Housing and the Business Cycle

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The recent boom and bust to residential investment and to overall production in the current recession can be viewed as a continuation of patterns that are evident in post-Korean war U.S. macroeconomic data. A few features of the data are worth highlighting. First, shown in Figure 1, residential investment and real GDP are highly correlated at business cycle frequencies.[1] Second, residential investment is much more volatile than investment in business capital. Table 1 shows that the standard deviation of detrended residential investment is more than six times the standard deviation of detrended GDP. This is also evident from the different scales of the axes of Figure 1. Third, residential investment leads GDP by about one quarter whereas investment in business capital lags GDP by about one quarter. Finally, house prices are contemporaneously correlated with GDP and are volatile.

An older literature studied the responsiveness of housing prices and quantities to changes in incomes, construction costs, and interest rates. A few examples from this literature include Alberts (1962), Fair (1972), Poterba (1984), Topel and Rosen (1988).[2] These papers uniformly assume interest rates are fixed, or are set outside of the model, in the sense that interest rates – the price of current consumption relative to future consumption – are not linked to changes in the marginal utility of consumption. As emphasized by Prescott (1986b), interest rates are a key price in any macroeconomic model. So, while the discussion about housing, mortgages, and so-called "Regulation

[1] All data have been logged and HP-Filtered with smoothing parameters $\lambda = 1,600$.

[2] See McCarthy and Peach (2002) for a recent example.

Q" in these older papers is interesting, they do not fit into the modern literature of business cycles.

The first business cycle models (Kydland and Prescott 1982) did not distinguish residential investment or housing from other forms of capital.[3] The goal of these papers was to understand the fraction of the variability of post-war output that could be explained by a neoclassical growth model (Cass 1965, Brock and Mirman 1972) with stochastic stationary shocks to the level of multi-factor productivity around a growing trend. Fairly early on, researchers learned that, while successful along some dimensions, the standard "real" business cycle model under-predicted the volatility of hours worked. In the data, the standard deviations of HP-Filtered log hours worked and log GDP are roughly the same, about 1.7 percent (Prescott 1986a). In the first set of real business cycle models, the standard deviation of simulated hours worked was roughly equal to half of the simulated standard deviation of output.

Soon after the study of Kydland and Prescott (1982), researchers were working on adapting the standard real business cycle model such that it would correctly predict that the standard deviation of hours worked and GDP are roughly the same order of magnitude. Early papers by Hansen (1985) and Rogerson (1988) modified the Kyldand and Prescott model to allow for indivisible labor supply.[4] Soon after, researchers were augmenting the standard real business cycle model to allow for "home production." In a home production model, households receive utility from market consumption, denoted c_m, and home (or non-market consumption), c_n; they accumulate capital to be rented to the market for the purposes of producing market output, k_m, and accumulate capital for the purposes of home production, k_n; and they allocate their time between work in the market, h_m, work at home, h_n, and leisure l. Both the home- and market- production functions are subject to shocks to productivity.[5] For recent very good summaries of

[3]See and Cooley and Prescott (1995) for a review.

[4]Hansen (1985) shows that when the standard model is adjusted to allow for indivisible labor supply, the standard deviation of hours worked is equal to three-quarters of the standard deviation of GDP.

[5]See Benhabib et. al. (1991) and Greenwood and Hercowitz (1991) for formal treatments.

home production models, see Chang and Hornstein (2006) and Kangopadhyay and Hatchondo (2009).

The home-production framework was considered an important extension of the original Kydland and Prescott (1982) model.[6] The available data suggest households spend about as much time engaged in working at home as they do in the market (Juster and Stafford 1991). For this reason changes to the allocation of time across the home- and market- sectors may be of first-order importance in accounting for the cyclical volatility of market hours. For the purposes of studying the role of housing in the business cycle, the home production models were the first papers to explicitly specify a different purpose for residential investment than investment in market-capital (such as spending on equipment and software and on non-residential structures).

Researchers have had a number of challenges in calibrating a basic home-production real business cycle model, in part because the inputs into the home production process are not all observed. In sum, researchers have had to take a stand on (a) the elasticity of substitution between home and market consumption in utility; (b) the statistical process characterizing shocks to productivity in the home sector and the correlation of home- and market- productivity shocks; and (c) what (in the data) should be considered as home capital. Taking each of the points in order: Benhabib et. al. (1991) use data on hours worked at home, hours worked in the market, and data on wages from the Panel Study of Income Dynamics to estimate the elasticity of substitution between home and market consumption. They find an elasticity of substitution greater than one, i.e. with preferences of the form

$$\begin{aligned} u\left(c_n, c_m, l\right) &= \frac{\bar{c}^{1-\sigma}}{1-\sigma}\, v\left(l\right) \\ \text{with} \quad \bar{c} &= \left[\alpha c_m^{\rho} + (1-\alpha)\, c_n^{\rho}\right]^{1/\rho} , \end{aligned} \tag{1}$$

they estimate $\rho = 0.8$. McGrattan et. al. (1997) estimate the process for shocks to home- and market- productivity using a structural estimation approach that takes

[6] Gomme and Rupert (2006) argue that the home production model is now the benchmark real business cycle model. Recent and important examples include Fisher (1997), Gomme et. al. (2001), and Fisher (2007).

advantage of the set of first-order conditions of the model. The authors show that home shocks are "relatively insignificant," in the sense that "the result that home production matters does not depend critically on the presence of home technology shocks," (p. 282). Finally, and importantly, when matching model statistics to data, all papers in the home-production literature define the stock of home capital in the data as the sum of the stock of housing structures and the stock of consumer durables.

Generally speaking, the home production models have been challenged in matching two features of the data related to investment in the home sector. First, contrary to the data, the models tend to predict that investment in business capital is more volatile than investment in home capital (Gomme et. al. 2001). Second, without adjustment costs, the home production real business cycle model predicts that investment in market- and home- capital are negatively correlated (Fisher 1997). In response to a positive shock to market productivity, households add to market capital first, since market capital is required to make more of everything. Later on, households increase their stock of home capital. As mentioned earlier, the data suggest that investment in home capital leads investment in market capital by about two quarters. I return to both these points later.

Davis and Heathcote (2005) argue that home production models are somewhat ill-suited to specifically study the business cycle properties of housing. They make two related points. First, in home production models it is assumed that home capital (the sum of housing and durable goods) is produced using the same technology as all other output.[7] This implies the real price of housing is constant over time, except for fluctuations due to the presence of adjustment costs. This is clearly at odds with the data. As mentioned earlier, the detrended real price of housing is volatile. But, as shown in Figure 2, the real price of housing also has an upward trend: After averaging

[7] A notable exception to this is Hornstein and Praschnik (1997), who study production of durable and non-durable goods.

through booms and busts, the trend rate of growth of real house prices has been about one-half percent per year since 1975.[8]

Second, when calibrating home production models, researchers treat the stock of housing and the stock of consumer durable goods (hereafter called "durable goods") as equivalent. But housing and durable goods have quite different properties. To start, housing is a much longer-lived asset than durable goods. The depreciation rate on the housing stock is 1.6 percent per year whereas it is 21.4 percent per year for other durable goods (Davis and Heathcote 2005). Second (and related), investment in housing is much more volatile than investment in other durable goods: Table 1 shows that the the standard deviation of residential investment is about twice that of consumer durables. Third, residential investment leads GDP by one quarter but consumer durables do not: The highest correlation of detrended real expenditures on consumer durables and GDP is at period t, cell f6. Fourth, house prices are about 4 times more volatile than the price of durable goods (cells e1 and g1). Finally, house prices are positively correlated with GDP (and might even lead GDP), cells e5 and e6, whereas durable goods prices are negatively correlated with GDP.

Davis and Heathcote (2005), hereafter DH, specify and simulate a model that is viewed by some as the first paper that explicitly studies the business-cycle properties of housing. The DH model is a frictionless, representative agent, neoclassical growth model that is a relatively straightforward extension of an otherwise standard home-production model. The key extension: DH specify that housing is produced using a different technology than other goods, allowing it to have a nontrivial relative price. The point of the DH paper is to quantify the extent to which a well-calibrated model can match the fluctuations in residential investment and house prices observed in the data. Any significant model failures in matching the data could then point to a meaningful role for frictions and/or incomplete markets.

[8]The trend is computed using data from 1975-2002. The trend rate of growth over the entire 1975-2009 period for which we have data is 1.3 percent per year. Note that 1975 is the starting date for the reliable data series on the price of existing homes – see the notes to Table 1.

The household side of the DH model borrows heavily from the home production literature. DH assume households receive flow utility of

$$\begin{aligned} U(c_m, h, l) &= \frac{(\bar{c}\, l^{\mu})^{1-\sigma}}{1-\sigma} \\ \text{with} \quad \bar{c} &= c_m^{\alpha} h^{1-\alpha} , \end{aligned} \tag{2}$$

where c_m and l are market consumption and leisure, as before, and h is the stock of housing, not the quantity of home production as in equation (1). As shown by Greenwood et. al. (1995), equation (1) reduces to equation (2) when (a) households have log-separable preferences over leisure, market consumption and home consumption, (b) the home produced good is produced using a Cobb-Douglas technology from home capital and labor, and (c) $\rho = 1$. DH argue, contrary to the results of McGrattan et. al. (1997), that available data support the assumption of a unitary elasticity of substitution between consumption and housing.[9] DH calibrate utility function parameters to match the average share of time households spend working and the average ratio of the value of the stock of residential structures relative to GDP.

Noted earlier, the production side of the DH model represents the most significant departure from the home production literature, and many recent macroeconomic models that generate nontrivial house prices borrow aspects of this production structure.[10] DH specify three types of firms in the economy. The first set of firms use capital and labor to make one of three intermediate goods called "construction," "manufacturing," and "services." Output of intermediate good i in period t, denoted x_{it}, for i equal to b (construction), m (manufacturing), and s (services) is specified as

$$x_{it} = k_{it}^{\theta_i} \left(z_{it} n_{it}\right)^{1-\theta_i} , \tag{3}$$

where k_{it} and n_{it} are capital and labor employed in production of good i and z_{it} is a sector-specific productivity shock. θ_i is the capital share of producers of intermediate goods i, which can vary for $i = b, m, s$. In contrast to the home-production function in

[9]Additional evidence supporting this claim is in Davis and Ortalo-Magné (2009).

[10]See Dorofeenko et. al. (2009), Iacoviello and Neri (2010), Kahn (2009), and Kiyotaki et. al. (2008) to name just a few recent examples.

the home production models, DH show that all aspects of this production technology are directly observable with available data. DH use the Gross Domestic Product by Industry Tables, produced by the Bureau of Economic Analysis (BEA), to identify the capital shares θ_i; and, given a value of θ_i, DH use data from the Gross Domestic Product by Industry tables and the Fixed Asset tables, also produced by the BEA, to uncover time series data for k_{it}, n_{it}, and z_{it}.[11]

A second set of firms uses a Cobb-Douglas technology to combine the intermediate goods into two "final" goods. The first final good can be costlessly split into consumption and investment in business capital; the second final good is residential investment. DH specify output of final good j in period t as y_{jt} for $j = c$ (consumption and business investment) and $j = d$ (residential investment) to equal

$$y_{jt} = b_{jt}^{B_j} m_{jt}^{M_j} s_{jt}^{S_j} , \tag{4}$$

where B_j, M_j, and S_j are the value-added shares of construction, manufacturing, and services in the production of final good j. DH show that these shares are identifiable using data from the Input-Output tables, also produced by the BEA.[12] DH show that residential investment is much more construction intensive than the other final good, which turns out to be important in explaining the relative volatility of residential investment.

A final set of firms in the DH model combine new residential investment with new land (made available by the government each period) to create new housing units. The specific production function for the quantity of new housing built in period t, y_{ht}, is

$$y_{ht} = x_{lt}^{\phi} x_{dt}^{1-\phi} , \tag{5}$$

where x_{lt} is the amount of newly developable land and x_{dt} is residential investment (produced according to equation 4). DH identify the parameter ϕ based on results about the share of the value of new housing attributable to raw land costs from an internal memo of the U.S. Census Bureau.

[11] See the Data Sources Appendix of DH for more details.

[12] DH calibrate these shares using data from 1992. The DH specification is inconsistent with the sectoral decline in manufacturing over the post-war period.

Thus, the DH model has three ingredients that allow for potentially interesting time-series variation in house prices. First, the statistical process (mean growth rate, variance, and autocorrelation) for z_{it} is allowed to vary across the construction, manufacturing and services sector. Second, firms that produce residential investment use different combinations of these three intermediate goods than firms that produce the other final good. The price of housing has a long term upward trend according to the DH model for these two reasons: DH show that z_{bt} has zero trend growth, and, construction accounts for about 50 percent of the value-added in residential investment (as compared to 3 percent of the value added of the other final good). Finally, new housing requires both new land and new residential investment, and new land is in fixed supply. The scarcity of land affects both the trend and the variance of house prices in the model.

Some key second moments from the data and from simulations of the DH model are reported in Table 2. The information in this table is copied directly from Table 10 of DH.[13] Rows (a) and (b) of Table 2 show that the DH model under-predicts the volatility of consumption and of hours worked. In this regard, the results of DH are similar to previous models. However, the DH model has great success replicating key facts about residential investment, namely that residential investment is about twice as volatile as business investment (rows c and d) and that residential and business investment are positively contemporaneously correlated (row f). DH show that the low depreciation rate on structures and the relatively high labor share of the construction sector are largely responsible for replicating the relative volatilities of residential and business investment. With a low depreciation rate, it is possible for households to "concentrate residential investment in periods of high productivity" (p. 774); and, with a high labor share of the construction sector, "it is easier to expand output rapidly the more important is labor in production, since holding capital constant, the marginal product of labor declines more slowly" (p. 774). The positive correlation of residential and business investment is attributable to the fact that new housing needs new land

[13]See the notes to Table 2 for details.

as an input in production, and new land is in fixed supply. In this regard, land in the DH model acts analogously to adjustment costs in the home production models.

Although the DH model replicates some key features of housing investment, it does not match some key features of the housing data. The DH model can not generate that residential investment leads GDP and business investment lags GDP (not shown).[14] Second, the DH model can not replicate two important features of house prices. Shown in row e of Table 2, the DH model under-predicts the volatility of house prices by about a factor of 3. The DH model also predicts that residential investment and house prices are negatively contemporaneously correlated, whereas in the data they are positively correlated (row g). Future researchers are actively focusing on reconciling these issues.

[14] Fisher (2007) has made some headway on this issue, but his approach of including home capital as a direct input to market production is not without controversy.

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Table 1: Properties of Selected Detrended U.S. Macroeconomic Data, 1955:1 - 2009:3

	Variable X	Std. Dev	Relative Std. Dev	Correlation of Variable X_s and GDP_t s = t-3	t-2	t-1	t	t+1	t+2	t+3
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(a)	GDP	1.57	1.00	0.38	0.62	0.85	1.00	0.85	0.62	0.38
(b)	Consumption	0.85	0.54	0.50	0.67	0.80	0.83	0.71	0.53	0.33
(c)	Res. Invest	9.84	6.28	0.64	0.72	0.74	0.64	0.41	0.15	-0.09
(d)	Non-Res. Invest	5.16	3.29	0.08	0.32	0.58	0.80	0.85	0.78	0.63
(e)	House Prices*	3.83	2.44	0.36	0.44	0.48	0.47	0.41	0.33	0.25
(f)	Durables Quant.	4.47	2.85	0.50	0.66	0.78	0.81	0.62	0.39	0.16
(g)	Durables Prices	0.96	0.61	0.16	0.06	-0.05	-0.16	-0.23	-0.27	-0.29

* House price 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 (1987-2009). 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.

Table 2: Business Cycle Properties of the Davis and Heathcote (2005) Model*

Standard Deviations Relative to GDP

	Variable	Data	DH
(a)	Consumption	0.78	0.48
(b)	Hours Worked	1.01	0.41
(c)	Res. Invest	5.04	6.12
(d)	Non-Res. Invest	2.30	3.21
(e)	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). Davis and Heathcote use annual data over the 1948-2001 range; they HP-Filter the data with smoothing parameters $\lambda = 100$. The use of annual data and the different sample range explain some of the discrepancies between this table and the data reported in Table 1.

Figure 1: Plot of Real Detrended Residential Investment and GDP, 1955:1 - 2009:3

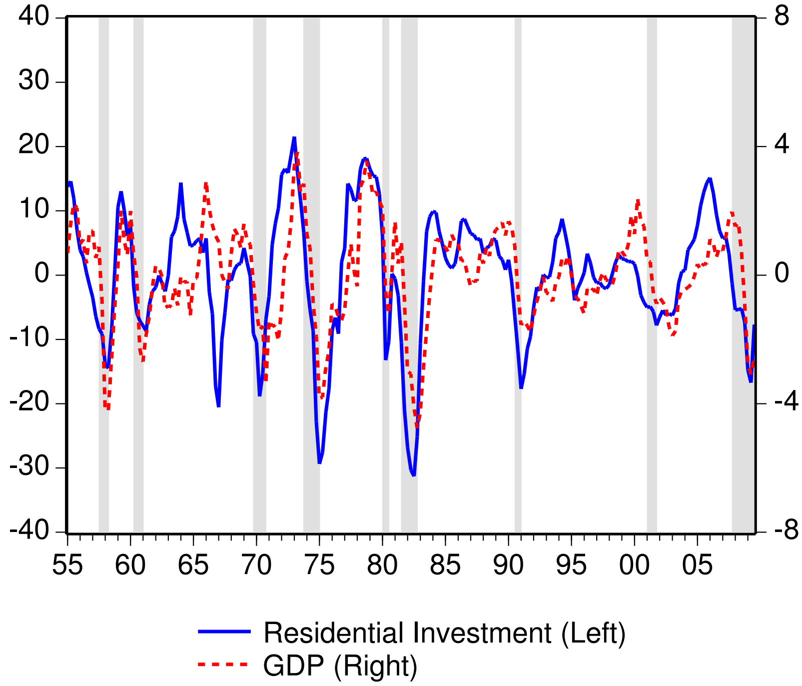
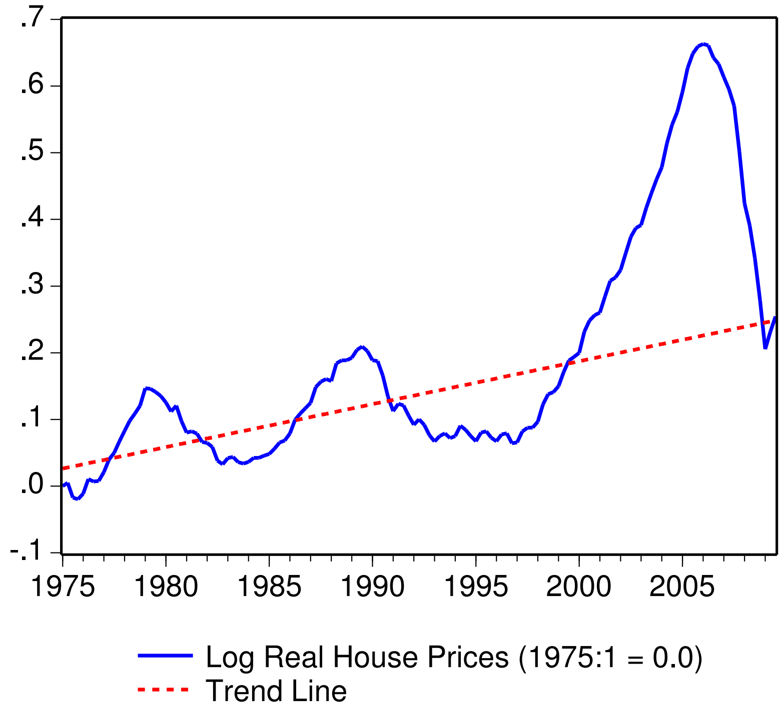


Figure 2: Plot of Real Log House Prices and Trend Line, 1975:1 - 2009:3



Notes: Trend is computed using data from 1975:1 - 2002:4.