

Housing, Finance and the Macroeconomy*

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September 1, 2014

*First draft: April 2014. 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.

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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 to data. In each section, we discuss the important questions, the typical set of tools used, and the insights that result from influential papers. 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.

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) to housing markets and subsequent financial crisis precipitated by an unforeseen surge in mortgage defaults has 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 don't understand. Prior to the dramatic events of the past decade, economists have 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 provides 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 housing and mortgage markets suggests these peculiarities might affect macroeconomic outcomes and all other asset prices.

Many excellent papers have been produced on these topics and it is impossible to cover all ground in one chapter. The papers 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 six 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 that, we review a recent set of papers 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 papers that fix house prices or take them as given and papers where house prices are determined

endogenously inside the model. The final section of the chapter describes the results of a small set of papers studying the impact and implications of U.S. 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 papers 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 microeconomics⁴ and papers investigating the role of mortgage finance in amplifying the housing boom and bust.⁵ Finally, our chapter is largely focused on the U.S. 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

2 Stylized Facts

2.1 Levels of Aggregates

In this section, we highlight a set of stylized facts from U.S. 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

¹Several macroeconomists have contributed to this area. A small set of examples include [Albrecht, Anderson, Smith, and Vroman \(2007\)](#), [Albrecht, Gautier, and Vroman \(2010\)](#), [Head, Lloyd-Ellis, and Sun \(2011\)](#), [Wong and Wright \(2011\)](#), [Head and Lloyd-Ellis \(2012\)](#), [He, Wright, and Zhu \(2013\)](#), [Hedlund \(2014\)](#), [Landvoigt, Piazzesi, and Schneider \(2013a\)](#), [Ngai and Tenreyro \(2014\)](#) and [Piazzesi, Schneider, and Stroebel \(2013\)](#).

²See, for example, [Mankiw and Weil \(1989\)](#) and [Davis, Fisher, and Whited \(2014\)](#).

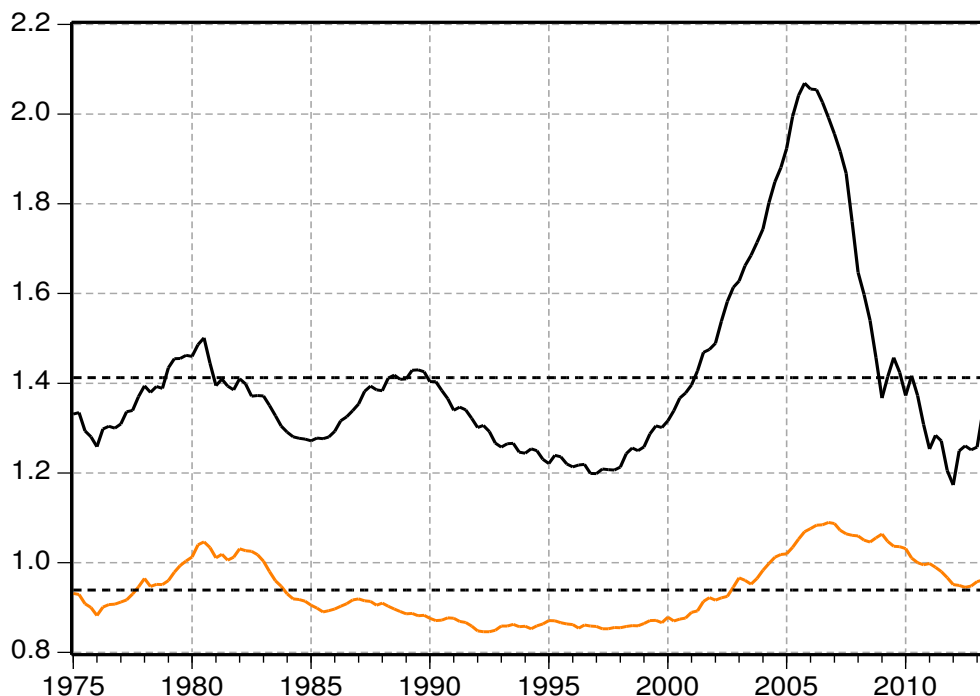
³See, for example, [Piazzesi and Schneider \(2009\)](#) and [Burnside, Eichenbaum, and Rebelo \(2011\)](#).

⁴Examples are [Mian and Sufi \(2009, 2011, 2012, 2014\)](#), [Mian, Rao, and Sufi \(2013\)](#), and [Mian, Sufi, and Trebbi \(2010, 2014\)](#) and the references therein.

⁵See, for example, [Keys, Mukherjee, Seru, and Vig \(2009, 2010\)](#), [Piskorski, Seru, and Vig \(2010\)](#), [Keys, Seru, and Vig \(2012\)](#), and the review paper by [Keys, Piskorski, Seru, and Vig \(2012\)](#).

⁶For papers describing experiences of OECD countries, see [Catte, Girouard, Price, and Andre \(2004\)](#) and [Hirata, Kose, Otrok, and Terrones \(2013\)](#). [Aruoba, Davis, and Wright \(2014\)](#) note that source data on house prices for many countries are simply unavailable prior to 1990, hindering empirical analysis.

Figure 1: RATIOS OF HOUSING WEALTH (BLACK) AND STRUCTURES (ORANGE) TO GDP, 1975:1 - 2013:3

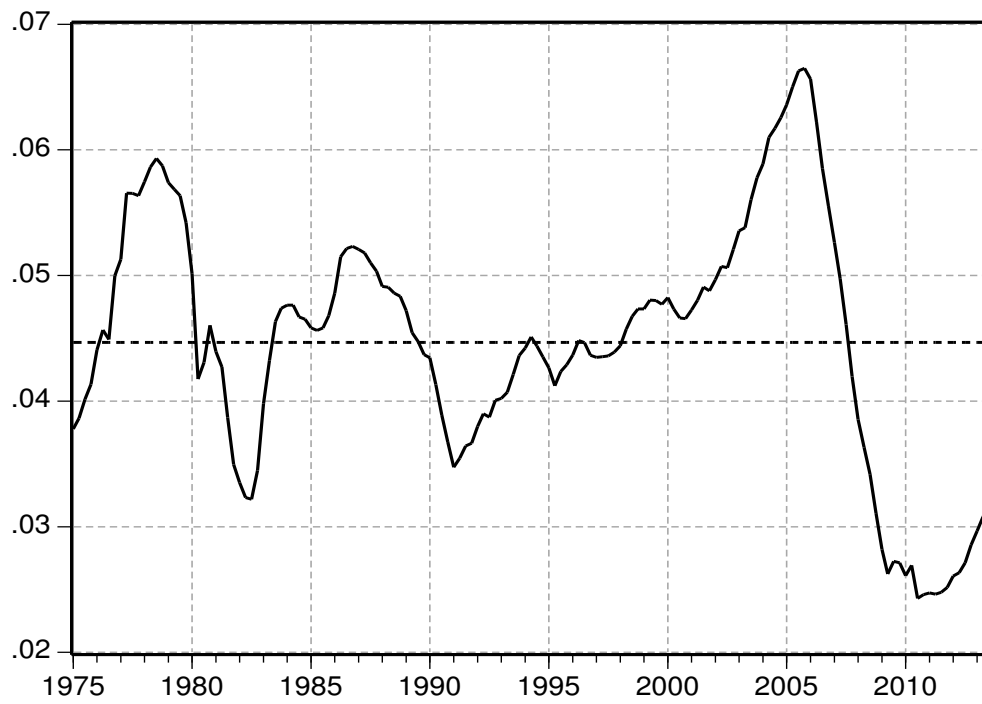


Notes: The figure plots the nominal value of housing, inclusive of land and structures, and the nominal value of structures, both relative to nominal GDP. The housing and structures data are from [Davis and Heathcote \(2007\)](#) and are available for download at <http://www.lincolnst.edu/subcenters/land-values/price-and-quantity.asp> and the nominal GDP data are from the National Income and Product Accounts.

to preferences and technology. Figure 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 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 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 percent 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.

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

Figure 2: RATIO OF RESIDENTIAL INVESTMENT TO GDP, 1975:1 - 2013:3



Notes: These data are derived from table 1.1.5 of the National Income and Product Accounts.

Figure 2 shows the ratio of residential investment to GDP over the same time periods.⁸ The average value of this ratio is 4.5 percent. 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 abstract from inflation and any trends to structures prices, we can divide both sides by GDP at time t , Y_t , to uncover

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

Denote the steady state ratios of structures-gdp, residential investment-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

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

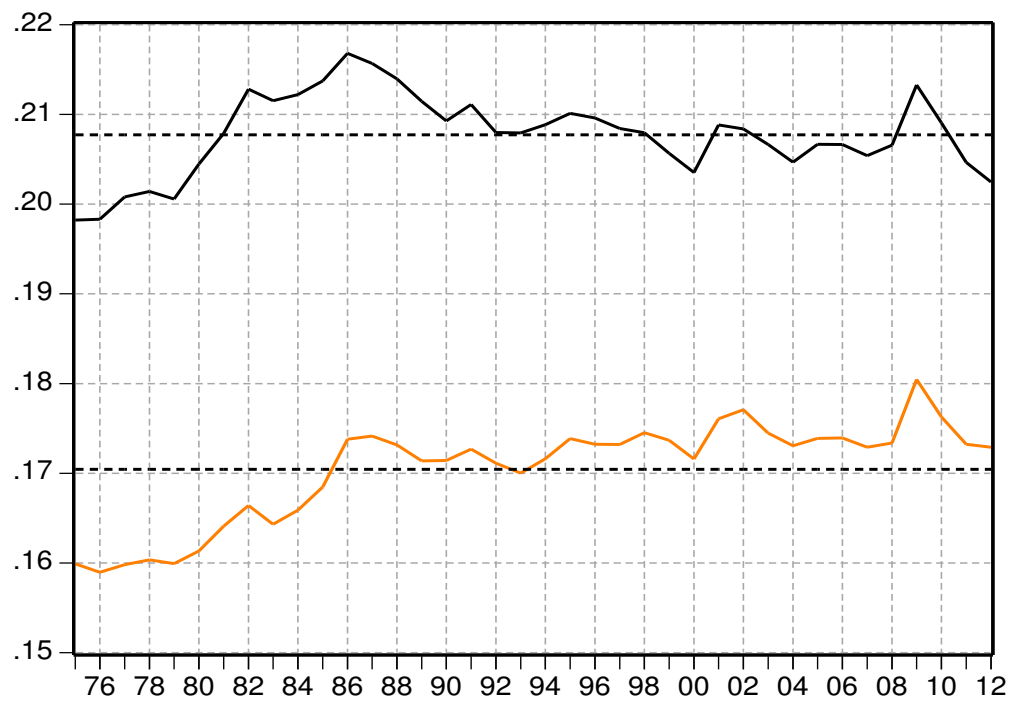
Taking I/Y as 0.045 and K/Y as 0.95, $g_y + \delta_K$ is equal to 0.047. If we think the growth rate of real GDP inclusive of population growth is 3% percent per year, then this gives an estimate for δ_K of 1.7 percent. Most studies use a number in the vicinity of this estimate.

Some other first moments help to pin down parameters related to preferences. Figure 3 shows the aggregate ratio of expenditures on housing rents and utilities (black line) and housing rents (orange line) to total consumption expenditures on nondurable goods and services.⁹ About 21 percent of aggregate consumption is accounted for by housing and utilities, 4 percent from utilities alone, and this percentage has remained constant despite real increases in consumption and rental prices

⁸These 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, occasionally authors remove these commissions from residential investment and adjust the estimate of the stock of structures accordingly.

⁹These data are derived from NIPA table 2.4.5.

Figure 3: RATIOS OF TOTAL SPENDING ON HOUSING AND UTILITIES (BLACK LINE) AND HOUSING (ORANGE LINE) TO CONSUMPTION EXPENDITURES ON NONDURABLE GOODS AND SERVICES, 1975:1 - 2013:3



Notes: These data are derived from table 2.4.5 of the National Income and Product Accounts.

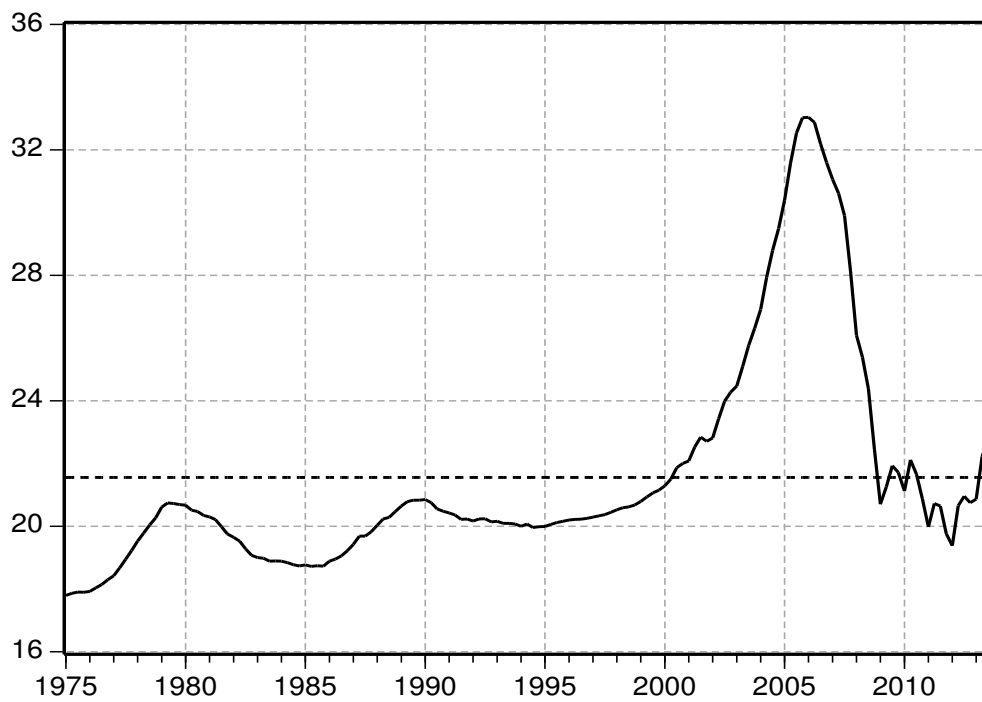
over time. One typical objection to this evidence notes that, on average after 1975, more than 60% of measured aggregate spending on housing rents and utilities is imputed as rents accruing to homeowners. [Davis and Ortalo-Magné \(2011\)](#) use micro data on renting households from the 1980, 1990 and 2000 Decennial Censuses of Housing to show that, across metro 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 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, Lehnert, and Martin \(2008\)](#) is shown in [figure 4](#).¹⁰ The 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 5](#) plots five additional 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 indexes (the Freddie Mac, square, the Core Logic, up triangle, and the national Case-Shiller House Price Index, down triangle) with the shelter component of the Consumer Price Index of the BLS.¹¹ All series display a similar pattern. The Flow of Fund (FoF) series and the Freddie Mac series (Freddie) display the least overall volatility, while the Case-Shiller (CS) and the Core Logic (CL) series display the largest boom and bust.

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

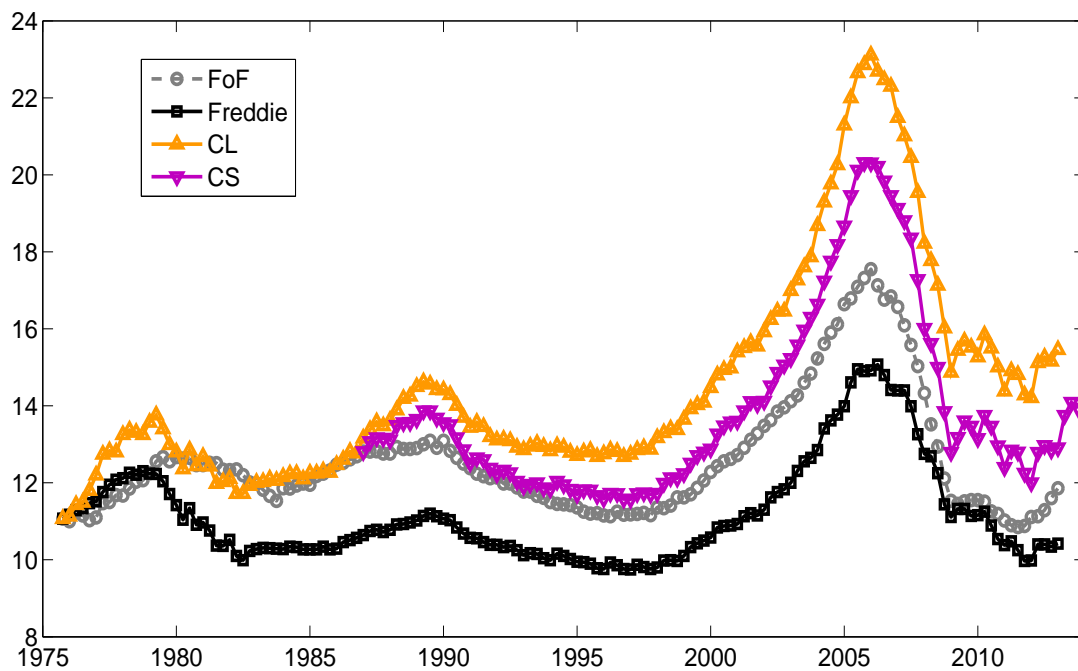
¹¹Since both price and rental series are indices, we set the first observation (1975:4) of the price-rent ratio for each of these three series equal to the corresponding quarter's observation for the Flow of Fund series. Since the Case-Shiller series only starts in 1987:1, we initialize this series at the 1987:1 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, Plazzi, Torous, and Valkanov \(2013\)](#).

Figure 4: ESTIMATE OF THE PRICE-RENT RATIO FOR HOMEOWNERS, 1975:1-2013:3



Notes: This is an estimate of price-rent ratio for homeowners as derived by [Davis, Lehnert, and Martin \(2008\)](#). These data are available for download at <http://www.lincolnnst.edu/subcenters/land-values/rent-price-ratio.asp>.

Figure 5: COMPARING PRICE-RENT RATIOS, 1975:4-2013:4

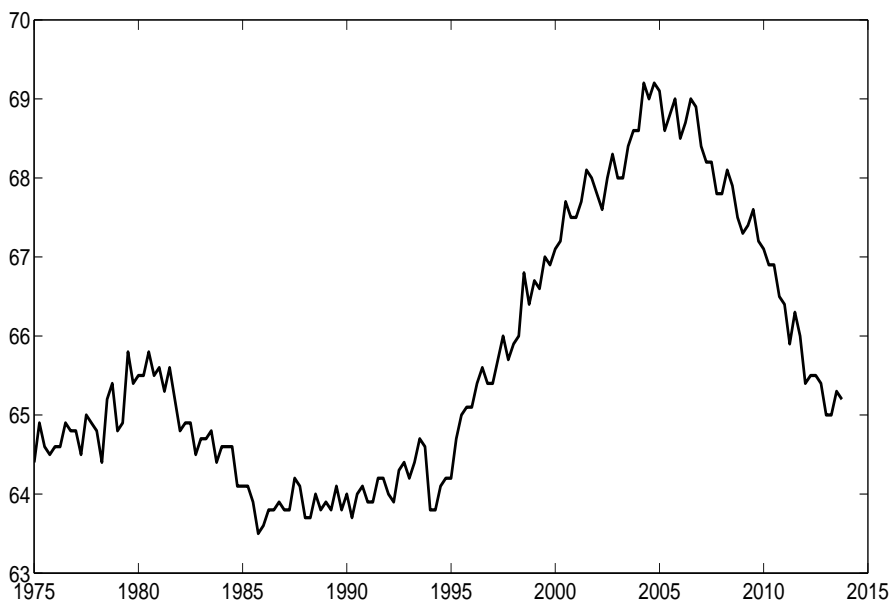


Notes: The figure compares five estimates of price-rent ratios. “Flow of Funds” is the ratio of residential real estate wealth of the household sector from the Flow of Funds to aggregate housing services consumption from then NIPA. “Freddie Mac” is the ratio of the Freddie Mac Conventional Mortgage Home Price Index for purchases to the Bureau of Labor Statistics’s price index of shelter (which measures rent of renters and imputed rent of owners). “Core Logic” is the ratio of the Core Logic 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 1975.Q4 or whenever first available until 2013.Q4.

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 6 shows the path of the home-ownership rate since 1975. In lock-step with the changes to house prices over the 2000-2010 period, the home ownership rate displays a pronounced boom and bust: A 4 percentage point increase and a 4 percentage point decline. Each percentage point represents the experiences of approximately one million households.¹²

Figure 6: HOME OWNERSHIP RATE, 1975:1-2013:4

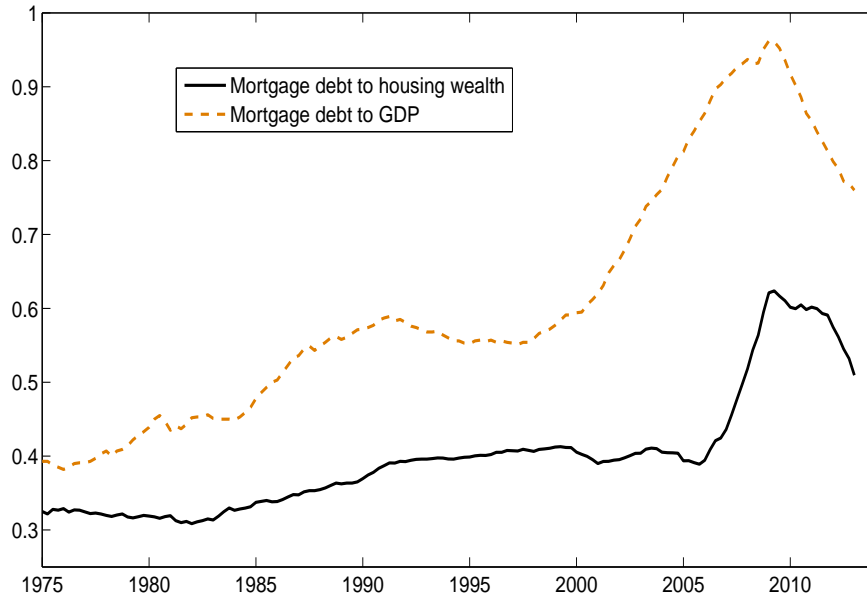


Notes: The figure plots the quarterly home ownership rate from the U.S. Department of Commerce: Census Bureau (FRED series ID RHORUSQ156N).

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 U.S. mortgage debt has increased significantly over time. The value of mortgages was equal to 20%

¹²As 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, Chambers, and Schlagenauf \(2014\)](#).

Figure 7: MORTGAGE DEBT, 1975:1-2013:1



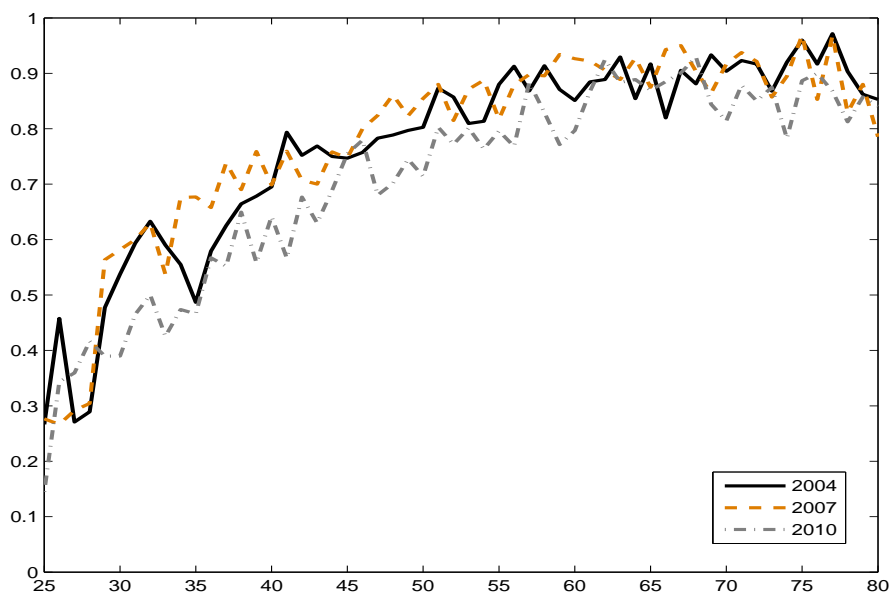
Notes: The figure plots mortgage debt relative to real estate wealth of the household sector (solid line) and mortgage debt of the household sector relative to GDP (dashed line) in the United States. Data are from the Federal Reserve Board’s Flow of Funds Accounts tables B100.d and B103.d. Household real estate wealth excludes the real estate wealth of non-profits 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 non-financial non-corporate sector. GDP data are from the Bureau of Economic Analysis National Income and Products Accounts.

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 have pushed the mortgage debt-to-housing wealth ratio back down to 50%. Figure 7 also shows the ratio of mortgage debt to GDP. It tracks the ratio of mortgage debt-to-household wealth during the run-up, but shows a stronger deleveraging effect because it does not directly reflect the improving real estate values. Over the last four 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 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 and then stay flat until age 80. Figure 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 8: HOME OWNERSHIP RATE BY AGE



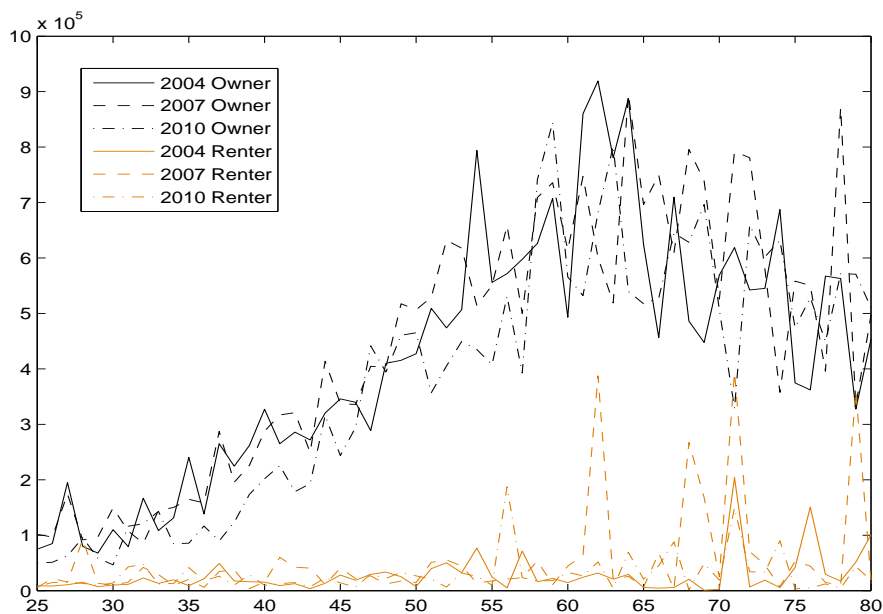
Notes: The figure plots the home ownership rate by age for the 2003, 2007 and 2010 waves of the Survey of Consumer Finances.

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

Figure 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

¹³Homeowners are identified as households having positive housing wealth.

Figure 9: AVERAGE WEALTH BY AGE



Notes: The figure plots net worth by age for the 2003, 2007 and 2010 Survey of Consumer Finances. All nominal wealth is deflated by the Consumer Price Index of the BLS, based in 2010. 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, IRA accounts, 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 primary residence, debt for other property, and other debt.

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 home owners early in life. Because most young home owners 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). As homeowners age, housing falls to about 50% of total assets by age 60 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.

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 it 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 [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 1](#) shows some of these second moments for U.S. 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 (HP) filter.¹⁷

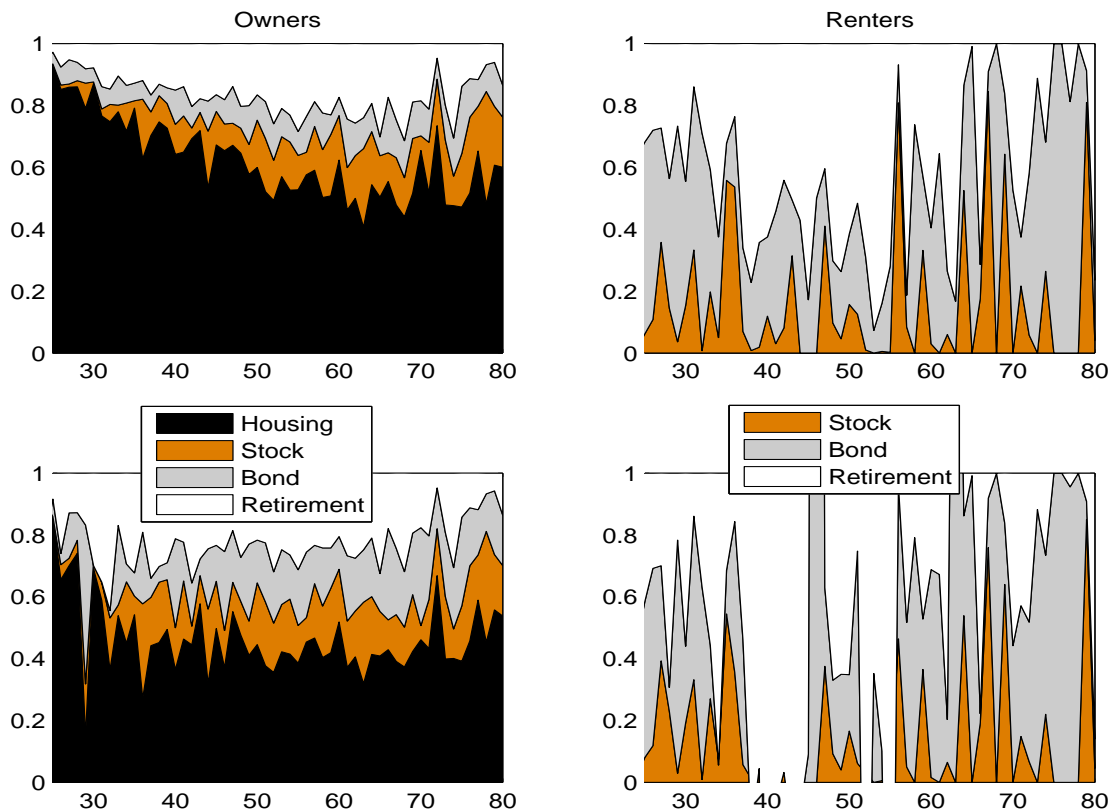
¹⁴Retirement assets are difficult to split into stocks and bonds and so we leave them as a separate category. We include bank accounts with bonds and mutual fund holdings with stocks. The four shares sum to one; for the calculation of these shares, we ignore the asset categories of vehicles, “other”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

¹⁵Bonds 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 one.

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

¹⁷The HP-filter removes a stochastic trend; see [Hodrick and Prescott \(1997\)](#) for details.

Figure 10: PORTFOLIO SHARES BY AGE



Notes: The figure plots portfolio shares by age for home owners (left panels) and renters (right panels) for the 2010 SCF 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 one. That is, for the calculation of these shares, we ignore 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 one.

Inspection of Table 1 yields several important stylized facts. First, consumption, non-residential 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); non-residential investment is three times more volatile than GDP (c2); residential investment is more than twice as volatile as non-residential

investment (d2); and house prices are more than 2.5 times as volatile as GDP (e2).¹⁸ Finally the highest correlation of non-residential investment and GDP occurs when GDP is lagged once relative to non-residential 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.

Table 1: Properties of Selected Detrended U.S. Macroeconomic Data, 1955:1 - 2013:3

Variable X	Relative		Correlation of Variable X_s and GDP_t						
	Std. Dev	Std. Dev	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) Non-Res. Invest	4.74	3.07	0.13	0.36	0.61	0.81	0.87	0.82	0.70
(d) Res. Invest	9.98	6.47	0.67	0.75	0.76	0.66	0.45	0.21	-0.02
(e) House Prices*	4.16	2.70	0.47	0.53	0.55	0.52	0.46	0.41	0.35
(f) Durables Quant.	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

* Data begin in 1975:1.

Notes: 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 (BEA). 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, LLC (1987-2013). All variables have been logged and HP-Filtered with smoothing parameter $\lambda = 1,600$. Real house and durable prices are computed as the nominal price index divided by price index for consumption of nondurable goods and services.

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 lead-lag relationship of housing with other macroeconomic aggregates, i.e. [Green \(1997\)](#), [Leamer \(2007\)](#) and [Ghent and Owyang \(2010\)](#), and the relationship of house prices and housing wealth to consumption, for example [Muellbauer and Murphy \(1997\)](#), [Davis and Palumbo \(2001\)](#) and [Case, Quigley, and Shiller \(2005\)](#).²⁰ In this

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

¹⁹Residential investment does not lead GDP in all countries, see [Kydland, Rupert, and Sustek \(2012\)](#).

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

section, we focus on one specific branch of the literature: Equilibrium aggregate models in the spirit of [Kydland and Prescott \(1982\)](#), i.e. “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 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.

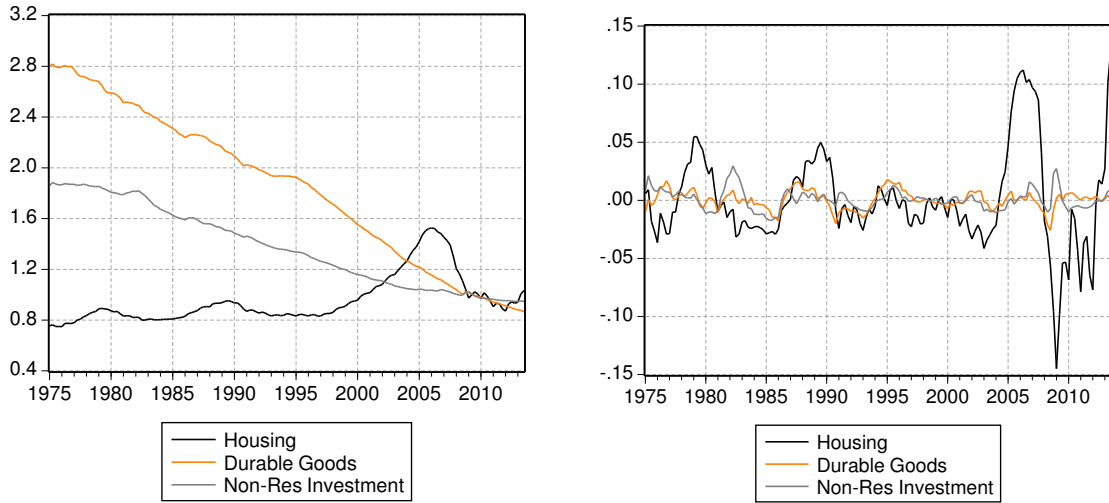
The first class of real business cycle models where housing variables entered as objects of interest were models with home production ([Benhabib, Rogerson, and Wright, 1991](#); [Greenwood and Hercowitz, 1991](#)). Those models are two-sector extensions of the canonical real business cycle model of [Kydland 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,” that is complementary in utility with leisure and with consumption purchased in the market. A justification for this approach (see [McGrattan, Rogerson, and Wright \(1997\)](#)) is that in time-use surveys, households on average spend about 25 percent 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, Rogerson, and Wright, 1995](#); [McGrattan, Rogerson, and Wright, 1997](#)).

In the home production literature, it is typically assumed that home 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 11](#), which graphs real house prices, durable goods prices, and the price of non-residential fixed investment over the 1975-2013 period, shows that these assumptions are at odds with the data.²² The left panel of the figure plots

²¹For 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.

²²The house price data start in 1975. All prices have been converted to real using the NIPA price index for consumption of non-durable goods and services.

Figure 11: RELATIVE PRICES (2009 = 1.0), 1975:1 - 2013:3



Notes: The price index for durable goods and for non-residential investment are from the National Index and Product Accounts (NIPA). 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, LLC (1987-2013). All prices have been converted to real by deflating using the NIPA price index for consumption of non-durable goods and services. The left panel shows the raw data and the right panel show the data after taking logs and applying the HP-Filter.

the raw data while the right panel shows the logged, HP-Filtered data. The left 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 right panel shows that cyclical durable goods prices and non-residential 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 than 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 is produced. Firms in each sector rent capital K and

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 (for example logistics, management structure, etc.) to more efficiently to make output.

labor L from households to produce output Y according to the functions below:

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

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 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

$$\begin{aligned} \max_{K_c, L_c} \quad & z_c K_c^\alpha L_c^{1-\alpha} - r K_c - w L_c, \\ \max_{K_h, L_h} \quad & p_h z_h K_h^\alpha L_h^{1-\alpha} - r K_h - w L_h. \end{aligned}$$

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

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

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

$$p_h = \frac{z_c}{z_h}. \tag{1}$$

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 motivates 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 paper to model shocks hitting the production of housing is by [Davis and Heathcote \(2005\)](#), called DH hereafter. The model of DH is similar in spirit to the simple two-sector model

²⁴Adjustment costs can introduce a wedge between the price producers receive as computed in (1) and the price households pay for additional installed unit of capital. See [Fisher \(1997\)](#) for more details.

described above. The key difference is that DH design the production-side of the model such that all the inputs and key parameters are identifiable using available data. Other papers that have adopted a similar housing production are [Kahn \(2008\)](#), [Iacoviello and Neri \(2010\)](#), [Kiyotaki, Michaelides, and Nikolov \(2011\)](#) and [Dorofeenko, Lee, and Salyer \(2014\)](#) to name just a few recent examples.

In DH, one set of firms produces “intermediate goods” (similar to the paper of [Hornstein and Praschnik \(1997\)](#)) and a second set of firms transforms these intermediate goods into final goods. There are three types of intermediate-goods producing firms –one 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 a industry-specific productivity shock z according to:

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

Notice that the capital share θ_i is allowed to vary by industry. DH 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 DH model.

Continuing, DH assume three types of final-goods producing firms. 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 final goods producing firms use construction, manufacturing, and services goods as inputs. These firms produce their output (y) according to:

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

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

DH identify the production-function parameters B_j , M_j , and S_j using data from the Input-

Output tables of the National Income and Product Accounts. Since all three intermediate goods are used in both final goods, shocks to all three industries affect both final goods production. To the extent that residential investment is more construction-intensive than consumption and business investment, $B_d > B_c$, the shocks hitting the construction sector will be relatively more important for determining residential investment. Thus, residential investment will have a different price than other goods and depending on the properties of the z_{it} terms and the values of B_j , M_j , and S_j for $j = c, d$.

The third final-goods producing firm 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 equal to:

$$y_{ht} = x_{lt}^\vartheta x_{dt}^{1-\vartheta} \quad (2)$$

DH assume that the amount of new land available in the economy is fixed at 1 each period. This assumption enables for a closed-form solution for the total quantity of housing in the economy as a function of past investments in structures 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, DH assumes a representative agent who receives utility from market consumption c_t , leisure $1 - L_t$, and housing H_t of the form of:

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

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

Table 2 compares some key moments from the data and from simulations of the DH model. Row (a) shows that the model under-predicts the volatility of hours worked. This finding is not surprising. Despite the fact that DH model three productivity shocks, all activity in the model occurs in

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

Table 2: BUSINESS CYCLE PROPERTIES OF THE DAVIS AND HEATHCOTE (2005) MODEL

Standard deviations relative to GDP			
	Variable	Data	DH
(a)	Hours worked	1.01	0.41
(b)	Non-res. invest	2.30	3.21
(c)	Res. invest	5.04	6.12
(d)	House prices	1.37	0.40

Period t Correlations			
	Variables	Data	DH
(f)	Res. and non-res. invest.	0.25	0.15
(g)	Res. invest. and house prices	0.34	-0.20

Notes: All results and data in this table are taken from Table 10 of [Davis and Heathcote \(2005\)](#). The standard deviations and correlations in this table do not exactly match those in Table 1. [Davis and Heathcote \(2005\)](#) use annual data over a different sample range (1948–2001); they HP-Filter the data with smoothing parameters $\lambda = 100$; and they use different source data for house prices.

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 non-residential and residential investment. Relative to the classic results from the home-production literature such as [Gomme, Kydland, and Rupert \(2001\)](#), the model has great success replicating the fact that residential investment is about twice as volatile as non-residential investment. Additionally, the model replicates the positive contemporaneous correlation of non-residential and residential investment (row f). This result arises from the fact that land acts as an adjustment cost to building new housing rapidly. As noted by [Fisher \(1997\)](#), these kinds of adjustment costs are necessary to generate positive co-movement of residential and non-residential investment.

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

²⁶The relative volatility of house prices is much lower in Table 2 than in Table 1 due to differences in sample periods and source data. See the notes to Table 2 for details.

data the correlation is positive (row g).

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 2-sector model without adjustment costs, $p_h = z_c/z_h$. 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 DH 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, 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 counter-factual 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, Lee, and Salyer \(2014\)](#) 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, Rupert, and Sustek \(2012\)](#) demonstrate that properties of the pricing of fixed rate mortgages may be critical to understanding why residential investment leads GDP. [Favilukis, Ludvigson, and Van Nieuwerburgh \(2011\)](#), which is discussed in more detail later in this chapter, generates 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 strong positive correlation between residential investment and house prices.

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

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 accounts for 35% of household assets and 40% of household net worth (assets minus liabilities), while home equity (housing wealth minus mortgage debt) is 23% of assets and 26% of net worth.²⁸ As shown in Figures 6, 8, and 10, two thirds of households in the U.S. 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 require 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 or so years, 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 versus 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 papers in this now mature literature.

²⁸The data are from the Flow of Funds for 1952.Q1 until 2013.Q1, 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 based on information in table B103.

4.1 A Typical Model

Utility

Most authors assume that finite-lived households receive utility from non-housing 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

$$\sum_{t=0}^T \beta^t \pi(t) E_0 [u(c, h, o)] . \quad (3)$$

In the equation above β is the rate at which households discount future utility, $0 < \beta < 1$ 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 aggregate over housing and non-housing consumption, with intra-temporal elasticity parameter $-\infty < \rho < 1$ and budget share parameter α :

$$u(c, h, o) = \frac{(\alpha c^\rho + (1 - \alpha) \xi_o h^\rho)^{\frac{1-\sigma}{\rho}}}{1 - \sigma} . \quad (4)$$

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

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, quantity of financial assets, and quantity of housing services. Studies vary 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 like stocks and bonds; and finally some studies allow households to choose among multiple types of mortgages, for example fixed payment (FRM) or variable payment (ARM). The discrete choice is whether or not to receive housing services by owning or renting.

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:

$$c_t + q_t h_t + \tau_t + a_t = w_t + a_{t-1} (1 + r_{t-1}) \quad (5)$$

$$a_t \geq \underline{a}_t \quad (6)$$

$$h_t \leq \bar{h} \quad (7)$$

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 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 papers, \underline{a}_t is set to 0 in each period and in a few papers \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 in the previous period and choose to own in the current period are more complicated. The simpler models tend to have the form

$$c_t + p_t h_t + \tau_t + mc + a_t = w_t + a_{t-1} (1 + r_{t-1}) + p_t (1 - \delta) h_{t-1} \quad (8)$$

$$mc = \zeta p_t h_{t-1} \text{ if } h_t \neq h_{t-1}, 0 \text{ otherwise} \quad (9)$$

$$h_t \geq \underline{h} \quad (10)$$

$$a_t \geq -(1 - \phi) p_t h_t . \quad (11)$$

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 (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, i.e. $h_t \neq h_{t-1}$. Some authors include a fixed component to 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 isn't too large. 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, for example [Vissing-Jorgensen \(2002\)](#).

Equation (10) specifies that owned housing cannot be too small. Equation (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 downpayment fraction. The downpayment 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 downpayment on their first house. This class of models usually rules 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 papers, the constraint about the maximum quantity of mortgage debt is typically only considered 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 adjustable rate mortgages. Some authors explicitly allow for long-term mortgages, usually modeled as perpetuities whose coupon payments are set to match the average duration of fixed-rate mortgages. Authors that 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.

Expectations on 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 they are fixed or growing at a predetermined rate, but most of the time they are stochastic. If random, typically the level is assumed to be persistent, either a random walk or a first-order auto-regressive process with a value for the auto-regressive coefficient near one. 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.

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

4.2 Calibration and Estimation

These models are estimated or calibrated using a two-step approach. The discount factor β and 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 percent. Survival probabilities by age are exogenous and come from life tables. Tax rates are also set exogenously, around 40 percent for non-retirees and 0 for households that are retired. Some parameter values related to housing are also set outside of the model, specifically the transactions cost of selling a house ζ is usually set somewhere between 5 and 10 percent,³¹ and the downpayment constraint for home buyers ϕ is set to either 5, 10, or 20 percent.³²

The depreciation rate on owned houses is set between 1 and 3 percent, based on evidence in the BEA. The remaining parameters – given sigma, the parameter determining the elasticity of substitution between consumption and housing ρ , the expenditure share on consumption as compared to housing α , the home ownership premium to utility, the maximum sized rental house \bar{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 is taken directly from the Panel Study of Income Dynamics (PSID) or from studies that use PSID data.³³ For example, log earnings from the PSID 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. Earnings processes are estimated separately

³⁰Chambers, Garriga, and Schlagenhaut (2009a), Chambers, Garriga, and Schlagenhaut (2009c) 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, Garriga, and Schlagenhaut (2009a) and Chambers, Garriga, and Schlagenhaut (2009c) set $\rho_1 = 3$ and $\rho_2 = 1$. They argue 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.

³¹The widely cited paper for this estimate is Gruber and Martin (2003). Some authors calibrate ζ to capture both monetary and non-pecuniary moving costs.

³²Occasionally this value is estimated based on data on loan-value ratios of first-time home buyers.

³³Standard references are Storesletten, Telmer, and Yaron (2004), Cocco, Gomes, and Maenhout (2005) and Heathcote, Storesletten, and Violante (2010).

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 varies 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 replicates the auto-correlation and variance of house price indexes such as the Federal Housing Finance Authority (FHFA) or Case-Shiller-Weiss (CSW) indexes. 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 1968-1992. They estimate 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 misses 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 there is zero correlation between individual house price returns and individual income realizations. Based on 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

³⁴The 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 in 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 Jr. and Ittner \(1992\)](#), [Bucks and Pence \(2008\)](#), [Benitez-Silva, Heiland, and Jimenez-Martin \(2010\)](#), and [Davis and Quintin \(2014\)](#).

³⁵The 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 percent.

³⁶Other studies measuring housing returns using micro data are [Piazzesi, Schneider, and Tuzel \(2007\)](#) who improve on the methodology of [Flavin and Yamashita \(2002\)](#) and [Landvoigt, Piazzesi, and Schneider \(2013b\)](#) who estimate high-quality housing price appreciation rates for San Diego. [Favilukis, Ludvigson, and Van Nieuwerburgh \(2011\)](#) discuss measurement issues and compare several approaches.

common component of income growth and national house price growth. The overall correlation with individual income growth is 14%. Summarizing 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.

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 percent of total wealth accounted for by housing, stock, and bond market wealth, i.e. portfolio shares. The literature also increasingly seeks to match systematic differences in portfolio shares across groups of households, sorted by tenant status (owner versus 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 6, we discuss similar models that endogenize house prices, while in section 7 we study the impact of tax and other policies on housing outcomes.

4.3.1 Housing and consumption patterns over the life-cycle

Home ownership over the life-cycle

An early 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, i.e., buy more expensive

housing, as they age or get 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 6.3.

Fernández-Villaverde and Krueger (2011) is one of the earlier papers in the literature: Although the paper was published in 2011, it was last revised in 2001. The authors 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. The authors 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 11) and consumer durables produces young agents who accumulate durables early in life and increase non-durable 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 non-durable spending (recall our Figure 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 home owners 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, the authors 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, Skinner, and Zeldes (1995) and Ameriks, Caplin, Laufer, and Van Nieuwerburgh (2010).

Halket and Vasudev (2014) study the life-cycle patterns of home ownership and mobility across Metropolitan Statistical Areas (MSAs). The authors show that the standard model, modified

to allow for [Lucas and Prescott \(1974\)](#)-style job mobility, 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 towards marrying later and the increase in income risk can account for almost the entirety of the decline. Unlike most of the papers in this literature, the authors allow for only three ages in their model (young, middle aged, old) and households transition stochastically between ages.

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 for better consumption smoothing. The authors 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, Luengo-Prado, and Sorenson \(2010\)](#) 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 home prices are falling, after disability or job loss households reduce consumption. The authors predict how the empirical results would change if downpayment constraints, adjustment costs, or the correlation of income and price growth were to change.

A related literature studies the response of consumption to house prices using micro data.

Campbell and Cocco (2007) use U.K. 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, 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 U.S. 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 home owners because their lifespan 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 riskiness of house prices and the probability of home ownership is ambiguous and depends on the degree of household risk aversion.

Bajari, Chan, Krueger, and Miller (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. The authors simulate the model and compare simulated household responses to a negative house price shock and, separately, a negative income shock. The authors 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, Bottazzi, Low, Nesheim, and Wakefield (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), the authors 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.

House price risk and demand for housing

[Han \(2008\)](#) studies housing demand when house prices are risky 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 on 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 down-size 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 price levels are high, because these areas are areas where land's share of home value is high. The authors 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.

4.3.2 The role of housing on the financial portfolio

Flavin and Yamashita (2002) is among the first papers 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 paper also proposes a resolution to an asset allocation puzzle. Standard portfolio theory prescribes that households combine the risk-free asset 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 only consider 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 each period. Agents in their model face the following tradeoff: Housing is risky, 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 stocks and houses and the high equity risk premium makes holding stocks relatively attractive.

Cocco (2005) is similar to 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), but includes a fixed cost of stock market participation. The model generates 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 towards real estate and are highly levered, similar 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 non-participation. 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 paper 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 home-owners and renters, but unlike the existing literature he considers Epstein-Zin preferences, such that the inter-temporal 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 inter-temporal 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.

Introducing Geography

One important feature of housing most of the literature abstracts from is its spatial aspect. A households' two largest assets, human wealth and housing wealth, are intimately tied to the fortunes of the location where they live and work. A large literature in urban economics, discussed elsewhere in this Handbook, centers around issues of geography. For our purposes, we highlight a couple of papers 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 each subsequent period they decide on portfolio composition.³⁷ For

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

tractability, preferences exhibit constant absolute risk aversion (CARA) 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 of the same size in the location 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 the results in [Hizmo \(2012\)](#), once location is 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 premia. 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 eliminate house price volatility.

4.3.3 Mortgage choice

[Campbell and Cocco \(2003\)](#) is the first paper to discuss household mortgage choice, and by extension household risk management. Their paper studies the risk and return features of the typical mortgage contracts, fixed rate (FRM) or adjustable rate (ARM), 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 pre-payment 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 authors refer to this as the wealth risk of FRMs. The authors 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 prefer an ARM to take advantage of the lower rate. The authors propose an inflation-indexed fixed

empirical in focus.

rate mortgage, a contract that removes the income risk associated with ARMs but also the wealth risk associated with FRMs.

The share of households that finances a house with a FRM fluctuates significantly over time. To explain this phenomenon, [Kojien, Hemert, and Van Nieuwerburgh \(2009\)](#) 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. [Kojien, Hemert, and Van Nieuwerburgh \(2009\)](#) 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 premia whose fluctuations line up with the observed fluctuations in the ARM share in the U.S., with the rule-of-thumb giving the strongest results. [Moench, Vickery, and Aragon \(2010\)](#) provide out-of-sample support for this theory by showing how the recent decline in rule-of-thumb bond risk premium can help explain the unusually low ARM share between 2007 and 2010. [Badarinza, Campbell, and Ramadoraim \(2013\)](#) 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 choice. He allows households to hold stocks, 1- 3- or 10-year long-term nominal bonds, and an adjustable- or fixed-rate mortgage. 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 a 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, similar 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 has taken great steps towards 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.

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 [Breedon \(1979\)](#) with constant relative risk aversion (CRRA) preferences fail to match the asset pricing data. In particular, predicted risk premia are too low and do not vary much over time and the risk-free rate is too high and too volatile ([Mehra and Prescott, 1985](#); [Hansen and Singleton, 1983](#); [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 understanding 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, counter-cyclical, 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, Kiku, and Yaron, 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 directly test. 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.

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 non-housing 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 non-housing goods and services as non-housing consumption, denoted c , and housing services as 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 $i = 1, \dots, N$ assets A_{t+1}^i to maximize the expected net present value of utility

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

subject to the budget constraint 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 pre-determined 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

$$\begin{aligned} c_t : \quad \lambda_t &= \frac{\partial u}{\partial c_t} \\ A_{t+1}^i : \quad \lambda_t &= \beta E [\lambda_{t+1} \mathcal{R}_{t+1}^i] \end{aligned}$$

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

$$1 = E_t [M_{t+1} \mathcal{R}_{t+1}^i]. \quad (12)$$

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 stochastic discount factor. One way to read equation (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 stochastic discount factor; specifically, the required compensation for risk is largely determined by the covariance of M and \mathcal{R} .

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

$$U(c_t, h_t) = \frac{\tilde{c}_t^{1-\sigma}}{1-\sigma}, \quad \tilde{c}_t = (\alpha c_t^\rho + (1-\alpha)h_t^\rho)^{\frac{1}{\rho}} \quad (13)$$

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

Given preferences as specified in equation (13), the log of the stochastic discount factor, call it m_{t+1} , can be written as the product of the standard single-good factor (non-housing consumption growth) and a new factor that captures the effect of the composition of the bundle of consumption and housing:

$$m_{t+1} = \log \beta - \sigma \Delta \log c_{t+1} + \frac{1-\rho-\sigma}{\rho} \log \left(\frac{1+S_{t+1}}{1+S_t} \right) \quad \text{and} \quad S_t = \frac{c_t}{q_t h_t} \quad (14)$$

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

In the special case of $\varepsilon = 1$, i.e. 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

(14) vanishes. The SDF reverts to that of the one-good endowment economy with its problematic asset-pricing predictions.

Piazzesi, Schneider, and Tuzel (2007) consider values for ε strictly greater than, but close to one, i.e. 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 premia. The model also implies that the ratio of non-housing to housing consumption predicts future stock returns, a prediction Piazzesi, Schneider, and Tuzel (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 (GMM) 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 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 inter-temporal elasticity of substitution (EIS), 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 intra-temporal elasticity ε of 0.5-0.7 and a low value of 0.023 for the EIS (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 papers, Flavin and Nakagawa (2008) consider a model with CES-aggregated preferences over nondurable consumption and durable housing. However, they study how the illiq-

uidity of housing alters the SDF, building on the seminal paper by [Grossman and Laroque \(1990\)](#). The presence of non-convex 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 for a decoupling of relative risk aversion from the inter-temporal elasticity of substitution while maintaining standard preferences, i.e. 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 and CRRA model. The Euler equation for individual households' housing returns cannot be rejected, and the authors estimate a plausible parameter value of $\sigma = 1.8$. The authors also estimate $\varepsilon = 0.13$ ($\rho = -6.7$), suggesting 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 estimate that the expenditure share on housing is roughly fixed.

Finally, recent work by [Giglio, Maggiori, and Stroebele \(2014\)](#) uses data on housing, specifically data on long-term property leases, to re-examine the shape and structure of stochastic discount factors. [Giglio, Maggiori, and Stroebele \(2014\)](#) compare the prices of freeholds (indefinite ownership of property) to 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 papers of [Campbell and Cochrane \(1999\)](#), [Bansal and Yaron \(2004\)](#); [Bansal, Kiku, and Yaron \(2012\)](#) 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, Maggiori, and Stroebele \(2014\)](#) suggests that most of the reward for investing in housing reflects compensation for near-term rather than long-term risk, consistent with the findings of [van Binsbergen, Brandt, and Koijen \(2012\)](#) 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 premia.

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 two “Lucas”-type trees, non-housing goods and housing, as in the model of Piazzesi, Schneider, and Tuzel (2007). The aggregate endowment of dividends of both trees is stochastic, and households differ in their realizations of the non-housing 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 repay 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 non-housing 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 log SDF of this economy contains a new term $\sigma \Delta \log \xi_{t+1}^a$ which measures the extent to which housing-collateral constraints bind in the economy:³⁸

$$m_{t+1} = \log \beta - \sigma \Delta \log C_{t+1} + \frac{1 - \rho - \sigma}{\rho} \log \left(\frac{1 + S_{t+1}}{1 + S_t} \right) + \sigma \Delta \log \xi_{t+1}^a \quad (15)$$

³⁸Specifically, ξ_{t+1}^a is a cross-sectional moment of individual ξ_{t+1}^i . 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, $\Delta \log \xi_{t+1}^a = 0$.

Note that the housing collateral effect operates even when preferences are separable between housing and non-housing consumption, or when the aggregator of these two goods in utility is Cobb Douglas. 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 counter-cyclical movements in the housing collateral ratio lead to persistent counter-cyclical 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 premia, consistent with the findings of [van Binsbergen, Brandt, and Kojen \(2012\)](#) and [Giglio, Maggiori, and Stroebel \(2014\)](#) 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 (15), the model predicts that an augmented “conditional” consumption-CAPM, that is a consumption CAPM model augmented with a housing-collateral term, should be able to fit data on returns. Using the housing collateral CCAPM implied by equation (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 due to liquidity reasons, i.e. low income realizations. The next section discusses models of housing default in some detail.

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

6 The Housing Boom and Bust and the Great Recession

A recent literature explores models that can simultaneously generate plausible business cycle moments, as discussed in section 3, realistic life-cycle consumption-savings and portfolio profiles, as discussed in section 4, and sufficiently volatile house and asset prices, as discussed in section 5. Much of the work in this area focuses on the epic housing boom and bust of the 2000s and studies how changes in the lending environment affected home ownership rates, house prices and other macroeconomic aggregates. These papers usually depart from the representative agent framework: Agents differ by age, income, and wealth; some agents rent and some own; and some agents borrow and others lend. We start by discussing several papers that assume that house prices are fixed – either they are set outside the model or are trivially pinned down by a simple production function for housing. These papers 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 inside 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 simpler to solve, the literature with exogenous house prices face 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.

6.1 Exogenous House Prices, No Default

A first branch of the literature studies the consequences of innovation in housing finance, either through lower downpayment constraints or the availability of new mortgage contracts. [Silos \(2007a\)](#) studies an equilibrium model with owner-occupied housing where agents vary in age, income and wealth and the price of housing is fixed. He shows that a relaxation of downpayment constraints does not change the business-cycle properties of the model, but affects residential and non-residential investment decisions of the young and poor. [Silos \(2007b\)](#) shows that adding rental housing as a choice greatly helps models such as [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, Garriga, and Schlagenhaut (2009a) study a model with different mortgage choices to determine the extent to which reductions in downpayment 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 authors show that most of the increase in home ownership rates over this time period is attributable to the availability of second mortgages. In closely related work, Chambers, Garriga, and Schlagenhaut (2009c) study how the multiple mortgage contracts that co-exist 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 fixed-rate mortgage, 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 is what 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 pro-cyclicality 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 2000s) to lower downpayment 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 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.

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). They solve the problem of a household that must decide how much to consume and whether to default on its 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 probability 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, Michaux, and Roussanov \(2013\)](#) 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 they can finance their house with a mortgage. Every period, agents can invest liquid assets at the risk free rate, refinance a mortgage, take out a home equity loan (HELOC), sell the home, or default. Both mortgages and HELOCs are subject to loan-to-value and loan-to-income limits; mortgages are long-term contracts that can be refinanced at a cost. The paper 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 authors demonstrate that the model can replicate the observed quantity of mortgage debt accumulation (our [Figure 7](#)) given observed dynamics for income and house prices.

Like [Chen, Michaux, and Roussanov \(2013\)](#), [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 non-recourse 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 home owners. 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 bullish 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, Martinez, and Sanchez \(2013\)](#) add mortgage default to the standard life-cycle model described in the previous section. Similar to [Campbell and Cocco \(2003\)](#), the size of housing is fixed. The authors allow households each period to choose their downpayment (which then implies a particular fixed mortgage payment) and then solve for the zero-profit mortgage rate associated with each mortgage.⁴⁰ Similar to [Li and Yao \(2007\)](#), the authors demonstrate that house price shocks are not an important source of consumption inequality. The focus of the paper is on two policies that can reduce default: tighter borrowing constraints and stronger recourse, as in [Laufer \(2013\)](#). First, requiring a 15% downpayment relative to an economy without a downpayment constraint minimally impacts the home ownership rate (it falls from 63.1 to 62.9 percent), but lowers defaults on mortgages by 30 percent (from 0.6% to 0.4%). Young potential home buyers are worse off because of the increase in downpayment 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 the variance of consumption but otherwise reduces default rates, boosts home-ownership rates, and reduces downpayment percentages.

[Corbae and Quintin \(2014\)](#) study the rise in foreclosures in the housing bust and ask how much

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

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 percent 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-value ratios allowed after relaxation of constraints imply 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 Schlagenhaut \(2009\)](#) argue that an essential feature to understand the spike in foreclosures 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 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 towards accounting for the observed run-up in mortgage debt and subsequent foreclosure rates. The natural next step in this literature is to endogenize house prices in the boom and bust.

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 downpayment 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 have 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, Michaelides, and Nikolov \(2011\)](#) 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 of 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 paper, [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 to owner-occupied 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, Ludvigson, and Van Nieuwerburgh \(2011\)](#), henceforth FLVN, aims to explain why house prices are more volatile than rents. FLVN also seeks to explain the slow but large increase in the price-rent ratio during the housing boom. FLVN study a two-sector general equilibrium model of housing and non-housing production, using a production framework similar to [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 non-housing 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, and because

of collateralized borrowing constraints on households, as discussed in section 4.

FLVN study the macroeconomic consequences of three systemic changes in housing finance, with an emphasis on how these factors affect risk premia in housing markets, and how risk premia 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 changes are meant to capture important changes to the U.S. economy after the year 2000.⁴² To model capital inflows, the third structural change in the model, FLVN introduce foreign demand for a domestic risk-free bond into the market clearing condition for that asset. Foreign capital purchases of the risk-free U.S. bond are determined outside the model.⁴³

According to the model, price-rent ratios increased during the housing boom due 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 premia on housing and equity assets and the decline in housing risk premia generated the increase in house prices relative to (imputed) rents. Risk premia in the model fell for two reasons. First, lower collateral requirements directly increased access to credit, 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.

FLVN attributes changes in price-rent ratios during the housing boom and bust largely to changes in housing risk premia and not to changes in risk-free interest rates. In the model, if credit standards become more lax, 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 risk premia to housing must have declined

⁴¹Garriga, Manuelli, and Peralta-Alva (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.

⁴²Van Nieuwerburgh (2012) and Favilukis, Kohn, Ludvigson, and Van Nieuwerburgh (2013) provide detailed evidence on all three changes and supporting references

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

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. FLVN attribute the decline in risk-free rates to an increase in foreign purchases of domestic bonds. FLVN 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 U.S. savers to purchase more equity and housing than they would have otherwise desired, thus increasing risk premia on housing and lowering house prices and the price of other risky assets.⁴⁴ In addition, FLVN suggest that foreign capital inflows stimulated residential investment, raising the expected stock of future housing and pushing down house prices. FLVN thus suggests the net effect of a large capital inflow from abroad into safe securities depressed real risk free interest rates but only had a small effect on house prices.

In summary, FLVN argue two opposing forces affected the price of housing risk during the housing boom and bust. During the boom, credit standards relaxed, lowering risk premia, and foreigners bought more U.S. bonds, raising risk premia. At the model's calibrated parameters, the decline in risk premia from the effects of the former exceeded than the rise in risk premia from the latter. During the bust, in which capital inflows held constant but credit standards tightened to their pre-boom levels, risk-free interest rates remained low but risk premia rose, lowering house prices relative to rents.⁴⁵

[Boldrin, Garriga, Peralta-Alva, and Sanchez \(2013\)](#) explore the role of the construction sector in explaining changes to aggregate employment and output during the housing boom. The authors emphasize that the construction sector has important inter-linkages 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 authors estimate that the construction sector accounted for 29 percent of growth of employment and 8 percent of the change in GDP during 2002-2007. The authors also estimate the contribution of construction to the decline in employment of 28 percent and 43 percent to the decline of GDP during the great

⁴⁴[Campbell, Davis, Gallin, and Martin \(2009\)](#) 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.

⁴⁵In related work, [Favilukis, Ludvigson, and Van Nieuwerburgh \(2012\)](#) study the welfare implications of a reversal of (stochastic) foreign purchases of safe U.S. debt.

recession.

In a detailed study of the housing market of San Diego, [Landvoigt, Piazzesi, and Schneider \(2013b\)](#) 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. The authors propose an assignment model of households to houses of various quality, and study how changes in income and asset distributions changed assignments between 2000 and 2005. [Landvoigt, Piazzesi, and Schneider \(2013b\)](#) 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 metro area. It also extends the housing ladder model of [Ortalo-Magné and Rady \(2006\)](#) by considering more quality types of housing.

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 papers discussed in section 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, Krueger, and Mitman \(2013\)](#) assume mortgage contracts last one period and study the effects of a specific government housing market policy, as discussed in the housing policy section

below. 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 downpayment requirements arise endogenously in the model of [Jeske, Krueger, and Mitman \(2013\)](#). The same result occurs in [Arslan, Guler, and Taskin \(2013\)](#) who study a model with default and endogenous house prices and evaluate how the model's predictions change when downpayment 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 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-LTV 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 to 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

⁴⁶In 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.

economic activity more broadly. Exploring this link seems quite important as casual empiricism suggests the Great Recession was caused by financial crisis resulting from a relatively small number of mortgage defaults.

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 final section of the chapter, 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 macro. In our view, this is an important topic where research is needed. Speaking loosely, events of the past 15 years suggest 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 a literature studying the interaction of monetary policy and housing/mortgage markets, and a recent literature evaluating mortgage modification programs.

Mortgage interest rate deductibility

The early literature focuses on the effects of the mortgage interest rate deductibility. One of the earliest papers 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 to 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 percent, the stock of housing capital would decrease by 8 percent, and one-quarter of households that own 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-one rate into consumption, business investment, or residential investment.

[Chambers, Garriga, and Schlagenhauf \(2009b\)](#) document that the majority of rental properties in the U.S. are owned by households. They model the decision to invest in rental housing, clear rental markets, 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 papers, [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 to save for a down payment on a house. In some simulations of alternative government tax policies, the home-ownership rate rises by almost 8 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, Kirker, and Stroebel \(2012\)](#) 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 born 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 paper underscores the importance of endogenizing house prices when evaluating how tax policy affects housing markets. In sum, abolishing current tax expenditures that benefit home owners would substantially increase welfare, increase home ownership, and reduce

inequality, but may lead to temporary capital losses for existing home owners.

Housing finance intermediaries

A conceptually similar question asks how the Government Sponsored Enterprises (GSEs), Fannie Mae and Freddie Mac, distort U.S. housing markets.⁴⁷ [Jeske, Krueger, and Mitman \(2013\)](#) 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 home owners 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. This conclusion is consistent with that in the literature on the mortgage interest rate deductibility.

Studying the GSEs is part of an important area of future research that takes 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 to 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.

Housing and monetary policy

A chapter on housing and the macroeconomy would be incomplete without mentioning a literature that explores the role that housing plays in transmitting monetary policy. The two best-known

⁴⁷See [Acharya, Richardson, Van Nieuwerburgh, and White \(2011\)](#) for a discussion of the historical evolution of the GSEs and a plan to reform them.

papers 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 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. The authors demonstrate that monetary policy shocks account for about 15-20 percent of the cyclical variation in house prices and residential investment. [Iacoviello and Neri \(2010\)](#) 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, Kydland, and Sustek \(2013\)](#), building off the work of [Kydland, Rupert, and Sustek \(2012\)](#), explores how monetary policy can affect the dynamics of residential investment. Unlike the papers of [Iacoviello \(2005\)](#) and [Iacoviello and Neri \(2010\)](#), the authors abstract from all nominal rigidities except one: Mortgage payments are specified in nominal terms. Changes in monetary policy affect the 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 authors show that monetary policy has a great influence on housing in economies with ARM mortgages rather than FRM mortgages: Price and wealth effects tend to reinforce each other with ARM mortgages and offset each other with FRM mortgages.

[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 eq-

⁴⁸[Aruoba, Davis, and Wright \(2014\)](#) 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.

uity using a home equity line of credit. The authors show that the presence of cash-in-advance constraints generates a decline in employment after borrowing constraints tighten: The tightening of liquidity constraints reduces the velocity of money and triggers a recession. To account for the cross-sectional pattern of leverage and employment in the data, the model also features wage rigidities and labor reallocation frictions.

[Feroli, Harris, Sufi, and West \(2012\)](#) 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 underwater mortgages and speed the transition from foreclosure to REO (real estate owned by banks) status will improve the effectiveness of monetary policy.

Mortgage modification programs

A related literature analyzes the 2009 Housing Affordable Modification Program (HAMP) and asks how many foreclosures HAMP prevented and at what cost ([Agarwal, Amromin, Ben-David, Chomsisengphet, Piskorski, and Seru, 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.

8 Conclusion

The recent housing boom and bust and financial crisis has 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 is on 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 due 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 to 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.

⁴⁹For a discussion of these issues, see Gerardi, Lehnert, Sherlund, and Willen (2008), Glaeser, Gottlieb, and Gyourko (2012), Van Nieuwerburgh (2012), and Foote, Gerardi, and Willen (2012).

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