Problems for a Fundamental Theory of House Prices

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T he recent turmoil in the U.S. residential housing market affects mainly the market for owner-occupied housing. In this market, most owners have less than a complete equity share in their home; rather, they obtain a mortgage and borrow against the value of their home. There is a presumption that over the last 30 years financial innovations have made it easier for households to borrow against the collateral value of their homes, thereby increasing the demand for housing and house prices. In this article we will argue that standard theories of the residential housing market do not predict that changes in collateral constraints significantly affect aggregate house prices. In fact, these standard theories find it difficult to account for the observed sustained house price increases. This suggests that we develop better theories of the underlying demand and supply for housing before we proceed to study the effects of financial frictions on the housing market.

There are two components of the market for single-family housing—the market for existing homes and the market for new homes. Changes in these two markets affect the aggregate economy in different ways, and over the last 30 years these two markets have behaved very differently. Almost by definition, the supply of existing homes in mature neighborhoods is less elastic than the supply of new homes in new neighborhoods. After all, the location of an existing home and the characteristics of its neighborhood cannot be easily replicated, whereas the supply of new land on the suburban fringe is relatively elastic, and the relative price of new homes is mainly determined by the price of residential structures. Thus, changes in the demand for housing should

mainly show up in the relative price of existing homes and the construction of new homes. Indeed, existing house prices have increased substantially relative to new house prices. At the same time increased construction of new homes has directly contributed to gross domestic product (GDP) through its contribution to investment in residential structures. Higher relative prices of existing homes affect GDP only indirectly through wealth redistribution between current owners and potential future owners.

The ability to obtain credit is affected by household income and by the available credit arrangements. For example, if household income increases, not only is there likely to be a demand for more housing services, but also an increase in the rate at which households save. A higher savings rate should enable them to make a down payment for a house earlier in their life cycle; that is, they enter the housing market earlier in their life cycle and this increases the demand for owner-occupied housing. Similarly, allowing households to put down a smaller down payment on the home purchase is likely to increase the demand for housing.

The growth of the government sponsored enterprises (GSEs), Fannie Mae and Freddie Mac, has changed the market for owner-occupied housing. These GSEs purchase mortgages that satisfy certain criteria and they issue securities backed by these mortgages. They have thereby "commodified" mortgages and, in the process, have reduced the borrowing costs for homeowners. Similarly, the growth of the market for subprime mortgages after 2000 introduced new segments of the population to the market for owner-occupied housing. The increasing share of subprime mortgages in overall mortgages was, to a large extent, driven by the ability of mortgage issuers to securitize these mortgages. The subprime mortgage market collapsed in 2007 and it is uncertain if it will reemerge in the future and, if so, what form it might take. Overall, innovations in financial markets have affected the demand for housing in the past and they are likely to affect that demand in the future.

In Section 1, we review some of the data on house prices and the availability of mortgage credit to households. In Section 2, we describe a simple model of the housing market based on Davis and Heathcote (2005), where land is an essential input to the production of houses. This model attributes endogenous changes in the price of housing to changes in the relative scarcity of land. In order to understand long-run trends in house prices, we study the balanced growth path of this model and find that the model is reasonably successful at accounting for long-run changes in the price of new homes. In Section 3, we model the demand for mortgage-financed housing using the Campbell and Hercowitz (2006) representation of collateral constraints. We find that changes in collateral constraints hardly affect the balanced growth path of house prices. Like most aggregate models of the housing market, the baseline housing model treats new and existing homes as perfect substitutes even though we have seen a marked divergence in the relative price of both types

of homes. Therefore, in Section 4 we argue that future research in housing should develop a theory that accounts for the differences between the market for new homes and the market for existing homes.

1. HOUSE PRICES AND FINANCIAL INNOVATIONS

The price of U.S. homes has increased significantly since the mid-1990s, and most of this price increase has shown up in the price of existing homes as opposed to the price of new homes. Over the last 30 years it has also become easier for owners to borrow against the collateral value of their home. The 2004–2006 boom of subprime mortgage lending was just another development that expanded the set of households that could enter the market for owner-occupied homes. One might, therefore, argue that house prices have increased because financial innovations that lowered the cost of owner-occupied housing have increased the demand for housing. In this section we summarize some of the developments in the U.S. housing market that pertain to house prices and the ability of homeowners to borrow against the value of their home. See the Appendix for a detailed description of the time series.

The nominal price of existing single-family homes in the United States has been steadily increasing since the 1970s and this process accelerated in the late 1990s (see Figure 1).[1] Even though the nominal price of existing homes increased nearly tenfold from 1970 to 2007, one has to keep in mind that the prices of other goods were also increasing, especially during the high inflation years of the 1970s. For reasons that will become clear later, we calculate the price of homes relative to the price of nondurable goods and services.[2] Relative prices of existing homes increased less than nominal prices, but even relative prices have almost doubled since 1970 and most of the price increase has taken place in the years since 1995. The relative price of homes peaked in 2006 after increasing by 50 percent in the 11 years since 1995. In contrast, this relative price increased by only 18 percent in the 25 years prior to 1995. One should note that even though the nominal price of existing homes never declined during this time period, the relative price of existing homes did decline in the early 1980s and 1990s.

The trend for the relative price of new single-family homes differs significantly from the relative price trend for existing homes. From 1970–2007, the relative price of new homes has increased by only one-third as much as the relative price of existing homes. Although new homes became relatively expensive in the late 1970s, their relative price then declined until the mid-1990s.

[1] All price indexes, for existing homes here and new homes below, are quality adjusted.

[2] The price index of nondurable goods and services is constructed using personal consumption expenditure data and excludes the service components related to housing. For a description of how the price index is constructed, see the Appendix.

Figure 1 Home Prices
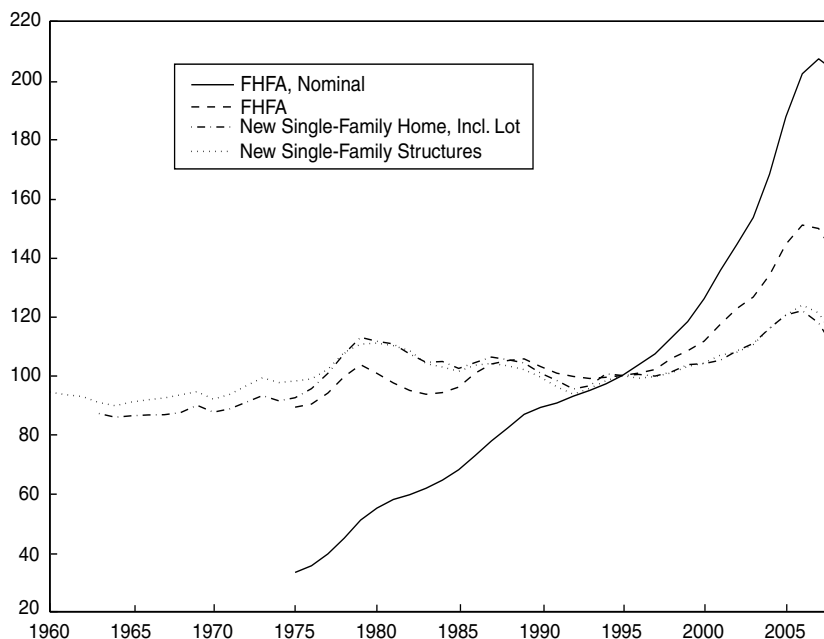
Notes: Except for the series "FHFA, Nominal," all prices are relative to a price index of nondurable consumption goods and services. All series are annual averages, except for 2008, which represents the average for the first three quarters. The series are described in the Appendix.

The price index of new single-family homes includes the value of the lot; thus, differences between the relative price of new and existing homes must be attributed to differences in the value of land embodied in the house price. In the National Income Account (NIA) measures of investment in residential structures, estimates of the value of land embodied in new single-family homes are removed from the new house price series. As we can see from Figure 1, the price index for single-family residential structures tracks the price index for new single-family homes quite closely. This suggests that the relative price of land used in the production of new homes has increased at about the same rate as has the price of residential structures. Finally, since there are persistent deviations of the price of new homes from the price of existing homes, we have to conclude that these two types of housing are imperfect substitutes.

The ability of owners to borrow against the collateral value of their house has increased over time. For example, there is some evidence that the average down payment on the purchase of a home declined significantly in the 1990s.

Figure 2 Mortgage Markets
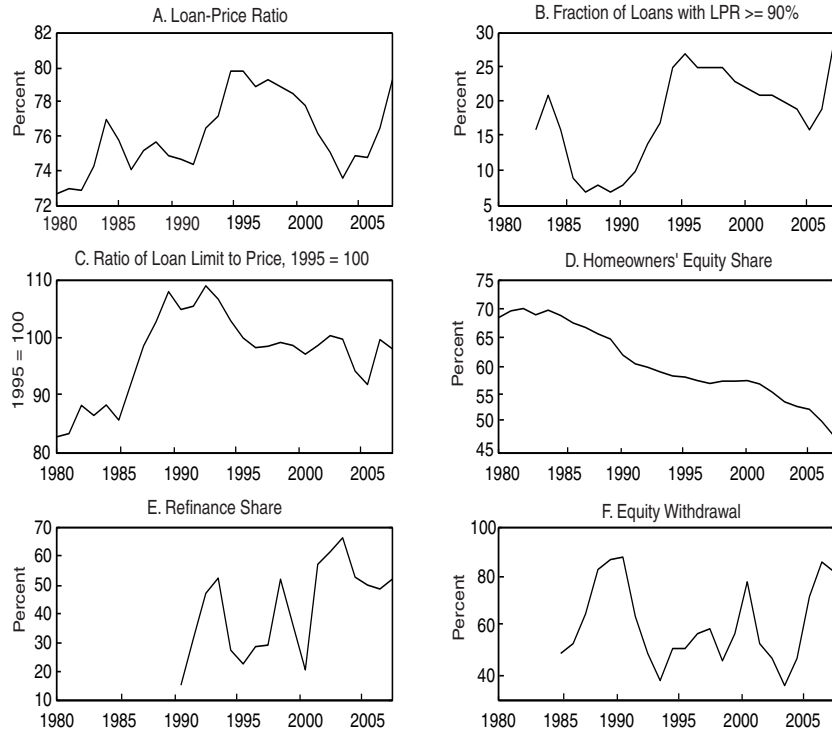
Notes: Panels A and B graph the average loan-price ratio and the distribution of loan-price ratios for conventional loans used to purchase homes. Panel C graphs an index of the ratio of conforming loan limits to average house prices. Panel D graphs the homeowners' equity share from Flow of Funds data. Panel E graphs the share of refinance in total mortgage originations, and Panel F graphs the fraction of refinances that resulted in a 5 percent increase in the outstanding loan. Detailed descriptions of the series are provided in the Appendix.

The loan-price ratio for conventional mortgages used to purchase single-family homes increased from 75 percent to a peak of 80 percent in the mid-1990s (Figure 2, Panel A). Furthermore, the fraction of these conventional loans that had loan-price ratios in excess of 90 percent reached a peak of 25 percent in the mid-1990s (Figure 2, Panel B).

For the time period considered, the majority of mortgages originated are conforming; that is, they satisfy the underwriting guidelines of Fannie Mae and Freddie Mac and they do not exceed the loan limit imposed by either one. Fannie Mae and Freddie Mac purchase and securitize conforming

mortgages. Up until September 2008, Fannie Mae and Freddie Mac were GSEs and mortgage market participants viewed them as being (implicitly) backed by the federal government.[3] Because of the implicit guarantee for GSE debt, the rates at which the two GSEs were able to borrow, and therefore the interest rates on conforming mortgages, tended to be low. Under these circumstances, homeowners can increase the loan share on which they pay relatively low interest rates; that is, they can lower the cost of a mortgage when the GSEs raise their loan limit relative to the average purchase price. Figure 2, Panel C plots the ratio of the loan limit imposed by Freddie Mac relative to the house price index for single-family homes purchased with con- ventional mortgages.[4] As we can see, the loan-limit to price ratio increased substantially in the late 1980s, and even today it is about 15 percent higher than in the 1980s.

A further sign that financial innovations made it easier for owners to borrow against the collateral value of their homes comes from the Flow of Funds data on homeowners' equity share in real estate. The homeowners' equity share declined from about 70 percent in 1980 to less than 50 percent in 2007 (Figure 2, Panel D). The fact that the decline in the homeowners' equity share is almost monotonic is a bit surprising since the evidence on down payment requirements for the purchase of homes suggests that these requirements started to increase again in the late 1990s. Yet, even though homeowners were apparently less able to borrow against the collateral of their house at the time of purchase, they were still able to extract some of the equity through refinancing their mortgages later on. With the exception of the mid-1990s and 2000, refinances constituted more than 40 percent of the total volume of mortgage originations (Figure 2, Panel E). In addition, more than 50 percent of all mortgage refinances resulted in a greater than 5 percent increase of the outstanding loan (Figure 2, Panel F).

Finally, the expansion of the market for subprime mortgages did introduce new population segments to the market for owner-occupied housing and made it possible for other homeowners to reduce their equity share substantially. It is, however, not straightforward to assess the quantitative importance of subprime mortgages since this market is less well-defined than the market for prime mortgages. Prime mortgages are essentially conforming mortgages and

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[3] Weinberg and Walter (2002) discuss the possibility of implicit government guarantees on GSE debt. On September 7, 2008, Fannie Mae and Freddie Mac were taken over by the U.S. government, and it would appear that the guarantee on GSE debt was made explicit. The regulator of Fannie and Freddie, the Federal Housing Finance Agency (FHFA) has, however, stated that the guarantee is "effective," but not "explicit" (Natarajan 2008). Mortgage investors apparently also see a distinction between effective and explicit guarantees and, as of the end of November 2008, the interest rate spreads of GSE debt relative to comparable Treasury debt was 1.5 percentage points, about twice the spread before the takeover.

[4] Whereas the loan limit series is in current dollars, the home price series is an index nor- malized to 100 in 1987. Therefore, we renormalized the ratio to 100 in 1995.

jumbo mortgages, that is, mortgages that exceed the loan limit imposed by the two GSEs for borrowers with good credit histories. Subprime mortgages, according to most definitions, involve borrowers with impaired credit histories, which is reflected in low credit ratings. Subprime mortgages also tend to involve high loan-to-value ratios. Occasionally, subprime mortgages are grouped together with Alt-A mortgages. Unlike subprime mortgages, Alt-A mortgages are taken out by borrowers with good credit history, but the mortgage may involve a loan-to-value ratio that is too high or documentation that is insufficient for the mortgage to conform to the GSE standards.

Even though subprime mortgages lie at the heart of the financial market disruptions of the last year, they became a quantitatively important part of the mortgage market only after 2000, long after house prices started to increase. Mayer and Pence (2008) suggest that the share of subprime mortgages in the total number of all originated mortgages increased from less than 10 percent before 2000 to more than 20 percent after 2000.[5] Furthermore, Mayer and Pence (2008) argue that subprime originations were predominantly cash-out refinances. Gorton (2008) provides some statistics on the value of subprime and Alt-A mortgages, both in originations and in total outstanding volume. According to Gorton (2008, Table 3), the share of subprime mortgages in the total value of originations increased from 8 percent in 2000 to about 20 percent in 2004–2006. Consequently, the share of subprime mortgages in the total value of outstanding mortgages increased from 3 percent in 2000 to more than 10 percent in 2004–2006 (Gorton 2008, Table 2).

2.   A SIMPLE MODEL OF HOUSING

We describe a simple general equilibrium model of the demand for housing where the price of housing is endogenous. A representative consumer has preferences over the consumption of nondurable goods and housing services. Housing services are proportional to the stock of housing. New housing is produced by combining new residential structures, structures for short, with land. New structures, together with nondurable consumption goods, are produced from aggregate output. The rate of transformation between nondurable consumption goods and structures is exogenous and determines the relative prices of structures. In this environment the relative price of housing depends on the supply of land and the relative price of structures.

We are interested in the model's ability to account for sustained house price increases such as those displayed in Figure 1. We will, therefore, study the model's balanced growth path, which reflects its long-run growth rates.

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[5] Mayer and Pence (2008) discuss different definitions of subprime mortgages and their most preferred measure is based on the subprime lender list maintained by the U.S. Department of Housing and Urban Development.

The Environment

Time is continuous and the horizon is infinite. A representative agent derives utility from the consumption of a nondurable good, c_0, and the consumption of housing services, h_0. The agent's preferences are

$$\int_0^\infty e^{-\rho_0 t} \left\{ \theta \ln h_0\left(t\right) + \left(1 - \theta\right) \ln c_0\left(t\right) \right\} dt, \qquad (1)$$

with time preference rate $\rho_0 > 0$ and $0 < \theta < 1$. The consumption of housing services is proportional to the stock of housing units owned by the agent. In this article, we will use the terms "housing services" and "housing stock" interchangeably.

The agent receives an exogenous endowment stream of an homogenous good. The value of the endowment in terms of the nondurable consumption good is y_0. We express all prices in terms of the nondurable consumption good. The agent also receives l_0 units of new land and the price of new land is p_l. The agent can use his income for consumption, the purchase of new housing units, x_{h0}, at the relative price, p_h, or he can save it at an interest rate, r. The flow budget constraint of the household is

$$\dot{a}_0\left(t\right) + c_0\left(t\right) + p_h\left(t\right) x_{h0}\left(t\right) = y_0\left(t\right) + p_l\left(t\right) l_0\left(t\right) + r\left(t\right) a_0\left(t\right), \qquad (2)$$

where a_0 is the agent's net financial wealth.[6] Housing depreciates at rate $\delta > 0$ and the stock of housing accumulates according to

$$\dot{h}_0\left(t\right) = x_{h0}\left(t\right) - \delta h_0\left(t\right). \qquad (3)$$

The homogenous good, y, can be used to produce the nondurable consumption good or it can be used to produce structures, x_s. The rate of transformation between nondurable consumption goods and structures is exogenous and the relative price of structures, p_s, is the inverse of the relative productivity of the structures sector. The aggregate resource constraint for nondurable consumption and structures is

$$c\left(t\right) + p_s\left(t\right) x_s\left(t\right) = y\left(t\right). \qquad (4)$$

Structures are combined with new land to produce new housing units using a Cobb-Douglas technology

$$x_h\left(t\right) = x_s\left(t\right)^\beta l\left(t\right)^{1-\beta}, \qquad (5)$$

with $0 \leq \beta \leq 1$. The production of all goods is competitive.

The representative agent owns all of the endowment of land and the homogeneous output good. Market clearing for land, the output good, the nondurable consumption good, new housing structures, and the credit market

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[6] The notation $\dot{z}\left(t\right) = \partial z\left(t\right)/\partial t$ denotes the time derivative of the variable, z, as a function of time, t.

imply (4), (5), and

$$l(t) = l_0(t), \, y(t) = y_0(t), \, c(t) = c_0(t), \, x_h(t) = x_{h0}(t), \, 0 = a_0(t).$$
(6)

We assume that the economy is growing over time. In particular, the endowments y and l and the relative price p_s all grow at constant rates γ_y, γ_l, and γ_s:

$$y(t) = \bar{y}e^{\gamma_y t}, \, l(t) = \bar{l}e^{\gamma_l t}, \text{ and } p_s(t) = \bar{p}_s e^{\gamma_s t}.$$
(7)

Before we proceed, some remarks on the properties of this environment are in order. First, new and existing housing are perfect substitutes in consumption. Therefore, new homes sell at the same price as do old homes, and this model cannot address the fact that the price of existing homes has been increasing at a faster rate than the price of new homes. Second, there is no meaningful distinction between renting housing or owning the housing stock. In other words, this model can be interpreted as one of owner-occupied housing, as is done here, or it can be interpreted as a model of rental housing.[7] Finally, this model entails some peculiar assumptions concerning the supply and use of land. The supply of new land used in the production of new homes is exogenous, and once land is embedded in new homes it depreciates at the same rate as do structures. In other words, once the structures of a house have depreciated, the plot cannot be reused for another house. The total stock of land then grows at the same rate as does the stock of new land.

Optimal Consumption and Production on the Balanced Growth Path

Hornstein (2008) provides a complete analysis of the optimization problem of the representative agent and the representative producer of new homes. We now summarize this analysis; we will drop the time index when not needed.

Optimal consumption of housing and nondurable consumption goods is such that the marginal rate of substitution between the two commodities is equated with their relative price,

$$\frac{\theta/h_0}{(1-\theta)/c_0} = \left(r + \delta - \hat{p}_h\right) p_h.$$
(8)

Here the price of nondurable goods is normalized at one and the price of housing services is equal to the user cost of housing, that is, the implicit rental rate paid for the use of the housing stock. This rental rate is the required return on the housing asset plus depreciation minus capital gains due to the

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[7] Alternatively, one could assume that renting a home simply yields less utility than owning a home. Together with assumptions on financial frictions, this can generate a well-defined demand for rental and owner-occupied housing, e.g., Kiyotaki, Michaelides, and Nikolov (2007).

changes in the capital value of the housing stock.[8] The optimal allocation of consumption over time is determined by a standard Euler equation,

$$r = \rho_0 + \hat{c}_0. \tag{9}$$

Competitive production of new housing implies that for the two inputs, structures and new land, the value of an input's marginal product is equal to the price of the input,

$$p_h \beta \frac{x_h}{x_s} = p_s \text{ and} \tag{10}$$

$$p_h (1 - \beta) \frac{x_h}{l} = p_l. \tag{11}$$

On a balanced growth path (BGP), all variables grow at constant, but potentially different, rates. The resource constraint for the output good (4) implies that the BGP nondurable consumption and the value of structures grow at the same rate as does output,

$$\hat{c} = \gamma_s + \hat{x}_s = \gamma_y. \tag{12}$$

The production function for new housing, equation (5), implies that investment in new housing grows at a rate that is a weighted average of the growth rates of new structures and land,

$$\hat{x}_h = \beta \hat{x}_s + (1 - \beta) \gamma_l. \tag{13}$$

The market clearing conditions (6) imply that the representative household's choice variables grow at the same rates as the corresponding aggregate variables,

$$\hat{c}_0 = \hat{y}_0 = \gamma_y \text{ and } \hat{x}_{h0} = \hat{x}_h. \tag{14}$$

The accumulation equation for the housing stock, (3), implies that the stock of housing grows at the same rate as does investment in new housing,

$$\hat{h} = \hat{x}_h \text{ and } \frac{x_h}{h} = \hat{h} + \delta. \tag{15}$$

Finally, the growth rates for the price of new housing and land are determined by the first-order conditions for optimal input use in the production of new housing, equations (10) and (11),

$$\hat{p}_h + \hat{x}_h = \hat{p}_l + \gamma_l = \gamma_s + \hat{x}_s = \gamma_y. \tag{16}$$

We can now express the growth rates for the housing stock and the relative price of housing on the BGP as functions of the exogenous growth rates of output, the relative price of structures, and the supply of new land. The impact of a higher output growth rate on the rate at which relative house prices increase is immediate. Combining expressions (13) and (15) yields the rate at which

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[8] The growth rate of a generic variable, z, is denoted $\hat{z}(t) = \dot{z}(t) / z(t)$.

the housing stock changes, and combining expressions (13) and (16) yields the rate at which the relative price of housing changes,

$$\hat{h} = \beta \left(\gamma_y - \gamma_s \right) + (1 - \beta) \gamma_l \text{ and} \tag{17}$$

$$\hat{p}_h = \beta \gamma_s + (1 - \beta) \left(\gamma_y - \gamma_l \right). \tag{18}$$

On the one hand, a higher growth rate of aggregate output increases both the rate of house price appreciation and the rate of housing stock accumulation. On the other hand, if the relative price of structures increases at a faster rate, or the rate at which new land becomes available declines, the relative price of housing increases at a faster rate but the housing stock is accumulated at a slower rate.

The impact of changes in the exogenous growth rates on the house price appreciation rate depends on the share of land in the production of homes. If land is not an input to the production of homes, that is, $\beta = 1$, then home production is proportional to the use of structures. Thus, house price appreciation is determined by the rate at which the relative price of structures changes and is independent of output growth and the availability of new land. Otherwise, if new homes are in fixed supply, that is, $\beta = 0$, then house price appreciation depends on the difference between the output growth rate and the land supply growth rate.

We normalize all variables such that they remain constant on the BGP. If the variable z grows at the rate $\hat{z}$ on the BGP, we define its normalized value as

$$\tilde{z}(t) = z(t) e^{-\hat{z}t}. \tag{19}$$

Essentially, the normalized value of a variable represents the level of its growth path. By construction the normalized variables do not change on the BGP, that is, $\dot{\tilde{z}} = 0$. In Hornstein (2008) we derive the solutions for the normalized levels of the BGP.

Quantitative Implications

What are the quantitative implications of our simple model for the rate at which house prices change over time? In particular, can the model account for the apparent increase of the house price appreciation rate after 1995? To answer this question we first calibrate the model by choosing parameter values to match certain statistics of the U.S. economy for the pre-1995 period. We then ask if changes in output growth rates or the rate at which the relative price of residential structures appreciate can account for the changes in house price appreciation rates.

We consider the U.S. economy from 1975 to 2007. For 20 years (1975–1995), average per capita GDP growth and average per household GDP growth were about 1 percent-per-year (see Table 1). Since the focus of analysis

Table 1 House Prices, Output, and Residential Investment: 1975–2007

	1976–1995	**1996–2007**
Prices		
OFHEO Home Price Index	0.6	3.5
New Single-Family Homes, Incl. Lot	0.4	1.4
Single-Family Residential Structures	0.1	1.4
Quantities, Per Capita		
Output	1.3	1.3
Single-Family Residential Structures	4.0	2.7
Quantities, Per Household		
Output	1.0	1.2
Single-Family Residential Structures	4.3	2.4

Notes: All prices are relative to the personal consumption expenditures (PCE) price index for nondurable goods and services (excluding housing services), and all quantities are nominal values deflated with the PCE price index for nondurable goods and services (excluding housing services). Detailed descriptions of the series are in the Appendix.

is residential housing, normalizing output per household seems to be more appropriate than the more standard per capita normalization and we choose $\gamma_y = 0.01$. For the same time period, the relative price of residential structures first increased and then declined such that the average annual appreciation rate from 1975 to 1995 was close to zero, $\gamma_s = 0$.

We calculate the housing accumulation rate based on the BGP equation (17) and, therefore, need a value for the share of land in the production of new homes and the rate at which new land becomes available. For new homes sold, the Bureau of Economic Analysis assumes a land value share of about 11 percent when it constructs the residential structures price index from the price index for new homes sold, where the latter includes the value of the lot (Davis and Heathcote 2007, 2602). This suggests $\beta = 0.9$. For the time period 1975–1995, this price index for new homes increased at an annual rate of about half a percentage point (Table 1). Davis and Heathcote (2007) also calculate an overall share of land in all home values, existing and new, that fluctuates between 30 and 45 percent. We, therefore, study the two extreme cases, $\beta = 0.9$ and $\beta = 0.5$.

The evidence on the rate at which new land becomes available is mixed at best. As part of their calculation of the value share of land in overall housing, Davis and Heathcote (2007) derive constant quality quantity indexes for residential land use. For the time period 1975–2006, their index of residential land use increases steadily at an average rate of 0.7 percent-per-year. At the same time, the number of households increased by 1.5 percent-per-year. Thus, according to Davis and Heathcote (2007), constant quality land use per household declined at an average annual rate of 0.8 percent-per-year. Overman, Puga, and Turner (2007) calculate the change in actual residential

land use in the continental United States from 1976–1992 based on satellite survey data. They find that actual residential land use increased at an annual rate of 2.4 percent-per-year. Accounting for different population growth and land use patterns across states, they estimate that the average land use per household increased by about 0.7 percent-per-year during this period. Overman, Puga, and Turner (2007) do not account for the quality of the residential land used, but, for their estimate of land use to be consistent with Davis and Heathcote's (2007) estimate, one would have to assume that the average quality of land declined at a rate of 1.5 percent-per-year.[9] This seems unlikely. We do not take a stand on land use and simply set the growth rate to zero for the analysis, $\gamma_l = 0$, and assume that the rate at which land has become available has not changed over time.

We assume an equilibrium real interest rate of 4 percent, which is standard in the literature. Equation (9) then implies the household's time discount factor, ρ_0. The Bureau of Economic Analysis (2004) reports depreciation rates between 1.1 and 3.6 percent for one- to four-unit residential structures and we chose a 1.5 percent depreciation rate. We determine the utility coefficient on housing services, θ, based on the share of nondurable consumption expenditures on the BGP. Since we do not model the consumption of durable goods services, it is not possible to construct a model-consistent measure of the share of nondurable goods. We, therefore, consider two alternative measures. First, we calculate the average share of nondurable consumption goods and services in total personal consumption expenditure plus expenditures on residential structures.[10] From 1975–1995, this expenditure share was about 80 percent and fluctuated between 76 and 82 percent. This measure probably understates the expenditure share of nondurable goods since its measure of residential structures includes multifamily units and we have included the purchase of durable consumption goods. Alternatively, we calculate the expenditure share of nondurable goods and services when total expenditures include only housing services next to the expenditures on nondurable goods and services. The latter share fluctuates between 82 and 84 percent between 1975 and 1995. Combining the two measures, we match an 80 percent expenditure share for nondurable goods and obtain the utility coefficient on housing services, $\theta = 0.556$. The parameter values are summarized in Table 2.

We find only one noticeable change in the driving forces of house price appreciation after 1995, namely a faster appreciation of the relative price of residential structures. As we can see from Table 1, whereas the appreciation rate of the relative price of residential investment increased by one percentage

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[9] Davis and Heathcote's (2007) estimate for land use is quite smooth and very similar average growth rates apply for subsamples, in particular for the time period 1976–1992.

[10] We exclude housing-related services from the service component of personal consumption expenditures.
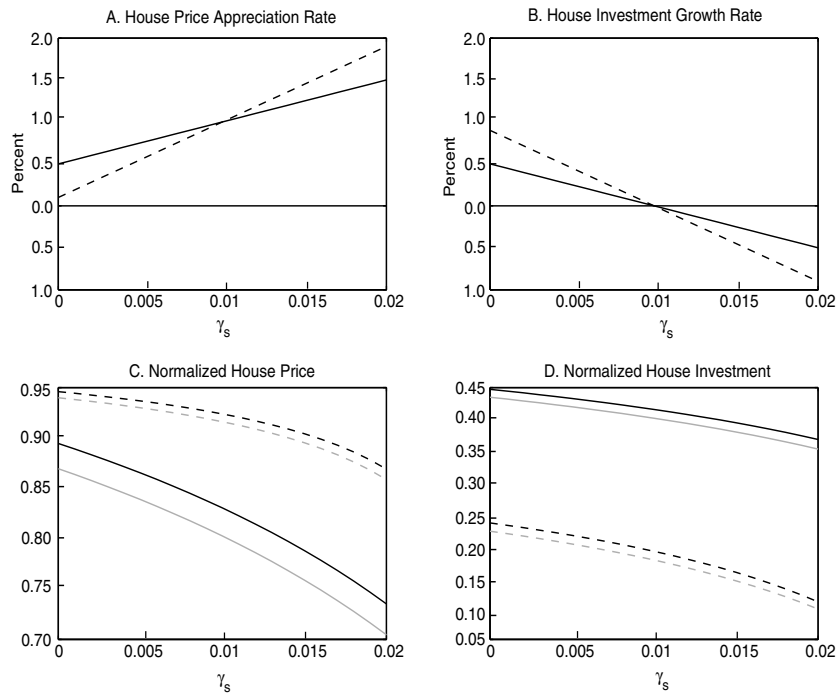
Table 2 Model Calibration

Baseline Model					
$\rho_0 = 0.03$	$\theta = 0.556$	$\delta = 0.015$	$\beta = 0.5$	$\gamma_y = 0.01$	$\gamma_s = \gamma_l = 0$
With Collateral Constraints					
$\rho_1 - \rho_0 = 0.02$	$\pi = 0.175$	$\phi = 0.0385$	$\alpha = 0.3$		

point after 1995, there was no corresponding significant increase of the output growth rate, either per capita or per household.

In Figure 3 we plot the growth rate and normalized level of the house price and investment as a function of the appreciation rate of the relative price of structures. The black lines denote this relation for the economy described in this section, and the gray lines denote the relation for the economy with collateral constraints, to be described in the next section. The solid (dashed) lines denote the economy with a large (small) new land value share in production, $\beta = 0.5$ ($\beta = 0.9$). We can see that the higher post-1995 new house price appreciation rate and the lower growth rate for residential structures is consistent with the higher price appreciation rate for residential structures (Table 1). While the change of the price appreciation rate for new homes fits qualitatively and quantitatively, the model does not capture the change of the growth rate for investment in residential structures quantitatively. Even for the period before 1995, the housing accumulation rate is predicted to be less than 1 percent, independent of the share parameter, β. This prediction is substantially below the observed 4 percent growth rate for residential investment (Table 1).

The comparison of BGP characteristics for different rates of relative price changes for residential investment probably overstates the model's ability to capture changes in the new house price appreciation rate. As we can see from Figure 3, Panel C, a higher appreciation rate of the price for structures not only increases the house price appreciation rate, but it also permanently lowers the price and investment path for homes. It is, thus, quite possible that for some time the transition to this new lower level of the BGP exerts a negative impact on the growth rates of prices and investment in new homes. This appears to be more of an issue when the contribution of new land to the production of new homes is large, since the normalized levels of new house prices and investment are more sensitive to parameter changes when the land value parameter is large.

Finally, note that the model does not make a distinction between new and existing homes. The model, therefore, does not capture the much faster price appreciation rate for existing homes after 1995. We now introduce financial frictions into the model and ask if innovations that eliminate some of these financial frictions can account for changes in house price appreciation rates.

Figure 3 The Impact of Price Appreciation for Residential Structures

A. House Price Appreciation Rate

B. House Investment Growth Rate

C. Normalized House Price

D. Normalized House Investment

Notes: Black (gray) lines refer to the model without (with) collateral constraints. Solid (dashed) lines refer to model calibrations with a large (small) share of land in the production of homes, $\beta = 0.5$ ($\beta = 0.1$).

3. FINANCIAL CONSTRAINTS AND THE DEMAND FOR HOUSING

We modify the simple general equilibrium model of the previous section and introduce a second consumer that is more impatient than the consumer studied above. At the equilibrium interest rate, the impatient agent will borrow from the patient agent. In fact, the impatient agent would like to borrow unlimited amounts. We, therefore, impose a borrowing constraint on the impatient agent that states that total borrowings are constrained by the collateral value of the agent's housing stock. We study how changes in the collateral constraint affect the equilibrium relative price of housing. Henceforth, we will distinguish between the lender, type 0 agent, and the borrower, type 1 agent.

Collateral Constraints for Housing

The borrower and lender have the same preferences with respect to the consumption of housing services and nondurable goods, (1), but the impatient borrower discounts future utility at a higher rate than the patient lender, $\rho_1 > \rho_0$. The amount of credit that the borrower can obtain is limited by the collateral value of the housing stock he owns. We assume that the required equity share of a borrower for a home of vintage τ is

$$\omega(\tau) = 1 - (1 - \pi) e^{-(\phi - \delta)\tau}, \tag{20}$$

with $\phi \geq \delta$. The down payment requirement for the purchase of new housing is $\omega(0) = \pi \in [0, 1]$. The required equity share remains constant if $\phi = \delta$, and increases with the age of the vintage to one if $\phi > \delta$.[11] The collateral constraint states that the household can borrow against the value of its undepreciated housing stock; that is, he can have negative financial net-wealth a_1, but the household has to retain a total equity position,

$$p_h(t) \int_0^\infty \omega(\tau) \left[e^{-\delta \tau} x_{h1}(t - \tau) \right] d\tau \leq p_h(t) h_1(t) + a_1(t). \tag{21}$$

Using the definition of the vintage-specific equity requirement, (20), the collateral constraint simplifies to

$$(1 - \pi) p_h(t) q_1(t) \geq -a_1(t), \tag{22}$$

where q_1 represents the part of the housing stock against which the household can borrow after a minimum down payment has been made. This collateralizable housing stock evolves according to

$$\dot{q}_1(t) = x_{h1}(t) - \phi q_1(t). \tag{23}$$

Thus, new purchases add to the collateralizable housing stock, but their use as collateral "depreciates" at rate ϕ rather than at rate δ, as does the physical housing stock. We refer to the collateralizable housing stock as the "collateral stock."

The borrower is assumed to maximize utility subject to a budget constraint and accumulation equation for the housing stock, analogous to equations (2) and (3). In addition, the borrower's choices have to satisfy the collateral constraint, (22), and the accumulation equation for the collateral stock, (23). Given these additional constraints, the capital value of a unit of housing stock for a borrower has to be adjusted for its contribution to the collateral stock. The marginal value of a unit of housing in terms of the nondurable consumption

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[11] When the required equity share is increasing with the age of the housing vintage, a borrower would like to own only the newest vintage since he wants to borrow as much as possible against the collateral value of his housing stock. To prevent this outcome we assume that the borrower cannot continuously turn over his housing stock but has to hold on to vintages purchased in the past.

good becomes

$$\frac{\mu_1}{\lambda_1} = p_h - \frac{\varphi_1}{\lambda_1}, \tag{24}$$

where μ_1 is the marginal value of a unit of housing in utility terms, λ_1 is the marginal utility of income, and φ_1 is the marginal value of an additional unit of collateral. Analogous to the lender's consumption of housing and nondurable consumption goods, the borrower's optimal choice again equates the marginal rate of substitution between the two commodities with their relative price,

$$\frac{\theta / h_1}{(1 - \theta) / c_1} = \left(\rho_1 + \delta - \hat{\mu}_1 \right) \left(p_h - \frac{\varphi_1}{\lambda_1} \right). \tag{25}$$

Because the housing stock not only provides direct consumption services but also collateral services, the borrower's effective price of a unit of the housing stock is reduced and this lowers the user cost of housing.

We now assume that the representative borrower interacts with the representative lender from Section 2 in a competitive equilibrium. Production of nondurable consumption goods, structures, and new homes continues to be determined by equations (4) and (5). We assume that the lender receives a fraction, α, of the endowment of the output good and the remainder goes to the borrower,

$$y_0 (t) = \alpha y (t) \text{ and } y_1 (t) = (1 - \alpha) y (t). \tag{26}$$

We also continue to assume that the lender receives all of the endowment of new land. Market clearing for the nondurable consumption goods, new housing, and the credit market now imply that

$$c (t) = c_0 (t) + c_1 (t), x_h (t) = x_{h0} (t) + x_{h1} (t), 0 = a_0 (t) + a_1 (t). \tag{27}$$

The growth rates of aggregate variables on the BGP are determined as before by equations (17) and (18) since the aggregate resource constraints have not changed. From the definition of market clearing, (27), it follows that, on the BGP, consumption of nondurable goods and housing, wealth, etc., for borrowers and lenders grows at the same rates

$$\hat{c}_i = \hat{a}_i = \gamma_y \text{ and } \hat{x}_{hi} = \hat{h}_i = \hat{q}_1 = \hat{h}, \text{ for } i = 0, 1, \tag{28}$$

and we normalize all variables as described by equation (19).

The interest rate on the BGP continues to be determined by the lender's time discount rate and the output growth rate (Equation [9]). One can show that on the BGP the collateral constraint is binding for the borrower since the borrower's marginal utility of wealth is positive and he is more impatient than the lender. Detailed derivations are in Hornstein (2008).

Quantitative Implications

Collateral constraints have only a limited impact on the equilibrium allocations and prices of the economy's BGP. The first thing to note is that collateral constraints cannot affect the growth rates on the BGP since the growth rates are determined by the aggregate resource constraints that are not affected by the presence of collateral constrained agents. This means that collateral constraints can only affect the levels of the BGP. We now show that the impact of collateral constraints on these growth path levels is quantitatively limited. This also means that collateral constraints are unlikely to have a great impact on the transition to a new BGP.

Our model of collateral constraints is based on Campbell and Hercowitz (2006) and we follow their parameterization closely. The impatient borrower's time discount rate is set two percentage points higher than the lender's time discount rate, $\rho_1 = \rho_0 + 0.02$. In their analysis, Campbell and Hercowitz (2006) take a broad view of the role of collateral constraints and they model them as applying to the purchase not only of homes, but also of durable goods. Our view is more narrowly focused on the home mortgage market and we, therefore, only use their estimates of the down payment parameter and the equity accumulation rate as it applies to home mortgages. Hercowitz and Campbell (2006) argue that, for the time period before 1982, collateral constraints for homes are best represented by a down payment parameter, $\pi = 0.23$, and an equity accumulation rate, $\phi = 0.052$. The latter reflects an average term to maturity for mortgages of about 20 years.

Campbell and Hercowitz (2006) argue that post-1982 initial down payments declined by six percentage points and the average term to maturity increased by six years. Their collateral constraint parameters for the post-1982 period are $\pi = 0.175$ and $\phi = 0.0385$. Campbell and Hercowitz (2006) set the break point for changes in the collateral constraints in the mid-1980s because they want to argue that weaker collateral reduced the aggregate labor supply elasticity and thereby contributed to the "Great Moderation" in the mid-1980s. Our focus is on the housing market and we want to account for the increased rate of house price appreciation since the mid-1990s. In Section 1 we argued that financial innovations most likely loosened collateral constraints further during the post-1995 period. Therefore, we study the impact of even bigger reductions of the down payment requirement and bigger increases of the duration to maturity than considered by Campbell and Hercowitz (2006).

Campbell and Hercowitz (2006) allocate about one-third of the output endowment to lenders and two-thirds to borrowers, $\alpha = 0.3$. Underlying this distribution of the endowment are the assumptions that lenders own all the capital and borrowers own all the labor in the economy. If we were to assume that the output good is produced using capital and labor as inputs to a constant-returns-to-scale production function and we were to allow for capital accumulation, then the first assumption is an equilibrium outcome since only

Figure 4 The Impact of Collateral Constraints
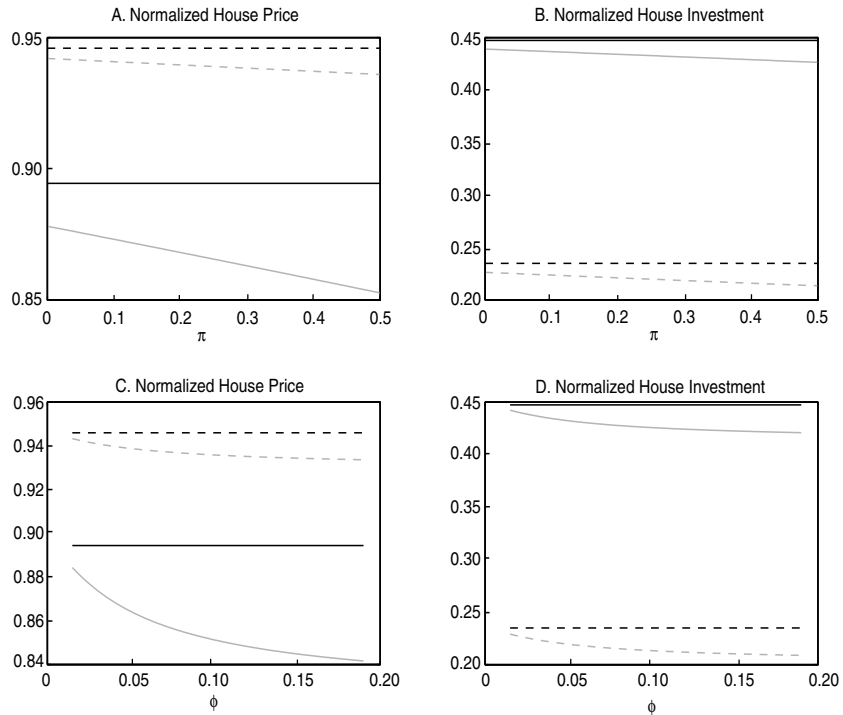
Notes: Panels A and B display the response of normalized house prices and investment on the balanced growth path to changes in the down payment rate, π. Panels C and D display the response of normalized house prices and investment on the balanced growth path to changes in the equity accumulation rate, ϕ. Otherwise, see notes to Figure 3.

the patient lenders will own capital. If only borrowers supply labor, then their share of the output good is the labor income share. In the U.S. economy, the labor income share is about two thirds and the capital income share is one third. The calibration of the housing coefficient in the agents' utility functions is not affected by the collateral constraints.

In Figure 4 we plot how normalized house prices and investment, that is, the growth path levels, relate to the collateral constraint parameters. Gray lines denote the economy with collateral constraints and black lines denote the relation for the corresponding economy without collateral constraints.[12]

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[12] Obviously, house prices and investment in the economy without collateral constraints do not respond to changes in the parameters, π and ϕ.

Lowering down payment requirements and the equity accumulation rate increases house prices and investment, but the effects are quantitatively small. We obtain the biggest effect on house prices and investment when the share of land in production is largest, $\beta = 0.5$. But even in this case, either completely eliminating down payment requirements or reducing equity accumulation rates to their lower bound does not increase house prices permanently by more than about 7 percent.

Returning to Figure 3, we see that the presence of collateral constraints does not affect much the impact of changes in the appreciation rate of the price of structures. With or without collateral constraints, normalized house price and investment levels decline with a faster rate of price appreciation. House prices and investments respond a bit more in the economy with collateral constraints, but the difference is marginal at best.

4.   CONCLUSION

We have argued that models of the aggregate housing market, such as Davis and Heathcote (2005), may be able to account for the trend of new house prices, but these models cannot account for the differential price trends in the market for existing homes. Furthermore, including an explicit model of the mortgage market apparently does not improve the model's ability to match house price trends. One might argue that the model is too stylized for it to be able to account for sustained increases in house prices, but two more elaborate versions of the basic framework have not been more successful.

Iacoviello and Neri (2008) use the same basic model of housing but add a more elaborate production structure with capital accumulation, and they add other nominal and real rigidities to the model. They are mainly interested in the cyclical implications of collateral constraints and their simulation studies indicate that collateral constraints may play some limited role for the cyclical behavior of nondurable consumption. Even though their model's production structure is quite complicated, it shares with our baseline model the feature that growth rates on the BGP are independent of collateral constraints.

Kiyotaki, Michaelides, and Nikolov (2007) provide a more detailed representation of the life-cycle aspects of housing consumption in a heterogeneous agent economy with collateral constraints. They find that even though changes in collateral constraints have a significant distributional impact in the sense that they affect the choices between owning and renting homes, these changes have only a minor impact on house prices. Kiyotaki, Michaelides, and Nikolov (2007) do find that permanently higher labor productivity growth rates can significantly increase house prices, but this feature seems to be independent of the presence of collateral constraints.

Overall, it appears that the long-run growth properties of any model that is consistent with a balanced growth path, in particular the rates of house price

appreciation, are likely to be determined by the basic supply and demand structure of the housing market and not by collateral constraints. Furthermore, given the persistent differences between the prices for new and existing homes, these two types of housing clearly represent imperfect substitutes. The first step toward improving our understanding of the housing market is then to develop a model that distinguishes between the market for new and existing homes. One possibility is to incorporate the recent externality-based theory of city structures, e.g., Lucas (2001), into models of the aggregate economy. This theory predicts land and house price gradients; that is, homes in different locations are imperfect substitutes. Conditional on a criterion that distinguishes between existing and new homes, one could work out the theory's implications for the determinants of the relative price of existing and new homes.

APPENDIX

The Office of Federal Housing Enterprise Oversight (OFHEO) publishes a house price index based on repeat sales transactions for single-family homes that are financed with mortgages that are conforming and conventional. The price index measures the average price change involved in the sale or refinancing of properties for which price data on previous transactions are available. The repeat sales feature of the price index is supposed to purge quality change from the measured price change. Mortgages are called *conforming* if they do not exceed a loan limit and they satisfy the underwriting guidelines of the two government sponsored agencies that purchase and securitize mortgages, the Federal National Mortgage Association (Fannie Mae) and the Federal Home Loan Mortgage Corporation (Freddie Mac). Mortgages are called *conventional* if they are neither insured nor guaranteed by the Federal Housing Administration, the Veterans Administration, or other federal government entities. Thus, conforming mortgages are prime mortgages while conventional mortgages can include both prime and subprime mortgages. OFHEO publishes a price index that involves actual transactions prices (purchases) and assessments (refinancing) since 1975. OFHEO also publishes a purchase-only price index since 1991. The Haver mnemonics for the comprehensive house price index is USHPI@USECON and for the purchase only price index it is USPHPI@USECON. This price index used to be known as the OFHEO house price index, but with the October 2008 merger of OFHEO into the new Federal Housing Finance Agency (FHFA), it is now referred to as the FHFA house price index.

We consider two other housing-related price series. First, the Census Bureau's price index for new single-family homes sold (HPDEX@USECON). Second, the price index for single-family structures from the national income accounts (JAFRSH1A@USNA). Whereas the first price index includes the value of the lot, the second price index applies only to new structures. Both series are constant quality price indexes.

We construct a price index for nondurable consumption goods and services, excluding housing services, from the NIA's data on PCEs. The growth rate of this price index is a Divisia index, that is, a weighted average of the components' quantity index growth rates, where the weights are the nominal expenditure shares of the components. The Haver mnemonics for the series involved are CNA@USNA, CSA@USNA, and CSRA@USNA for the nominal series, and CNHA@USNA, CSHA@USNA, and CSRHA@USNA for the chained 2000 dollar series.

The Federal Housing Finance Board publishes terms for conventional mortgages used to purchase single-family homes. For Figure 2, Panels A and B, we use the annual time series for loan-to-price ratios (FCMR@USECON)

and the fraction of loans with loan-to-price ratios above 90 percent (FCMR4@ USECON). These series represent national averages of major lenders and they include fixed rate and adjustable rate mortgages, but they exclude refinances. The alternative measure on down payment requirements for conventional mortgages in Figure 2, Panel C, is calculated as the ratio of the Fannie Mae conventional loan limit for a first mortgage on a single-family home (FCL1@USECON) to the average price of a single-family home financed with a conventional mortgage (USCMPHP1@USECON). The latter is also a repeat sales price index published by Freddie Mac.

From the Federal Reserve Board's Flow of Funds data, Balance Sheets of Households and Nonprofit Organizations, Table B.100, we obtain homeowners' equity as the market value of household real estate less the value of outstanding mortgages. The homeowners' equity share (PL15HOM5@FFUNDS) in Figure 2, Panel D, is then the share of homeowners' equity in the market value of household real estate.

The Mortgage Bankers Association provides data on the composition of mortgage originations, whether they are used for the purchase of homes (HMTOP@USECON) or to refinance an existing mortgage (HMTOR@ USECON). Figure 2, Panel E plots the value share of refinance originations and Figure 2, Panel F plots the fraction of refinances that resulted in at least a five percentage point higher loan amount (HRFHA@USECON).

For Table 1, we use the nominal value of single-family residential structures investment (FRSH1A@USNA) and the nominal value of GDP (GDPA@ USNA) for output. Both series are deflated by the above-described price index for nondurable consumption goods and services, excluding housing services. We then calculate per capita series using the U.S. resident population 16 years and older (POP16O@USECON) and per household series using the number of U.S. households (POPH@USECON).

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