exhibit constant absolute risk aversion, and consumption occurs at the end of life. In Ortalo-Magné and Prat (2013), households must pay rent where they work but they can invest in housing in every region, separating housing consumption from housing ownership. In Hizmo (2012), households own a home where they work. Markets are incomplete in that there are not enough risky assets to span all the shocks that hit labor income.

Focusing on from the results in Hizmo (2012), once the location has been determined, households optimally hold more of a stock whose returns hedge local income risk. Stocks whose returns covary strongly with house prices are poor hedges and require higher risk premiums. In addition to making risk sharing incomplete, the unspanned regional risk distorts the efficient spatial allocation of labor. Risk-averse households may end up in regions with lower house price volatility rather than where they will be most productive. The normative implication of this work is that households are willing to pay up handsomely for securities that reduce house price volatility.

12.4.3.3 Mortgage choice

Campbell and Cocco (2003) study the risk and return features of the typical mortgage contracts, FRMs or ARMs, when labor income, house prices, and real interest rates are uncertain and the size of the house is predetermined. The expectations hypothesis of the term structure is assumed to hold in their model: long-term bonds and FRMs contain no term risk premium. Campbell and Cocco (2003) note that ARMs are risky because payments might fluctuate more than income or might rise when incomes fall, forcing homeowners to reduce consumption. FRMs are expensive even when inflation is relatively stable because the cost of an FRM includes the value of a prepayment option—if interest rates fall, households have the option to refinance their FRM after paying a small monetary cost. FRMs are cheap only when inflation is high; the study authors refer to this as the wealth risk of FRMs. They document that households with large houses relative to income, with volatile labor income, and with high-risk aversion have a preference for an FRM. Households with a high probability of moving typically

[37] Van Nieuwerburgh and Weill (2010) and Davis et al. (2013) study spatial equilibrium models where agents optimally choose where to live and are mobile in each period. However, while both articles study the equilibrium interactions of housing and migration decisions, neither article studies a portfolio choice problem. Han (2013) also studies differences in expected returns to housing across metropolitan areas, but her study is largely empirical in focus.

prefer an ARM to take advantage of the lower rate. The study authors propose an inflation-indexed FRM, a contract that removes the income risk associated with ARMs but also the wealth risk associated with FRMs.

The share of households that finance a house with an FRM fluctuates significantly over time. To explain this phenomenon, Koijen et al. (2009) solve a two-period mortgage choice model where risk-averse households trade off the expected payments on an FRM and an ARM contract with the risk of these payments. The model generates an intuitive risk-return trade-off for mortgage choice: the ARM contract is more desirable the higher the nominal bond risk premium, the lower the variability of the real rate, and the higher the variability of expected inflation. The model predicts that time variation in the aggregate FRM share is caused by time variation in the bond risk premium, defined as the difference between the long-term bond yield (or FRM rate) and the expected average future short-term bond yield (ARM rate) over the life of the contract. Koijen et al. (2009) specify households form expectations over future short rates inside the model using vector autoregressions, blue chip forecaster data, or a backward-looking weighted average of past short rates. All three produce bond risk premiums whose fluctuations line up with the observed fluctuations in the ARM share in the United States, with the rule of thumb giving the strongest results. Moench et al. (2010) provide out-of-sample support for this theory by showing how the recent decline in rule-of-thumb bond risk premiums can help explain the unusually low ARM share between 2007 and 2010. Badarinza et al. (2013) extend the analysis of term-structure determinants of mortgage choice to multiple countries. Campbell (2013) studies mortgage market design around the world.

A natural question to ask is how the asset side (portfolio choice) interacts with the liability side (mortgage choice) of a household's balance sheet. Van Hemert (2010) extends the basic framework of Cocco (2005) and Yao and Zhang (2004) to include more interesting mortgage choices. He allows households to hold stocks, 1-, 3-, or 10-year long-term nominal bonds, and an ARM or an FRM. In his framework, ARMs are short positions in 1-year bonds, while FRMs are short positions in 10-year bonds. In the benchmark calibration, which features stochastic interest rates, households prefer to finance their house with an ARM to avoid paying the bond risk premium present in an FRM. Since young agents have most of their wealth in human capital, which is analogous to a bond, they invest their financial asset portfolio mostly in stocks. Middle-aged households hold some long-term bonds to hedge against real interest rate changes affecting their ARM. This long-term bond position increases as investors age and the value of their human capital declines. A risk-averse investor in retirement holds a negative position in 10-year bonds and a positive position in short-term bonds, similarly to a hybrid ARM. That position hedges real interest rate risk while avoiding exposure to inflation risk.

In sum, the portfolio choice and life-cycle literature have taken great steps toward understanding the economic forces motivating households' observed asset and liability choices. Housing and mortgage choice are not only key components of households' asset and liability structure, but also play a crucial role in understanding household demand for financial assets and liabilities. In the next section, we investigate how households' demand for housing and financial assets affects equilibrium asset prices.

12.5. HOUSING AND ASSET PRICING

Given that housing importantly affects households' optimal portfolio choices, such as stock holdings, the presence of housing may affect how stocks and other assets are priced in equilibrium. In this section, we review the insights from the asset pricing literature with housing. Specifically, we study endowment economies and discuss models with production in the next section. It is well known that the canonical endowment economies of Lucas (1978) and Breeden (1979) with constant relative risk aversion preferences fail to match the asset pricing data. In particular, predicted risk premiums are too low and do not vary much over time and the risk-free rate is too high and too volatile (Hansen and Singleton, 1983; Mehra and Prescott, 1985; Weil, 1989). Adjusting these models to allow for production, as in Jermann (1998) and others, amplifies these problems.

The asset pricing literature has made great strides in the past two decades in determining the required properties of stochastic discount factors (SDFs) necessary to generate asset-pricing behavior that looks like the data. In summary, SDFs need to be persistent, countercyclical, and heteroskedastic—in particular, higher conditional variance is required in bad times. The external habit framework (Campbell and Cochrane, 1999), the long-run risk framework (Bansal and Yaron, 2004; Bansal et al., 2012), and the variable rare disaster framework (Gabaix, 2012) all deliver SDFs that have these properties, at least in endowment economies. Assumptions on preferences and technology in these frameworks are difficult to test directly. For this reason, economists studying housing have asked if SDFs can be generated that look like the data in a relatively standard model once observable housing-market constraints and frictions are considered.

12.5.1 Representative agent model

The baseline model extends the representative agent endowment economy of Lucas (1978) to allow for two distinct types of "trees" in the economy, one that yields nonhousing goods and services as "fruit" (dividends) and the other that yields housing services. The representative agent owns both types of trees and consumes all fruits. For simplicity, call the nonhousing goods and services nonhousing consumption, denoted c, and call housing services housing, denoted h. In any period t, households in this model choose consumption c_t, housing to purchase h_t at price per unit p_t, and the quantities of each of $i = 1, \ldots, N$ assets A^i_{t+1} to maximize the expected net present value of utility

$$\sum_{t=0}^{\infty} \beta^t E\left[u\left(c_t, h_t\right)\right]$$

subject to the budget constraint in each period

$$c_t + p_t h_t + \sum_i^N A_{t+1}^i \leq \sum_i^N A_t^i \mathcal{R}_t^i + p_t h_{t-1} + w_t,$$

where w_t is income. h_{t-1} and $A_t^i \mathcal{R}_t^i$ for each i are predetermined as of the start of period t; the future realizations of $\mathcal{R}_{t+1}^i$ may be random.

Denote the Lagrange multiplier on the budget constraint at period t as λ_t. The first-order conditions for consumption at t and for the optimal choice of period $t+1$ holdings of asset i are

$$c_t: \ \lambda_t = \frac{\partial u}{\partial c_t},$$
$$A_{t+1}^i: \ \lambda_t = \beta E\left[\lambda_{t+1} \mathcal{R}_{t+1}^i\right].$$

Since households can freely purchase any asset, the second equation above must hold for all assets $i = 1, \ldots, N$. When we combine the above first-order conditions, the return on any asset must satisfy the following equation:

$$1 = E_t\left[M_{t+1} \mathcal{R}_{t+1}^i\right]. \tag{12.12}$$

where M_{t+1} is β times the ratio of the marginal utility of consumption at $t+1$ to marginal utility of consumption at t. M_{t+1} is the SDF. One way to read Equation (12.12) is that it specifies that all assets must pay the same expected return after accounting for risk. The term that determines the required compensation for risk for each asset is the SDF; specifically, the required compensation for risk is largely determined by the covariance of M and $\mathcal{R}$.

Piazzesi et al. (2007) explore the asset-pricing implications of this model when households are assumed to have constant relative risk aversion preferences over a CES bundle of consumption and housing:

$$U\left(c_t, h_t\right) = \frac{\tilde{c}_t^{1-\sigma}}{1-\sigma}, \quad \tilde{c}_t = \left(\alpha c_t^\rho + (1-\alpha) h_t^\rho\right)^{\frac{1}{\rho}}, \tag{12.13}$$

where α is the weight on nonhousing consumption and $\varepsilon = \frac{1}{1-\rho}$ is the elasticity of substitution between c and h. The Cobb–Douglas case ($\varepsilon = 1$ or $\rho = 0$) is a special case and is discussed later.

Given preferences as specified in Equation (12.13), the logarithm of the SDF, call it m_{t+1}, can be written as the product of the standard single-good factor (nonhousing consumption growth) and a new factor that captures the effect of the composition of the bundle of consumption and housing:

$$m_{t+1} = \log \beta - \sigma \Delta \log c_{t+1} + \frac{1-\rho-\sigma}{\rho} \log \left(\frac{1+S_{t+1}}{1+S_t} \right) \quad \text{and} \quad S_t = \frac{c_t}{q_t h_t}. \tag{12.14}$$

q_t is defined as the rental price of one unit of housing, and thus S_t is the ratio of total nonhousing consumption to the rental value of housing.

In the special case of $\varepsilon = 1$—that is, Cobb–Douglas preferences—optimal budget shares on consumption and housing are fixed and the ratio S_t is constant. In this case, the final term of the SDF in Equation (12.14) vanishes. The SDF reverts to that of the one-good endowment economy with its problematic asset-pricing predictions.

Piazzesi et al. (2007) consider values for ε strictly greater than, but close to 1—that is, ρ slightly positive. This choice makes the coefficient in front of the final term negative and large in absolute value. Given this parameterization, consider the covariance of the SDF and the return on an asset. An asset whose return is low when growth in the total expenditure to housing expenditure ratio $1 + S$ is low is risky—thus, it will require a high expected return. When ρ is slightly larger than zero, the two-factor model with housing has the potential to explain equity risk premiums. The model also implies that the ratio of nonhousing to housing consumption predicts future stock returns, a prediction Piazzesi et al. (2007) show is supported in the data.

Davis and Martin (2009) estimate the preference parameters generated by this model and argue that it fails to simultaneously price a portfolio of stocks and T-bills. Their generalized method of moments estimate of ρ is 0.2 (standard error 0.05). This value is too far from zero to deliver the required amplification to the standard Lucas–Breeden kernel in order to simultaneously price stocks and bonds. Davis and Martin (2009) expand their model to allow for leisure and home production rather than housing to enter utility. In each of these cases, they show that the model cannot price a portfolio of stocks and T-bills.

In related work, Yogo (2006) studies a model with Epstein–Zin preferences over a CES aggregate of nondurable and durable consumption. He shows that when the elasticity of substitution between nondurable and durable consumption is higher than the intertemporal elasticity of substitution, the marginal utility of consumption rises when durable consumption falls, which is in bad times. Using asset return data, he estimates a value of the intratemporal elasticity ε of 0.5–0.7 and a low value of 0.023 for the elasticity of substitution (alongside an unappealingly high value for the coefficient of relative risk aversion). If that 0.5–0.7 estimate for ε is valid for housing, too little action will be generated by the SDF to deliver plausible asset-pricing implications.

Like the previous articles, Flavin and Nakagawa (2008) consider a model with CES-aggregated preferences over nondurable consumption and durable housing. However, they study how the illiquidity of housing alters the SDF, building on the seminal article by Grossman and Laroque (1990). The presence of nonconvex adjustment costs makes the house a state variable, generating an SDF that displays considerable volatility and that depends on the history of wealth. Furthermore, adjustment costs allow a decoupling of relative risk aversion from the intertemporal elasticity of substitution while maintaining standard preferences—that is, time-separable utility. Given the similar properties of the SDF, the housing model with adjustment costs produces a structural interpretation of an external habit. Furthermore, the housing adjustment model outperforms both the standard external habit model and the constant relative risk aversion model. The Euler equation for individual household's housing returns cannot be rejected, and the study authors estimate a plausible parameter value of $\sigma = 1.8$. They also estimate $\varepsilon = 0.13$ ($\rho = -6.7$), suggesting that housing expenditure shares rise by a lot in response to an increase in house prices, a result that is at odds with work by Davis and Ortalo-Magné (2011) and others that estimates that the expenditure share on housing is roughly fixed.

Finally, recent work by Giglio et al. (2014) uses data on housing, specifically data on long-term property leases, to reexamine the shape and structure of SDFs. Giglio et al. (2014) compare the prices of freeholds (indefinite ownership of property) with those of leaseholds (very long term but finite ownership) in England, Wales, and Singapore. They find that leaseholds trade at a substantial discount to freeholds, implying that housing services in the distant future are discounted at a surprisingly low rate. This result contradicts implications of the articles by Campbell and Cochrane (1999), Bansal and Yaron (2004), Bansal et al. (2012), and Gabaix (2012) discussed earlier. Combined with the high average returns on housing, inclusive of the entire stream of housing services, the work of Giglio et al. (2014) suggests that most of the reward for investing in housing reflects compensation for near-term risk rather than long-term risk, consistent with the findings of van Binsbergen et al. (2012) for the equity market. Their result suggests future researchers should search for preferences and constraints such that an asset-pricing model can generate a downward sloping term structure of housing and equity risk premiums.

12.5.2 Risk sharing with housing collateral

Lustig and Van Nieuwerburgh (2007) study the asset-pricing implications when housing is used as collateral. They model a heterogeneous agent economy with two "Lucas"-type trees, nonhousing goods and housing, as in the model of Piazzesi et al. (2007). The aggregate endowment of dividends of both trees is stochastic, and households differ in their realizations of the nonhousing endowment (labor income). Households have access to a full set of securities to share their income risk with each other. The key friction in the model is that households cannot commit to repaying their debt. This friction limits the degree of risk sharing that can be achieved as in the limited commitment model of Alvarez and Jermann (2000, 2001). Unlike other models in which households that default are denied access to financial markets, the punishment for default in Lustig and Van Nieuwerburgh (2007) is the loss of housing collateral. As a result, in equilibrium, households' borrowing is limited to the value of the collateral. Equivalently, the housing collateral constraint can be thought of as a solvency constraint which keeps households' net worth strictly positive. Since future labor income cannot be pledged, housing is the only collateralizable asset in the model.

A key state variable of the model is the ratio of housing wealth to total wealth, the "housing collateral" ratio. When the housing collateral ratio is high, risk sharing is nearly complete and the economy's allocations and prices are close to those of the representative-agent Lucas economy. When housing collateral is scarce, risk sharing is incomplete. In this environment, agents who have received persistent positive income shocks require an increase in their share of nonhousing and housing consumption to encourage them to continue to participate in risk-sharing arrangements. Unconstrained agents experience a reduction in their share of aggregate consumption. The net effect is that cross-sectional distribution of consumption growth widens and risk sharing deteriorates.

Lustig and Van Nieuwerburgh (2007) show that the logarithm of the SDF of this economy contains a new term, $\sigma\Delta\log\xi^a_{t+1}$, which measures the extent to which housing collateral constraints bind in the economy[38]:

$$m_{t+1} = \log\beta - \sigma\Delta\log C_{t+1} + \frac{1-\rho-\sigma}{\rho}\log\left(\frac{1+S_{t+1}}{1+S_t}\right) + \sigma\Delta\log\xi^a_{t+1}. \qquad (12.15)$$

Note that the housing collateral effect operates even when preferences are separable between housing and nonhousing consumption, or when the aggregator of these two goods in utility is of the Cobb–Douglas type. A key implication of this framework is that the degree of risk sharing and equilibrium asset prices vary with the housing collateral ratio. The persistent and countercyclical movements in the housing collateral ratio lead to persistent countercyclical movements in the SDF. Times of scarce housing collateral lead to high market prices of risk and high conditional volatility (heteroskedasticity) in the SDF. In addition, the model delivers a downward sloping term structure of equity and housing risk premiums, consistent with the findings of van Binsbergen et al. (2012) and Giglio et al. (2014) cited above.

Lustig and Van Nieuwerburgh (2005) test three asset-pricing predictions of the model of Lustig and Van Nieuwerburgh (2007). First, a low housing collateral ratio should predict periods of high market prices of risk and therefore high future excess returns on stocks. Regressions on the predictability of US stock returns confirm this. Second, in the cross section, risky assets have returns that covary strongly with aggregate consumption growth when housing collateral is scarce and opportunities for risk sharing are limited, as predicted by the model. Third, as shown in Equation (12.15), the model predicts that an augmented "conditional" consumption capital asset pricing

[38] Specifically, ξ^a_{t+1} is a cross-sectional moment of individual ξ^i_{t+1}. The latter are cumulative Lagrange multipliers on the housing collateral constraint. These multipliers increase over time whenever an agent's constraint binds, but otherwise stay constant. When no agent's constraint binds, $\Delta\log\xi^a_{t+1} = 0$.

model, that is, a consumption capital asset pricing model augmented with a housing collateral term, should be able to fit data on returns. Using the housing-collateral consumption capital asset pricing model augmented implied by Equation (12.14), the model is able to account for more than 80% of the cross-sectional variation in size, book-to-market portfolios, a long-term bond portfolio, and the overall stock market portfolio. It is also able to reconcile the difference in expected returns between value and growth stocks.[39]

An advantage of the limited commitment framework is that it gives rise to a unique SDF despite the presence of endogenously incomplete markets. Because unconstrained agents price the assets at each date and state of the world, the SDF is volatile, which is key for asset-pricing predictions. A disadvantage of the model is that default only occurs for "strategic" reasons. In the data, many households default for liquidity reasons—that is, low income realizations. The next section discusses models of housing default in some detail.

12.6. THE HOUSING BOOM AND BUST AND THE GREAT RECESSION

A recent body of literature explores models that can simultaneously generate plausible business cycle moments, as discussed in Section 12.3, realistic life-cycle consumption-savings and portfolio profiles, as discussed in Section 12.4, and sufficiently volatile house and asset prices, as discussed in Section 12.5. Much of the work in this area focuses on the epic housing boom and bust of the first decade of the twenty-first century and studies how changes in the lending environment affected home ownership rates, house prices, and other macroeconomic aggregates. These articles usually depart from the representative agent framework: agents differ by age, income, and wealth; some agents rent and some own housing; and some agents borrow and others lend money. We start by discussing several articles that assume that house prices are fixed—either they are set outside the model or they are trivially pinned down by a simple production function for housing. These articles differ from the portfolio literature discussed earlier in that they study events of the past 15 years and focus on heterogeneity across agents. We then review studies where house prices are determined endogenously in the model economy. In both cases, we distinguish between models that allow for default and those that do not. The models with default naturally focus on the housing bust. While these models are simpler to solve, the literature with exogenous house prices faces the criticism that it ignores the fact that changes in the model environment associated with the housing boom or bust may well affect house prices.

[39] In addition, Lustig and Van Nieuwerburgh (2010) document using quantity data that the degree of risk sharing between US metropolitan areas decreases when housing collateral is scarce.

12.6.1 Exogenous house prices, no default

A first branch of the literature studies the consequences of innovation in housing finance, through either lower down-payment constraints or the availability of new mortgage contracts. Silos (2007a) studies an equilibrium model with owner-occupied housing where agents differ in age, income, and wealth and the price of housing is fixed. He shows that a relaxation of down-payment constraints does not change the business-cycle properties of the model, but affects residential and nonresidential investment decisions of the young and poor. Silos (2007b) shows that adding rental housing as a choice greatly helps models such as those of Fernández-Villaverde and Krueger (2011) and Diaz and Luengo-Prado (2010) explain the distribution of wealth by age, since the choices of renters, who are younger and poorer on average, are not well captured by models without renting.

Chambers et al. (2009a) study a model with different mortgage choices to determine the extent to which reductions in down-payment constraints and availability of second mortgages increased the home ownership rate in the United States between 1994 and 2005. Agents in their model face idiosyncratic income and mortality risk, and idiosyncratic capital gains upon house sales but no aggregate risk. The model also includes a market for rental services. The study authors show that most of the increase in home ownership rates over this period is attributable to the availability of second mortgages. In closely related work, Chambers et al. (2009c) study how the multiple mortgage contracts that coexist in equilibrium affect home ownership rates, the size of owned housing, and risk sharing. They first assume the economy has one type of mortgage, the FRM, and then ask what happens if a second type of mortgage is added to the economy. Different types of mortgages are considered in the experiment. The addition of mortgage contracts that allow for lower down payments or increasing payment schedules over time increases the home ownership rate.

Iacoviello and Pavan (2013) study the business cycle properties of a life-cycle model with housing where agents differ in their discount factor and preference for renting. House prices are fixed and mortgage default is not allowed. They show that the model can replicate the basic life-cycle facts discussed earlier, but can also account for the procyclicality of household debt. The heterogeneity in the model is sufficiently rich to match observed inequality in wealth. The model attributes the Great Moderation (a period of reduced volatility of major macroeconomic aggregates that occurred from the early 1980s until the early years of the twenty-first century) to lower down-payment constraints and increased individual earnings volatility. On the one hand, the reduction in down payments leads to an increase in home ownership and a reduction in the volatility of housing investment because homeowners face adjustment costs in changing investment, whereas renters do not. On the other hand, the increase in earnings volatility makes people less likely to be homeowners and less willing to buy an asset subject to transactions costs. Thus, the impact on housing volatility is ambiguous, since renters adjust more but homeowners adjust by much less, again due to transactions costs. The study authors argue that the reduction of housing investment during the Great Recession was the consequence of tightening financial conditions coupled with a bad aggregate productivity shock.

12.6.2 Exogenous house prices with default

A second branch of the literature aims to understand observed mortgage defaults in the housing bust by studying optimal mortgage default models that take house prices as given. House price shocks, unemployment shocks, home equity extraction, and new mortgage contracts are four (interacting) channels of interest in this literature.

Campbell and Cocco (2012) study how default rates vary by mortgage type (FRM, ARM, and interest-only mortgage). They solve the problem of a household that must decide how much to consume and whether to default on the mortgage. The household faces idiosyncratic income risk, as well as house price and interest rate risk. When home equity becomes sufficiently negative, households default. The negative-equity threshold for default depends on the degree to which households are borrowing constrained, which itself depends on income shocks, interest rates, and the terms of the mortgage contract (ARM vs. FRM). Higher loan-to-value ratios affect default probabilities by increasing the likelihood of negative equity and reducing incentives for repayment. A higher debt-to-income ratio also increases default by reducing the affordability of mortgages, making borrowing constraints more likely to bind and reducing the threshold level of negative equity that triggers default.

Taking house prices, interest rates, and aggregate income as given, Chen et al. (2013) investigate why households increased mortgage debt during the recent housing boom. In their model, agents can either rent or own housing, and if they own hosing, they can finance it with a mortgage. In every period, agents can invest liquid assets at the risk-free rate, refinance a mortgage, take out a home equity loan (home equity line of credit), sell the home, or default. Both mortgages and home equity lines of credits are subject to loan-to-value and loan-to-income limits; mortgages are long-term contracts that can be refinanced at a cost. The article avoids the simplifying assumption made in most of the portfolio literature that mortgages are negative bond positions. Under the set of housing-finance frictions considered, the study authors demonstrate that the model can replicate the observed quantity of mortgage debt accumulation (Figure 12.7) given observed dynamics for income and house prices.

Like Chen et al. (2013), Laufer (2013) studies the importance of home equity extraction in accounting for the observed surge in mortgage defaults during the housing bust. In his model, households can refinance their mortgage at a cost and are subject to collateral constraints. Mortgages are nonrecourse in the model, but on default households are forced to rent. He estimates the parameters of his model using income data from the

PSID, asset data from the SCF, and data on the experiences of a large panel of Los Angeles homeowners. Given realized house-price dynamics, the model can replicate the observed time series of home equity extraction, home sales, and mortgage defaults at different loan-to-value ratios. In his model, homeowners extract equity when house prices increase and when liquid assets are close to zero. He shows that when homeowners have strongly positive house price expectations, they use home equity extraction to finance additional consumption. The model attributes the increase in mortgage defaults to negative house price shocks wiping out home equity rather than to negative income/unemployment spells. Laufer (2013) runs counterfactual experiments with his model to study the implications of two policies that might reduce default: tighter borrowing constraints and stronger recourse. Under both policies, defaults fall sharply and less home equity is extracted.

Hatchondo et al. (2013) add mortgage default to the standard life-cycle model described in the previous section. Similarly to what is done by Campbell and Cocco (2003), the size of housing is fixed. The study authors allow households in each period to choose their down payment (which then implies a particular fixed mortgage payment) and they then solve for the zero-profit mortgage rate associated with each mortgage.[40] Similar to Li and Yao (2007), Hatchondo et al. demonstrate that house price shocks are not an important source of consumption inequality. The focus of the article is on two policies than can reduce default: tighter borrowing constraints and stronger recourse, as in Laufer (2013). First, requiring a 15% down payment relative to an economy without a down-payment constraint minimally impacts the home ownership rate (it falls from 63.1% to 62.9%), but lowers defaults on mortgages by 30% (from 0.6% to 0.4%). Young potential home buyers are worse off because of the increase in down-payment constraints, but existing homeowners benefit since they can refinance at the lower interest rate that arises as a result of lower default. Second, a policy of temporary income garnishment as a punishment for default holds fixed the variance of consumption but otherwise reduces default rates, boosts home ownership rates, and reduces down-payment percentages.

Corbae and Quintin (2015) study the rise in foreclosures in the housing bust and ask how much can be explained by the large number of high-leverage mortgage contracts. They model households who choose between different mortgage contracts and face exogenous income and house price shocks. They show that the relaxation of credit constraints during the housing boom can account for more than 60% of the increase in foreclosures during the housing bust. This result holds despite the fact that each mortgage contract is priced such that mortgage originators earn zero expected profits, so the surge in foreclosures does not represent *ex ante* mispricing of loans. The result arises for two reasons: The higher loan-to-value ratios allowed after relaxation of constraints imply that

[40] Since households with positive equity can refinance, they can essentially choose their sequence of mortgage payments.

households are more likely to have negative equity in the event of a bad realization of house prices; and the relaxation of constraints allowed borrowers more prone to default (i.e., they had lower income and less assets) to purchase housing.

In related work, Garriga and Schlagenhauf (2009) argue that an essential feature to understand the spike in the foreclosure rate is leverage. An increase in leverage exposes homeowners to additional risk in the event of declines in house prices. To test the quantitative importance of the leverage channel, the study authors develop an equilibrium model of long-term mortgage choice and default. The model captures the pattern of foreclosure rates across loan products observed in the subprime crisis. The decline in house prices can account for most of the observed increase in the foreclosure rate and decline in home ownership in the United States.

In sum, the combination of home equity extraction during the boom—facilitated by new mortgage contracts—and sustained by rising house prices, combined with a negative house price shock during the bust, goes a long way toward accounting for the observed run-up of mortgage debt and the subsequent foreclosure rates. The natural next step in this literature is to endogenize house prices in the boom and bust.

12.6.3 Endogenous house prices, no default

Predating the housing boom and bust, Stein (1995) and Ortalo-Magné and Rady (2006) studied the effect of down-payment constraints on equilibrium house prices and housing transactions. They explain how changes to constraints or income for people purchasing at one end of the housing ladder alter the entire distribution of house prices. The last few years has seen a burst of research activity trying to account for the massive rise in housing prices during the boom in models with down-payment constraints.

Recently, Kiyotaki et al. (2011) use a general equilibrium life-cycle model to study the implications of an unexpected increase in land's share of housing in an environment where interest rates are set outside the model. They show that when land's share of the value of housing rises, land and house prices become more sensitive to productivity shocks and to shocks to world interest rates, causing a large redistribution of wealth between net buyers and sellers of housing in response to these shocks. They show that after an increase in the share of housing attributable to land, a tightening of financial constraints does not impact house prices.

In contrast with the previous article, Chu (2014) shows that a relaxation of credit constraints can cause a big change in the purchase price of owned houses relative to the rental price of rental properties if owner-occupied and rental properties are inelastically supplied and if conversion from rental property to owner-occupied property and vice versa is costly. Chu (2014) also finds that changes in supply of housing and changes in the process for income (an increase in the level and the volatility) importantly affected house prices from 1995 to 2005. He shows that the transition path from an initial steady state to a new steady state at different levels of income volatility and credit constraints produces an "overshooting" of house prices—house prices initially rise above their new steady-state value and then slowly decline, as predicted by Ortalo-Magné and Rady (2006).

In earlier work, Favilukis et al. (2011) aim to explain why house prices are more volatile than rents. They also seek to explain the slow but large increase in the price–rent ratio during the housing boom. They study a two-sector general equilibrium model of housing and nonhousing production, using a production framework similar to that of Davis and Heathcote (2005), but where heterogeneous households face limited risk-sharing opportunities as a result of incomplete financial markets. A house in the model is a residential durable asset that provides utility to the household, is illiquid (expensive to trade), and can be used as collateral in debt obligations. The model economy is populated by a large number of overlapping generations of households who receive utility from both housing and nonhousing consumption and who face a stochastic life-cycle earnings profile. Market incompleteness arises because heterogeneous agents face idiosyncratic and aggregate risks against which they cannot perfectly insure themselves, and because of collateralized borrowing constraints on households, as discussed in Section 12.4.

Favilukis et al. (2011) study the macroeconomic consequences of three systemic changes in housing finance, with an emphasis on how these factors affect risk premiums in housing markets, and how risk premiums in turn affect home prices: the impact of changes in housing collateral requirements, the change in borrowing costs (the spread of mortgage rates over risk-free debt), and the impact of an influx of foreign capital into the domestic bond market.[41] These are meant to capture important changes to the US economy after the year 2000.[42] To model capital inflows, the third structural change in the model, Favilukis et al. introduce foreign demand for a domestic risk-free bond into the market clearing condition for that asset. Foreign capital purchases of the risk-free US bond are determined outside the model.[43]

According to the model, price–rent ratios increased during the housing boom owing to the simultaneous occurrence of positive aggregate productivity shocks and a relaxation of credit standards. Both of these events generated an endogenous decline in risk premiums on housing and equity assets, and the decline in housing risk premiums generated the increase in house prices relative to (imputed) rents. Risk premiums in the model fell for two reasons. First, lower collateral requirements directly increased access to credit,

[41] Garriga et al. (2012) also study the impacts of these changes on land and house prices, but they assume a representative agent and do not allow for aggregate shocks to productivity.

[42] Van Nieuwerburgh (2012) and Favilukis et al. (2013) provide detailed evidence on all three changes and supporting references.

[43] Krishnamurthy and Vissing-Jorgensen (2012) estimate that such foreign governmental holders, such as central banks, have a zero price elasticity for US Treasuries, because they are motivated by reserve currency or regulatory motives (Kohn, 2002).

which acted as a buffer against unexpected income declines. Second, lower costs of borrowing reduced the expense of obtaining the collateral required to increase borrowing capacity and provide insurance. The model attributes the housing bust to a sudden tightening of credit constraints and a set of negative economic shocks.

Favilukis et al. (2011) attribute changes in price–rent ratios during the housing boom and bust largely to changes in housing risk premiums and not to changes in risk-free interest rates. In the model, if credit standards become laxer, the need for precautionary savings falls, which, by itself, generates an increase in risk-free interest rates. If price–rent ratios increase following a relaxation of credit standards, absent other changes, the model suggests that housing risk premiums must have declined by more than the increase in risk-free rates.

Of course, during the housing boom, risk-free interest rates did not increase, but rather declined. Favilukis et al. attribute the decline in risk-free rates to an increase in foreign purchases of domestic bonds. They suggest that the decline in interest rates did not, by itself, cause house prices to boom relative to rents. The reason is that foreign purchases of domestic bonds forced US savers to purchase more equity and housing than they would have otherwise desired, thus increasing risk premiums on housing and lowering house prices and the price of other risky assets.[44] In addition, Favilukis et al. suggest that foreign capital inflows stimulated residential investment, raising the expected stock of future housing and pushing down house prices. They thus suggest the net effect of a large capital inflow from abroad into safe securities depressed real risk-free interest rates but had only a small effect on house prices.

In summary, Favilukis et al. argue two opposing forces affected the price of housing risk during the housing boom and bust. During the boom, credit standards were relaxed, lowering risk premiums, and foreigners bought more US bonds, raising risk premiums. With the model's calibrated parameters, the decline in risk premiums from the effects of the former exceeded the rise in risk premiums from the latter. During the bust, in which capital inflows held constant but credit standards were tightened to their preboom levels, risk-free interest rates remained low but risk premiums rose, lowering house prices relative to rents.[45]

Boldrin et al. (2013) explore the role of the construction sector in explaining changes to aggregate employment and output during the housing boom. They emphasize that the construction sector has important interlinkages with other sectors of the economy, and that variation in the demand for residential investment propagates to aggregate output through these linkages. After calibrating these linkages using input–output data, the study

[44] Campbell et al. (2009) show that prior to the housing boom and bust, the historical covariance of risk-free interest rates and the risk premium to housing was negative.

[45] In related work, Favilukis et al. (2012) study the welfare implications of a reversal of (stochastic) foreign purchases of safe US debt.

authors estimate that the construction sector accounted for 29% of the growth in employment and 8% of the change in GDP during 2002–2007. They also estimate the contribution of construction to the decline in employment was 28% and its contribution to the decline of GDP was 43% during the Great Recession.

In a detailed study of the housing market of San Diego, Landvoigt et al. (2013b) emphasize heterogeneity in the quality of housing. They show that the areas of San Diego that experienced the largest housing boom also experienced the greatest bust. They propose a model in which households are assigned to houses of various quality, and study how changes in income and asset distributions changed assignments between 2000 and 2005. Landvoigt et al. (2013b) show that a relaxation of credit constraints played an important role in determining the cross-sectional patterns of capital gain to house prices. The study complements the previous literature in that it infers the importance of the relaxation of credit constraints on house prices using data from within one metropolitan area. It also extends the housing ladder model of Ortalo-Magné and Rady (2006) by considering more quality types of housing.

12.6.4 Endogenous house prices with default

A final strand of the general equilibrium heterogeneous agent literature studies mortgage default. These models add endogenous house price determination to the partial equilibrium framework of the default models discussed in Section 12.6.2. The feedback between foreclosures and house prices is important in accounting for the substantial house price decline in the bust. Particularly, Chatterjee and Eyigungor (2009, 2011, 2012) and Hedlund (2014) build general equilibrium models of housing in order to evaluate the effects of the drop in house prices and a change in housing supply on equilibrium foreclosure rates. Like the default models with exogenous house prices, their focus is to understand the underlying reasons for, and consequences of, the recent foreclosure crisis.

Chatterjee and Eyigungor (2009) attribute the foreclosure crisis to overbuilding: an increase in housing supply not matched by an increase in demand. House prices must fall to absorb the excess supply. Because of leverage, the initial fall in house prices pushes some households into foreclosure and forces them to demand a smaller house in the rental market. For housing markets to clear, house prices must adjust downward even further.

Jeske et al. (2013) assume mortgage contracts last one period and study the effects of a specific government housing market policy, as discussed in Section 12.7. Combining the assumption that contracts last one period with perfect competition delivers a sharp characterization of equilibrium mortgage interest rates and default policies.[46] Minimum down-payment requirements arise endogenously in the model of Jeske et al. (2013). The same result occurs in Arslan et al. (2013), who study a model with default and

[46] In related work, Mitman (2012) considers the interaction of recourse and bankruptcy on the decision to default in an environment with one-period mortgages and costless refinancing.

endogenous house prices and evaluate how the model's predictions change when down-payment constraints, interest rates, or unemployment rates change.

Hedlund (2014) models a search friction and emphasizes that housing illiquidity, measured by the probability of selling a home (or the time on the market), increases the probability of default for a financially distressed homeowner. Mortgage banks charge a higher default risk premium on new mortgages in times of housing illiquidity, which tightens borrowing constraints and causes mortgage illiquidity. Higher mortgage rates force some households to sell rather than to refinance their mortgage. These tend to be households with high loan-to-value loans. With high asking prices, their homes are unlikely to sell, worsening housing liquidity. More homeowners also go into foreclosure, and the selling delays associated with real-estate-owned properties further increase housing illiquidity. The interaction between housing and mortgage illiquidity increases equilibrium house price volatility. It generates house prices, mortgage debt, time on the market, and foreclosure dynamics in line with the data. A policy that improves lenders' recourse reduces house price and residential investment volatility, increases existing sales volatility, and all but eliminates foreclosures.

In sum, the literature has made great strides in accounting for the boom and bust in house prices in models with heterogeneous borrowers and lenders, and borrowing constraints that depend on endogenously determined house prices. In response to large and unforeseen changes in credit constraints, these models can generate booms and busts in house prices of nearly the same amplitude as observed in the 2000–2010 period. While this result is useful and informative, it leaves unanswered a set of primary questions that in our view should be the focus of future research: Why did credit constraints change, why were the changes unforeseen, and are large and unforeseen changes in credit constraints necessary to generate large house price fluctuations or can other changes or mechanisms generate the same-sized booms and busts? The models in this section also do not allow any direct feedback from changes in house prices and defaults to measured aggregate productivity and economic activity more broadly. Exploring this link seems quite important as casual empiricism suggests the Great Recession was caused by a financial crisis resulting from a relatively small number of mortgage defaults.

12.7. HOUSING POLICY

A host of government policies subsidize mortgage debt and provide financial incentives for home ownership. Economists and policy makers are concerned with the welfare implications of these policies and their impact on home ownership, house prices, mortgage debt, and financial stability. In this section, we briefly discuss research that evaluates the effect of housing policy on outcomes, such as housing demand and house prices, and welfare using the tools of modern quantitative macroeconomics. In our view, this is an important topic where research is needed. Events of the past 15 years suggest that the existing housing finance architecture has proven deficient in providing a stable environment in which the young or poor would be comfortable with the risks associated with home ownership. Studying the effects of a major overhaul of that system requires a general equilibrium analysis, using the tools described in this chapter. We close by discussing briefly literature studying the interaction of monetary policy and housing/mortgage markets, and recent literature evaluating mortgage modification programs.

12.7.1 Mortgage interest rate deductibility

The early literature focuses on the effects of the mortgage interest rate deductibility. One of the earliest articles in this literature is by Gervais (2002), who studies the impact of the tax code on the accumulation of housing and other wealth in a general equilibrium model. He finds that the failure to tax imputed rents from owner-occupied housing and the tax deductibility of mortgage interest distort the rate of return on housing capital as compared with business capital. If the government were to tax imputed rents, holding total revenue collected unchanged by lowering income taxes, the stock of business capital would increase by 6%, the stock of housing capital would decrease by 8%, and one-quarter of households that own housing would switch to renting. The elimination of mortgage interest deductibility leaves the total stock of housing capital unchanged, but increases the rental stock relative to the owner-occupied stock. Both policies would be uniformly welfare improving. Note that Gervais (2002) holds house prices fixed—output can be costlessly transformed at a one–to–one rate into consumption, business investment, or residential investment.

Chambers et al. (2009b) document that most rental properties in the United States are owned by households. They model the decision to invest in rental housing and analyze the connection between the asymmetric tax treatment of homeowners and landlords and the progressivity of income taxation. They find that eliminating the mortgage interest deduction—assuming budget neutrality—has a positive effect on home ownership because it lowers the average tax rate in the economy. This leads to an increase in average household income and wealth. Under the assumption that house prices are fixed, the increase in wealth prompts a switch from renting to owning.

In contrast to the previous articles, Sommer and Sullivan (2013) endogenize not only rental but also ownership prices. They include a very detailed treatment of the tax code in their model. They show that repealing tax deductions causes house prices to decline but does not affect rents. The decline in house prices and price–rent ratios boosts home ownership as it encourages more young people to save for a down payment on a house. In some simulations of alternative government tax policies, the home ownership rate rises by almost eight percentage points. Eliminating mortgage interest rate or property tax deductibility also shifts housing consumption from the rich to the poor and is associated with an overall welfare gain.

Floetotto et al. (2012) investigate the same policy changes but focus on the welfare effects in the transition between steady states. Upon removal of the tax on rental income and the interest rate deductibility of mortgage interest, a quarter of households suffer initial welfare losses, driven by house prices that fall by 4% on impact before recovering to a 1.6% decline relative to the initial steady state. The initial welfare losses are largely borne by middle-income earners in their model. The alternative policy of eliminating the asymmetric tax treatment of owner-occupied and rental housing by taxing imputed rents leads to a larger fraction of initial losers (a third) and affects wealthy households the most. This article underscores the importance of endogenizing house prices when evaluating how tax policy affects housing markets. In sum, abolishing current tax expenditures that benefit homeowners would substantially increase welfare, increase home ownership, and reduce inequality, but may lead to temporary capital losses for existing homeowners.

12.7.2 Housing finance intermediaries

A conceptually similar question asks how the government-sponsored enterprises (GSEs) Fannie Mae and Freddie Mac distort US housing markets.[47] Jeske et al. (2013) study the effect of bailout guarantees to the GSEs, modeled as a 0.3 percentage point subsidy to the mortgage interest rate and financed by taxes on income. This interest rate subsidy is regressive, hurting low-income, low-asset renters and homeowners with a small mortgage, while benefiting the wealthy. The subsidy affects the amount of leverage in the housing system and its distribution, but has little effect on the home ownership rate. Eliminating the subsidy increases aggregate welfare and is especially beneficial to low-income, low-asset households.

Studying the GSEs is part of an important area of future research that will take seriously the role that intermediaries play in the housing finance system. The financial regulatory reforms enacted in the Great Recession prompted economists to understand better how regulation affects the behavior of these financial intermediaries and the housing outcomes they influence. Quantitative research on this important topic has just begun. Landvoigt (2012) models a banking sector that intermediates mortgage credit between borrowers and savers, and studies the effects of bank capital regulation and the cost of raising equity on house prices, risk sharing, and welfare. He also studies the effect of lower cost mortgage securitization as an alternative to mortgage banking. He concludes that securitization accounted for approximately 30% of the increase in mortgage debt during the period in which collateral constraints on housing were relaxed. In the model, securitization lowers borrowing costs, leading to more valuable collateral; and the lower intermediation costs cause a faster transition to a high-debt regime.

[47] See Acharya et al. (2011) for a discussion of the historical evolution of the GSEs and a plan to reform them.

12.7.3 Housing and monetary policy

A chapter on housing and the macroeconomy would be incomplete without mentioning literature that explores the role that housing plays in transmitting monetary policy. The two best-known articles in this area are by Iacoviello (2005) and Iacoviello and Neri (2010). The production side of Iacoviello and Neri (2010) is similar to that of Davis and Heathcote (2005), but other key features of the model are different. Rather than a representative household, Iacoviello and Neri (2010) have two types of households, patient and impatient, with impatient households always borrowing constrained. An increase in house prices allows impatient households to borrow and consume more. The model also has features common to the new-Keynesian framework: monopolistically competitive firms, sticky prices, and a monetary authority setting interest rates according to a Taylor rule. The benefit of this additional richness is that the model can match many business cycle moments. Iacoviello and Neri (2010) demonstrate that monetary policy shocks account for about 15–20% of the cyclical variation in house prices and residential investment. They also show that technology shocks and monetary policy shocks cannot fully account for the increase in house prices during the housing boom. Rather, their model attributes two-thirds of the increase in house prices during the boom to shocks to preferences for housing.[48]

Recent work by Garriga et al. (2013), building on the work of Kydland et al. (2012), explores how monetary policy can affect the dynamics of residential investment. Unlike the articles by Iacoviello (2005) and Iacoviello and Neri (2010), they specify mortgage payments are in nominal terms and do not model any other nominal rigidity. Changes in monetary policy affect the distribution of real payments of mortgages over the life of the loan (the "price" effect) but also affect the amount of interest paid (the "wealth" effect). The study authors show that monetary policy has a great influence on housing in economies with ARMs rather than FRMs: price and wealth effects tend to reinforce each other with ARMs and offset each other with FRMs.

Midrigan and Philippon (2011) examine the cross-sectional relationship between household leverage, house prices, and unemployment, motivated by the empirical evidence in Mian and Sufi (2009). They observe that the regions with the largest changes to household debt also experienced the largest declines in employment and output during the financial crisis. To match this fact, they study a model with a cash-in-advance constraint, but where households can borrow against their home equity using a home equity line of credit. They show that the presence of cash-in-advance constraints generates a decline in employment after borrowing constraints are tightened: the tightening of liquidity constraints reduces the velocity of money and triggers a recession. To account

[48] Aruoba et al. (2014) also study the impact of monetary policy on housing in a model where housing is a capital input to home production. Their focus is on the relationship between steady-state inflation rates and the level of house prices and aggregate welfare.

for the cross-sectional pattern of leverage and employment in the data, the model also features wage rigidities and labor reallocation frictions.

Feroli et al. (2012) argue that a physical overhang of existing homes, depressed house prices due to foreclosures, and tight credit conditions all impaired the normal monetary transmission mechanism. They argue that policies that subsidize the refinancing of under-water mortgages and speed the transition from foreclosure to real estate owned by banks will improve the effectiveness of monetary policy.

12.7.4 Mortgage modification programs

Related literature analyzes the 2009 Housing Affordable Modification Program (HAMP) and asks how many foreclosures HAMP prevented and at what cost (Agarwal et al., 2012; Scharlemanny and Shorez, 2013; Hembre, 2014). We think a potentially interesting line of research embeds HAMP and other foreclosure-relief policies into a general equilibrium model and studies the extent to which these policies altered the level of house prices and overall welfare.

12.8. CONCLUSION

The recent housing boom and bust and financial crisis have renewed the curiosity of economists of all stripes about the interplay of housing, finance, and macroeconomics. In this chapter, we have surveyed the state of research in this field with an emphasis on its development over the past decade. While much progress has been made, many challenges and interesting problems remain.

One unsettled debate concerns the origins of the housing boom and bust and, related, why a relatively modest number of mortgage defaults precipitated a financial crisis and a severe recession. A common explanation is that housing boomed owing to the availability of exotic mortgage products and an expansion of mortgage credit. This pushes the question back one level. Specifically, why did these mortgage products become available or more widely adopted, and did the availability of these products cause house prices to rise, or did the products emerge because market participants expected continued appreciation of housing? Similarly, if house price expectations are to blame, what triggered the change in expectations?[49]

In our view, researchers should be focusing on the role played by housing and real estate in causing financial crises, if any, and on the welfare consequences of government policies designed to encourage home ownership and reduce foreclosures. In addition, more work also remains to be done in integrating the local aspects of housing and labor markets into standard portfolio choice, asset pricing, and macroeconomic models with housing.

[49] For a discussion of these issues, see Gerardi et al. (2008), Glaeser et al. (2013), Van Nieuwerburgh (2012), and Foote et al. (2012).

ACKNOWLEDGMENTS

We thank Gilles Duranton, Jack Favilukis, Carlos Garriga, David Kohn, Ralph Koijen, Sydney Ludvigson, Erwan Quintin, and Will Strange for comments and suggestions, and Vadim Elenev for excellent research assistance.

REFERENCES

Acharya, V.V., Richardson, M., Van Nieuwerburgh, S., White, L.J., 2011. Guaranteed to Fail: Freddie, Fannie, and the Debacle of Mortgage Finance. Princeton University Press, Princeton, NJ.

Agarwal, S., Amromin, G., Ben-David, I., Chomsisengphet, S., Piskorski, T., Seru, A., 2012. Policy intervention in debt renegotiation: evidence from the home affordable modification program. Fisher College of Business, Working paper No. 2012-03-020.

Albrecht, J., Anderson, A., Smith, E., Vroman, S., 2007. Opportunistic matching in the housing market. Int. Econ. Rev. 48 (2), 641–664.

Albrecht, J., Gautier, P.A., Vroman, S., 2010. Directed search in the housing market. Georgetown University, Working paper.

Alvarez, F., Jermann, U.J., 2000. Efficiency, equilibrium, and asset pricing with risk of default. Econometrica 68 (4), 775–798.

Alvarez, F., Jermann, U.J., 2001. Quantitative asset pricing implications of endogenous solvency constraints. Rev. Financ. Stud. 14, 1117–1152.

Ameriks, J., Caplin, A., Laufer, S., Van Nieuwerburgh, S., 2010. The joy of giving or assisted lining? Using strategic surveys to separate bequest and precautionary motives. J. Financ. 66 (2), 519–561.

Arslan, Y., Guler, B., Taskin, T., 2013. Joint dynamics of house prices and foreclosures. Indiana University, Working paper.

Aruoba, S.B., Davis, M.A., Wright, R., 2014. Homework in monetary economics: inflation, home production, and the production of homes. University of Wisconsin-Madison, Working paper.

Attanasio, O.P., Bottazzi, R., Low, H.W., Nesheim, L., Wakefield, M., 2011. Inflation, nominal debt, housing and welfare. Institute for Fiscal Studies, Working paper.

Badarinza, C., Campbell, J.Y., Ramadoraim, T., 2013. What calls to ARMs? International evidence on interest rates and the choice of adjustable-rate mortgages. Harvard University, Working paper.

Bajari, P., Chan, P., Krueger, D., Miller, D., 2013. A dynamic model of housing demand: estimation and policy implications. Int. Econ. Rev. 54 (2), 409–442.

Bansal, R., Yaron, A., 2004. Risks for the long run: a potential resolution of asset prizing puzzles. J. Financ. 59 (4), 1481–1509.

Bansal, R., Kiku, D., Yaron, A., 2012. An empirical evaluation of the long-run risks model for asset prices. Crit. Financ. Rev. 1 (1), 183–221.

Benhabib, J., Rogerson, R., Wright, R., 1991. Homework in macroeconomics: household production and aggregate fluctuations. J. Polit. Econ. 99 (6), 1166–1187.

Benitez-Silva, H., Heiland, F., Jimenez-Martin, S., 2010. How well do individuals predict the selling prices of their home? SUNY-Stony Brook, Working paper.

Boldrin, M., Garriga, C., Peralta-Alva, A., Sanchez, J.M., 2013. Reconstructing the great recession. Federal Reserve Bank of St. Louis, Working paper 2013-006B.

Breeden, D.T., 1979. An intertemporal asset pricing model with stochastic consumption and investment opportunities. J. Financ. Econ. 7 (3), 265–296.

Bucks, B., Pence, K., 2008. Do homeowners know their house values and mortgage terms? J. Urban Econ. 64 (2), 218–233.

Burns, A., Mitchell, W., 1946. Measuring Business Cycles. NBER, New York.

Burnside, C., Eichenbaum, M., Rebelo, S., 2011. Understanding booms and busts in housing markets. NBER Working paper 16734.

Campbell, J.Y., 2013. Mortgage market design. Rev. Financ. 17 (1), 1–33.

Campbell, J.Y., Cocco, J.F., 2003. Household risk management and optimal mortgage choice. Q. J. Econ. 118 (4), 1449–1494.
Campbell, J.Y., Cocco, J.F., 2007. How do house prices affect consumption? Evidence from micro data. J. Monet. Econ. 54 (3), 591–621.
Campbell, J.Y., Cocco, J.F., 2012. A model of mortgage default. Harvard University, Working paper.
Campbell, J.Y., Cochrane, J.H., 1999. By force of habit: a consumption-based explanation of aggregate stock market behavior. J. Polit. Econ. 107 (2), 205–251.
Campbell, S.D., Davis, M.A., Gallin, J., Martin, R.F., 2009. What moves housing markets? A variance decomposition of the rent-price ratio. J. Urban Econ. 66 (2), 90–102.
Case, K.E., Quigley, J.M., Shiller, R.J., 2005. Comparing wealth effects: the stock market versus the housing market. Adv. Macroecon. 5 (1), 1–32.
Catte, P., Girouard, N., Price, R.W., Andre, C., 2004. Housing markets, wealth and the business cycle. OECD Economics Department, Working papers No. 394.
Chambers, M., Garriga, C., Schlagenhauf, D.E., 2009a. Accounting for changes in the homeownership rate. Int. Econ. Rev. 50 (3), 677–726.
Chambers, M., Garriga, C., Schlagenhauf, D.E., 2009b. Housing policy and the progressivity of income taxation. J. Monet. Econ. 56 (8), 1116–1134.
Chambers, M., Garriga, C., Schlagenhauf, D.E., 2009c. The loan structure and housing tenure decisions in an equilibrium model of mortgage choice. Rev. Econ. Dyn. 12 (3), 444–468.
Chatterjee, S., Eyigungor, B., 2009. Foreclosures and house price dynamics: a quantitative analysis of the mortgage crisis and the foreclosure prevention policy. Federal Reserve Bank of Philadelphia, Working paper 09-22.
Chatterjee, S., Eyigungor, B., 2011. A quantitative analysis of the US housing and mortgage markets and the foreclosure crisis. Federal Reserve Bank of Philadelphia, Working paper 11–26.
Chatterjee, S., Eyigungor, B., 2012. Maturity, indebtedness, and default risk. Am. Econ. Rev. 102 (6), 2674–2699.
Chen, H., Michaux, M., Roussanov, N., 2013. Houses as ATMs? Mortgage refinancing and macroeconomic uncertainty. University of Southern California, Working paper.
Chu, Y., 2014. Credit constraints, inelastic supply, and the housing boom. Rev. Econ. Dyn. 17 (1), 52–69.
Cocco, J.F., 2005. Portfolio choice in the presence of housing. Rev. Financ. Stud. 18 (2), 535–567.
Cocco, J.F., Gomes, F.J., Maenhout, P.J., 2005. Consumption and portfolio choice over the life cycle. Rev. Financ. Stud. 18 (2), 491–533.
Cooper, D., Dynan, K., 2013. Wealth shocks and macroeconomic dynamics. Federal Reserve Bank of Boston, Working paper.
Corbae, D., Quintin, E., 2015. Leverage and the foreclosure crisis. J. Polit. Econ., forthcoming.
Corradin, S., Fillat, J.L., Vergara-Alert, C., 2014. Optimal portfolio choice with predictability in house prices and transaction costs. Rev. Financ. Stud. 27 (3), 823–880.
Davis, M.A., Heathcote, J., 2005. Housing and the business cycle. Int. Econ. Rev. 46 (3), 751–784.
Davis, M.A., Heathcote, J., 2007. The price and quantity of residential land in the United States. J. Monet. Econ. 54 (8), 2595–2620.
Davis, M.A., Martin, R.F., 2009. Housing, home production, and the equity and value premium puzzles. J. Hous. Econ. 18 (2), 81–91.
Davis, M.A., Ortalo-Magné, F., 2011. Household expenditures, wages, rents. Rev. Econ. Dyn. 14 (2), 248–261.
Davis, M.A., Palumbo, M., 2001. A primer on the economics and time series econometrics of wealth effects. Federal Reserve Board of Governors, Working paper FEDS 2001-09.
Davis, M.A., Quintin, E., 2014. Default when house prices are uncertain. University of Wisconsin-Madison, Working paper.
Davis, M.A., Lehnert, A., Martin, R.F., 2008. The rent-price ratio for the aggregate stock of owner-occupied housing. Rev. Income Wealth 54 (2), 279–284.
Davis, M.A., Fisher, J.D.M., Veracierto, M., 2013. Gross migration, housing and urban population dynamics. Federal Reserve Bank of Chicago, Working paper 2013–19.

Davis, M.A., Fisher, J.D.M., Whited, T., 2014. Macroeconomic implications of agglomeration. Econometrica 82 (2), 731–764.
Diaz, A., Luengo-Prado, M.J., 2010. The wealth distribution with durable goods. Int. Econ. Rev. 51 (1), 143–170.
Dorofeenko, V., Lee, G.S., Salyer, K.D., 2014. Risk shocks and housing supply: a quantitative analysis. J. Econ. Dyn. Control. 45, 194–219.
Ejarque, J., Leth-Petersen, S., 2008. Consumption and savings of first time owners: how do they deal with adverse income shocks. University of Copenhagen, Working paper.
Favilukis, J., Ludvigson, S.C., Van Nieuwerburgh, S., 2011. The macroeconomic effects of housing wealth, housing finance and limited risk sharing in general equilibrium. Unpublished Paper, New York University.
Favilukis, J., Ludvigson, S.C., Van Nieuwerburgh, S., 2012. Foreign ownership of U.S. safe assets: good or bad? Unpublished Paper, New York University.
Favilukis, J., Kohn, D., Ludvigson, S.C., Van Nieuwerburgh, S., 2013. International capital flows and house prices: theory and evidence. In: Glaeser, E.L., Sinai, T. (Eds.), Housing and the Financial Crisis. National Bureau of Economic Research, pp. 235–299.
Fernández-Villaverde, J., Krueger, D., 2011. Consumption and saving over the life cycle: how important are consumer durables. Macroecon. Dyn. 15 (5), 725–770.
Feroli, M., Harris, E., Sufi, A., West, K., 2012. Housing, monetary policy, and the recovery. In: Proceedings of the U.S. Monetary Policy Forum 2012.
Fisher, J.D.M., 1997. Relative prices, complementarities and comovement among components of aggregate expenditures. J. Monet. Econ. 39 (3), 449–474.
Fisher, J.D.M., 2007. Why does household investment lead business investment over the business cycle. J. Polit. Econ. 115 (1), 141–168.
Fisher, J.D.M., Gervais, M., 2011. Why has home ownership fallen among the young. Int. Econ. Rev. 52 (3), 883–912.
Flavin, M., Nakagawa, S., 2008. A model of housing in the presence of adjustment costs: a structural interpretation of habit persistence. Am. Econ. Rev. 98 (1), 474–495.
Flavin, M., Yamashita, T., 2002. Owner-occupied housing and the composition of the household portfolio. Am. Econ. Rev. 92 (1), 345–362.
Floetotto, M., Kirker, M., Stroebel, J., 2012. Government intervention in the housing market: who wins, who loses? Stanford University, Working paper.
Foote, C.L., Gerardi, K.S., Willen, P.S., 2012. Why did so many people make so many ex post bad decisions? The causes of the foreclosure crisis. FRB Boston Public Policy Discussion Paper Series, Paper No. 12–2.
Gabaix, X., 2012. Variable rare disasters: an exactly solved framework for ten puzzles in macro finance. Q. J. Econ 127 (2), 645–700, Working paper NYU Stern.
Garriga, C., Schlagenhauf, D.E., 2009. Home equity, foreclosures, and bailouts. Federal Reserve Bank of St. Louis, Working paper.
Garriga, C., Manuelli, R., Peralta-Alva, A., 2012. A model of price swings in the housing market. Federal Reserve Bank of St. Louis, Working paper 2012-022A.
Garriga, C., Kydland, F.E., Sustek, R., 2013. Mortgages and monetary policy. NBER Working paper 19744.
Garriga, C., Chambers, M., Schlagenhauf, D.E., 2014. Did housing policies cause the post-war housing boom? A general equilibrium analysis. In: Fishback, P., Snowden, K., White, E. (Eds.), Housing and Mortgage Markets in Historical Perspective. University of Chicago Press.
Gerardi, K., Lehnert, A., Sherlund, S.M., Willen, P., 2008. Making sense of the subprime crisis. Brookings Papers on Economic Activity, pp. 69–145.
Gervais, M., 2002. Housing taxation and capital accumulation. J. Monet. Econ. 49 (7), 1461–1489.
Ghent, A.C., Owyang, M.T., 2010. Is housing the business cycle? Evidence from U.S. cities. J. Urban. Econ. 67 (3), 336–351.
Ghysels, E., Plazzi, A., Torous, W., Valkanov, R., 2013. Forecasting real estate prices. In: Elliott, G., Timmermann, A. (Eds.), Handbook of Economic Forecasting, vol. II. Elsevier, pp. 509–580.

Giglio, S., Maggiori, M., Stroebel, J., 2014. Very long-run discount rates. New York University, Working paper.
Glaeser, E.L., Gottlieb, J.D., Gyourko, J., 2013. Can cheap credit explain the housing boom? In: Glaeser, E.L., Sinai, T. (Eds.), Housing and the Financial Crisis. University of Chicago Press, pp. 301–359.
Gomme, P., Kydland, F.E., Rupert, P., 2001. Home production meets time to build. J. Polit. Econ. 109 (5), 1115–1131.
Goodman Jr., J.L., Ittner, J.B., 1992. The accuracy of home owners' estimates of house value. J. Hous. Econ. 2 (4), 339–357.
Green, R.K., 1997. Follow the leader: how changes in residential and non-residential investment predict changes in GDP. Real Estate Econ. 25 (2), 253–270.
Greenwood, J., Hercowitz, Z., 1991. The allocation of capital and time over the business cycle. J. Polit. Econ. 99 (6), 1188–1214.
Greenwood, J., Rogerson, R., Wright, R., 1995. Household production in real business cycle theory. In: Cooley, T.F. (Ed.), Frontiers of Business Cycle Research. Princeton University Press, pp. 157–174.
Grenadier, S.R., 1995. The persistence of real estate cycles. J. Real Estate Financ. Econ. 10 (2), 95–119.
Grossman, G., Laroque, G., 1990. Asset pricing and optimal portfolio choice in the presence of illiquid durable consumption goods. Econometrica 58 (1), 25–51.
Gruber, J., Martin, R.F., 2003. Precautionary savings and the wealth distribution with illiquid durables. Federal Reserve Board of Governors, Working paper.
Halket, J., Amior, M., 2013. Do households use homeownership to insure themselves? Evidence across U.S. cities. University of Essex, Working paper.
Halket, J., Vasudev, S., 2014. Saving up or settling down: home ownership over the life cycle. Rev. Econ. Dyn. 17 (2), 345–366.
Han, L., 2008. Hedging house price risk in the presence of lumpy transaction costs. J. Urban Econ. 64 (2), 270–287.
Han, L., 2013. Understanding the puzzling risk-return relationship to housing. Rev. Financ. Stud. 26 (4), 877–928.
Hansen, L.P., Singleton, K., 1983. Stochastic consumption, risk aversion, and the temporal behavior of asset returns. J. Polit. Econ. 91 (2), 249–265.
Hatchondo, J.C., Martinez, L., Sanchez, J.M., 2013. Mortgage defaults. Federal Reserve Bank of St. Louis, Working paper.
He, C., Wright, R., Zhu, Y., 2013. Housing and liquidity. University of Wisconsin-Madison, Working paper.
Head, A., Lloyd-Ellis, H., 2012. Housing liquidity, mobility, and the labour market. Rev. Econ. Stud. 79 (4), 1559–1589.
Head, A., Lloyd-Ellis, H., Sun, H., 2011. Search and the dynamics of house prices and construction. Queens University, Working paper.
Heathcote, J., Storesletten, K., Violante, G.L., 2010. The macroeconomic implications of rising wage inequality in the United States. J. Polit. Econ 118 (4), 681–722.
Hedlund, A., 2014. The cyclical dynamics of illiquid housing, debt, and foreclosures. University of Missouri, Working paper.
Hembre, E., 2014. HAMP, home attachment, and mortgage default. University of Wisconsin-Madison, Working paper.
Hirata, H., Kose, M.A., Otrok, C., Terrones, M.E., 2013. Global house price fluctuations: synchronization and determinants. In: Giavazzi, F., West, K.D. (Eds.), NBER International Seminar on Macroeconomics 2012. National Bureau of Economic Research, pp. 119–166.
Hizmo, A., 2012. Risk in housing markets: an equilibrium approach. New York University, Working paper.
Hodrick, R.J., Prescott, E.C., 1997. Postwar U.S. business cycles: an empirical investigation. J. Money Credit Bank 29 (1), 1–16.
Hornstein, A., Praschnik, J., 1997. Intermediate inputs and sectoral comovement in the business cycle. J. Monet. Econ. 40 (3), 573–595.
Hryshko, D., Luengo-Prado, M.J., Sorenson, B.E., 2010. House prices and risk sharing. J. Monet. Econ. 57 (8), 975–987.

Hubbard, G.R., Skinner, J., Zeldes, S.P., 1995. Precautionary saving and social insurance. J. Polit. Econ. 103 (2), 360–399.
Hurst, E., Stafford, F., 2004. Home is where the equity is: mortgage refinancing and household consumption. J. Money Credit Bank. 36 (6), 985–1014.
Iacoviello, M., 2005. House prices, borrowing constraints, and monetary policy in the business cycle. Am. Econ. Rev. 95 (3), 739–764.
Iacoviello, M., Neri, S., 2010. Housing market spillovers: evidence from an estimated DSGE model. Am. Econ. J. Macroecon. 2 (2), 125–164.
Iacoviello, M., Pavan, M., 2013. Housing and debt over the life cycle and over the business cycle. J. Monet. Econ. 60 (2), 221–238.
Jermann, U.J., 1998. Asset pricing in production economies. J. Monet. Econ. 41 (2), 257–275.
Jeske, K., Krueger, D., Mitman, K., 2013. Housing, mortgage bailout guarantees and the macro economy. J. Monet. Econ. 60 (8), 917–935.
Kahn, J.A., 2008. What drives housing prices. Federal Reserve Bank of New York, Staff Report No. 345.
Kaldor, N., 1957. A model of economic growth. Econ. J. 67 (268), 591–624.
Kaplan, G., Violante, G.L., 2014. A model of the consumption response to fiscal stimulus payments. Econometrica 82 (4), 1199–1239.
Keys, B.J., Mukherjee, T., Seru, A., Vig, V., 2009. Financial regulation and securitization: evidence from subprime loans. J. Monet. Econ. 56 (5), 700–720.
Keys, B.J., Mukherjee, T., Seru, A., Vig, V., 2010. Did securitization lead to lax screening? Evidence from subprime loans. Q. J. Econ. 125 (1), 307–362.
Keys, B., Piskorski, T., Seru, A., Vig, V., 2013. Mortgage financing in the housing boom and bust. In: Glaeser, E., Sinai, T. (Eds.), NBER Book Housing and the Financial Crisis. pp. 143–204.
Keys, B.J., Seru, A., Vig, V., 2012. Lender screening and the role of securitization: evidence from prime and subprime mortgage markets. Rev. Financ. Stud. 25 (7), 2071–2108.
Kiyotaki, N., Michaelides, A., Nikolov, K., 2011. Winners and losers in housing markets. J. Money Credit Bank. 43 (2–3), 255–296.
Kohn, D., 2002. Panel: implications of declining treasury debt. What should the federal reserve do as treasury debt is repaid? J. Money Credit Bank. 34 (3), 941–945.
Koijen, R.S.J., Hemert, O.V., Van Nieuwerburgh, S., 2009. Mortgage timing. J. Financ. Econ. 93 (2), 292–324.
Krishnamurthy, A., Vissing-Jorgensen, A., 2012. The aggregate demand for treasury debt. J. Polit. Econ. 120 (2), 233–267.
Kydland, F.E., Prescott, E.C., 1982. Time to build and aggregate fluctuations. Econometrica 50 (6), 1345–1370.
Kydland, F.E., Rupert, P., Sustek, R., 2012. Housing dynamics over the business cycle. NBER, Working paper 18432.
Landvoigt, T., 2012. Aggregate implications of the increase in securitized mortgage debt. Stanford University, Working paper.
Landvoigt, T., Piazzesi, M., Schneider, M., 2013a. Housing assignment with restrictions: theory and evidence from the Stanford campus. Stanford University, Working paper.
Landvoigt, T., Piazzesi, M., Schneider, M., 2013b. The housing market(s) of San Diego. Stanford University, Working paper.
Laufer, S., 2013. Equity extraction and mortgage default. Federal Reserve Board, Working paper.
Leamer, E.E., 2007. Housing is the business cycle. NBER Working paper No. 13428.
Li, W., Yao, R., 2007. The life-cycle effects of house price changes. J. Money Credit Bank. 39 (6), 1375–1409.
Lucas, R.E.J., 1978. Asset prices in an exchange economy. Econometrica 46 (6), 1429–1454.
Lucas, R.E.J., Prescott, E.C., 1974. Equilibrium search and unemployment. J. Econ. Theory 7 (2), 188–209.
Lustig, H., Van Nieuwerburgh, S., 2005. Housing collateral, consumption insurance and risk premia: an empirical perspective. J. Financ. 60 (3), 1167–1219.
Lustig, H., Van Nieuwerburgh, S., 2007. Can housing collateral explain long-run swings in asset returns? New York University, Working paper.

Lustig, H., Van Nieuwerburgh, S., 2010. How much does housing collateral constrain regional risk sharing? Rev. Econ. Dyn. 13 (2), 265–294.
Mankiw, N.G., Weil, D.N., 1989. The baby boom, the baby bust, and the housing market. Reg. Sci. Urban Econ. 19 (2), 235–258.
McGrattan, E.R., Rogerson, R., Wright, R., 1997. An equilibrium model of the business cycle with household production and fiscal policy. Int. Econ. Rev. 38 (2), 267–290.
Mehra, R., Prescott, E.C., 1985. The equity premium: a puzzle. J. Monet. Econ. 15 (2), 145–161.
Mian, A., Sufi, A., 2009. The consequences of mortgage expansion: evidence from the U.S. mortgage default crisis. Q. J. Econ. 124 (4), 1449–1496.
Mian, A., Sufi, A., 2011. House prices, home equity-based borrowing, and the U.S. household leverage crisis. Am. Econ. Rev 101 (5), 2132–2156.
Mian, A., Sufi, A., 2012. The effects of fiscal stimulus: evidence from the 2009 cash for clunkers program. Q. J. Econ. 127 (3), 1107–1142.
Mian, A., Sufi, A., 2014. What explains the 2007–2009 drop in employment? University of Chicago, Working paper.
Mian, A., Sufi, A., Trebbi, F., 2010. The political economy of the US mortgage default crisis. Am. Econ. Rev. 100 (5), 1967–1998.
Mian, A., Rao, K., Sufi, A., 2013. Household balance sheets, consumption, and the economic slump. Q. J. Econ. 128 (4), 1687–1726.
Mian, A., Sufi, A., Trebbi, F., 2014. Foreclosures, house prices, and the real economy. University of Chicago, Working paper.
Midrigan, V., Philippon, T., 2011. Household leverage and the recession. New York University, Working paper.
Mitman, K., 2012. Macroeconomic effects of bankruptcy and foreclosure policies. University of Pennsylvania, Working paper.
Moench, E., Vickery, J.I., Aragon, D., 2010. Why is the market share of adjustable-rate mortgages so low? Curr. Issues Econ. Financ. 16 (8), 1–11.
Muellbauer, J.N., Murphy, A., 1997. Booms and busts in the UK housing market. Econ. J. 107 (445), 1701–1727.
Nakajima, M., Telyukova, I.A., 2012. Home equity in retirement. Federal Reserve Bank of Philadelphia, Working paper.
Ngai, L.R., Tenreyro, S., 2014. Hot and cold seasons in the housing market. Am. Econ. Rev. 104 (12), 3991–4026.
Ortalo-Magné, F., Prat, A., 2013. Spatial asset pricing: a first step. Columbia University, Working paper.
Ortalo-Magné, F., Rady, S., 2006. Housing market dynamics: on the contribution of income shocks and credit constraints. Rev. Econ. Stud. 73 (2), 459–485.
Piazzesi, M., Schneider, M., 2009. Momentum traders in the housing market: survey evidence and a search model. Am. Econ. Rev. 99 (2), 406–411.
Piazzesi, M., Schneider, M., Tuzel, S., 2007. Housing, consumption and asset pricing. J. Financ. Econ. 83 (3), 531–569.
Piazzesi, M., Schneider, M., Stroebel, J., 2013. Segmented housing search. Stanford University, Working paper.
Piskorski, T., Seru, A., Vig, V., 2010. Securitization and distressed loan renegotiation: evidence from the subprime mortgage crisis. J. Financ. Econ. 97 (3), 369–397.
Scharlemanny, T.C., Shorez, S.H., 2013. Does reducing 'underwaterness' prevent mortgage default? Evidence from HAMP PRA. Georgia State University, Working paper.
Silos, P., 2007a. Housing, portfolio choice and the macroeconomy. J. Econ. Dyn. Control. 31 (8), 2774–2801.
Silos, P., 2007b. Housing tenure and wealth distribution in life cycle economies. B.E. J. Macroecon 7 (1), 1–24.
Sinai, T., Souleles, N., 2005. Owner-occupied housing as a hedge against rent risk. Q. J. Econ. 120 (2), 763–789.

Sommer, K., Sullivan, P., 2013. Implications of U.S. tax policy for house prices, rents and homeownership. Federal Reserve Board of Governors, Working paper.
Stein, J., 1995. Prices and trading volume in the housing market: a model with down-payment effects. Q. J. Econ. 110 (2), 379–406.
Storesletten, K., Telmer, C.I., Yaron, A., 2004. Consumption and risk sharing over the life cycle. J. Monet. Econ. 51 (3), 609–633.
Topel, R., Rosen, S., 1988. Housing investment in the United States. J. Polit. Econ. 96 (4), 718–740.
van Binsbergen, J., Brandt, M., Koijen, R., 2012. On the timing and pricing of dividends. Am. Econ. Rev. 102 (4), 1596–1618.
Van Hemert, O., 2010. Household interest rate risk management. Real Estate Econ. 38 (3), 467–505.
Van Nieuwerburgh, S., 2012. The research agenda: Stijn Van Nieuwerburgh on housing and the macroeconomy. Econ. Dyn. Newslett. 13(2). http://www.EconomicDynamics.org/News261.htm#agenda.
Van Nieuwerburgh, S., Weill, P.-O., 2010. Why has house price dispersion gone up? Rev. Econ. Stud. 77 (4), 1567–1606.
Vestman, R., 2012. Limited stock market participation among renters and home owners. Stockholm University, Working paper.
Vissing-Jorgensen, A., 2002. Limited asset market participation and the elasticity of intertemporal substitution. J. Polit. Econ. 110 (4), 825–853.
Weil, P., 1989. The equity premium puzzle and the risk-free rate puzzle. J. Monet. Econ. 24 (3), 401–421.
Wong, Y.-Y., Wright, R., 2011. Buyers, sellers and middlemen: variations on search-theoretic themes. National Bureau of Economic Research, Working paper No. 17511.
Yang, F., 2009. Consumption over the life cycle: how different is housing. Rev. Econ. Dyn. 12 (3), 423–443.
Yao, R., Zhang, H.H., 2004. Optimal consumption and portfolio choices with risky housing and borrowing constraint. Rev. Financ. Stud. 18 (1), 197–239.
Yogo, M., 2006. A consumption-based explanation of expected stock returns. J. Financ. 61 (2), 539–580.