Asset Pricing in Home Production Economies[*]

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This Version
November 14th 2008

Abstract

In search of a model linking financial and housing markets to the real economy, this work proposes to study the asset pricing implications of a home production economy. House prices and equity returns can be studied within the context of a general equilibrium framework where the decisions to invest in business and in residential capital, and to supply labor, are endogenously determined. Some key aspects of the dynamics of house prices, the equity premium, and the Dunlop-Tarshis observations can be explained.

- Keywords: House Prices, Habit Formation, Equity Premium, Home Production
- JEL: E2, E3, G1

1 Introduction

Understanding the channels through which asset markets and the real economy interact constitutes a major challenge for the macro-finance literature. As emphasized by the subprime crisis, central banks and regulators are facing an increasing number of complex questions involving a deep understanding of this nexus. Despite the importance of this issue, the gap between the

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[*] This work has benefited from comments and suggestions from G. Lombardo, O. Tristani, E. Pasten, G. Korteweg and seminar participants at the University of Mannheim and at the ECB. Any remaining errors are my own responsibility.

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macroeconomics, the housing and the finance literatures remains difficult to fill.

Most of the asset pricing literature studies equity returns in models abstracting from the determination of business cycle and housing market variables. While labor income represents two-third of total value added, the role of labor supply in explaining the behavior of asset prices remains widely unexplored. Moreover, whereas housing is by far the largest component of household total wealth, few studies have attempted to study equity returns in a model also able to explain the dynamics of house prices and residential investment.

Constructing more realistic asset pricing models and relaxing the endowment economy assumption [Lucas (1978)] is not as straightforward as it might at first seem. Introducing investment and labor supply facilitates consumption smoothing and often compromises the ability of standard models to explain asset pricing puzzles. As shown by many studies [Jermann (1998); Lettau and Uhlig (2000); Boldrin, Christiano and Fisher (2001)], once the potential for intertemporal smoothing is facilitated by the introduction of a richer set of endogenous choices, explaining asset pricing puzzles becomes even more challenging.

The business cycle literature, in contrast, has been quite successful at building more realistic models where many decisions are allowed to be endogenously determined. In particular, the introduction of home production has led to the development of a class of general equilibrium models producing an enriched set of choices [Greenwood and Hercowitz (1991); Benhabib, Rogerson and Wright (1991); Greenwood, Rogerson and Wright (1995)]. In Davis and Heathcote (2005), for instance, the decisions to work in the business and in the home sector or to invest in business and residential capital are endogenously determined. In addition, the introduction of a stock of effective housing allows to simultaneously study house prices. In Davis and Heathcote (2005), however, despite some important improvements with respect to the business cycle literature, the dynamics of house prices is only partially explained and the financial market implications of the model are not investigated.

In this study, we propose to ask whether the implications of a home production economy could be reconciled with asset market facts. As argued by Greenwood, Rogerson and Wright (1995), the benefits of the home production literature lie in the enriched set of choices that such models produce. The predictions of these models are however rarely confronted with asset pricing data. Given the central role of house prices and financial markets in modern economies, this work proposes to study the following questions:

Can a home production economy model explain the equity premium? Is it possible to simultaneously explain the dynamics of house prices? Finally, is it possible to explain these asset pricing facts without compromising the model's ability to explain the main business cycle regularities?

1.1 Results

The main finding of this study is that introducing habit formation and adjustment costs significantly improves the ability of a home production economy to simultaneously explain asset pricing, business cycle, and housing market facts. The high observed equity premium as well as the volatility of equity and house prices can be explained in a model also able to reproduce a large number of business cycle facts.

Compared to the finance literature, in this study, asset pricing puzzles can be explained in a richer environment where many economic decisions are allowed to be endogenously determined. Following the home production approach, the decisions to invest in residential and business capital or to work in the market and in the home sectors are explicitly modelled.

Compared to the business cycle literature, the main difference is that the Dunlop-Tarshis observations can be explained in a model also able to generate plausible asset pricing predictions. Despite being solely driven by technology shocks, the proposed framework can successfully reproduce the high observed volatility of market hours and the correlation between output and real wages.

1.2 Methodology and Assumptions

Generating plausible asset pricing facts in a business cycle model with endogenous labor supply is not an easy task. The problem comes from the fact that labor effort is affected by the intertemporal consumption and saving choice, or marginal utility of consumption [Greenwood, Hercowitz, and Huffman (1988)][1]. The strength of this negative wealth effect, which generates a counterfactual reduction in the volatility of hours worked, is a well-known problem in the business cycle literature [see Rebelo and Jaimovich (2006) for a recent example]. Without a strong response of hours worked, business cycle models loose their ability to amplify the effects of shocks. This has

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[1] This is also the case in models where separability between consumption and leisure is assumed. Greenwood, Hercowitz, and Huffman (1988) introduce preferences allowing labor effort to be determined independently of the intertemporal consumption and savings choice.

always been a main weakness of the real business cycle approach [Mankiw (1989), King and Rebelo (1999)] and of business cycle models in general.

In asset pricing models, this negative wealth effect is exacerbated by the introduction of habit formation in consumption. In these models, households end up using labor supply to insure themselves against undesirable fluctuations in consumption [Uhlig (2007b)]. This willingness to avoid fluctuations in consumption gives rise to countercyclical movements in hours worked, generating a reduction in the volatility of output. While this reduction in output volatility facilitates consumption smoothing, it also generates counterfactual predictions. In particular, without a strong propagation mechanism, standard models fail to generate plausible asset pricing and business cycle predictions.

In this study, this problem is overcome by introducing two modifications. First, following the home production approach, we assume that agents can divide their total number of hours worked into a market and a home component. In our economy, the time spent at home is dedicated to home improvement activities, and increases in the housing stock can be obtained by combining hours worked at home with residential capital. The second important ingredient is to relax the assumption that agents' habit stock only depends on consumption and to introduce leisure into the analysis. Compared to a standard specification of habit formation that leads to consumption smoothing, the difference is that, in our economy, this new specification creates an incentive to smooth changes in the utility level provided by the composite of consumption *and* leisure.

We find that combining these two elements: (i) the introduction of a home component in the disutility of working with (ii) a specification of habit formation in the composite of consumption and leisure (the composite good); has important asset pricing and business cycle implications. Introducing a distinction between market and home hours allows agents to better insure themselves against undesirable fluctuations in this composite good. The fact that this can be achieved without generating a counterfactual reduction in the volatility of market hours is key. In response to a technology shock, agents can choose to work harder in the market sector to take advantage of the temporary increase in productivity. With a home component in the disutility of working, this negative effect on utility can be neutralized by simultaneously decreasing the number of hours worked at home. Large variations in market hours can thus be obtained without generating an increase in the volatility of the composite good.

This substituability between market and home hours on which our mechanism relies has been documented in several recent studies. For instance, Aguiar and Hurst (2005) have shown that the time spent on home production increases sharply at the time of retirement. Blankenau and Kose (2007) have found a strong negative correlation between home and market hours using international data.

As far as the dynamics of house prices is concerned, we find that introducing real rigidities affecting the accumulation of residential capital allows the proposed model to capture some important aspects. In our economy, agents need to combine home hours with residential capital to increase their housing stock. The introduction of adjustment costs has an impact on the dynamics of house prices that works through the discount rate used by homeowners to discount the flow of benefits from owning a house. By creating a wedge between the risk-free rate and the borrowing cost of residential capital, this real rigidity increases the cost of financing real estate projects. In terms of quantitative implications, the introduction of adjustment costs allows the candidate model to explain the differences in the volatility of equity and house prices. The model also generates a gradual and hump-shaped response of house prices to technology shocks, which seems in line with the type of boom and bust phases that is often documented.

To identify the contribution of habit formation and adjustment costs, we start by asking whether a standard home production model could explain asset pricing puzzles. Our results show that, compared to a standard business cycle model, the introduction of home production exacerbates the problem. Introducing a richer set of choices increases the potential for intertemporal smoothing and, without real rigidities, only contributes to reinforce the equity premium puzzle.

2 Data Description

The empirical relevance of the proposed model is evaluated in terms of its ability to simultaneously explain business cycle and asset pricing facts. The set of asset pricing and business cycle facts that corresponds to the artificial economy that will be developed in the next section are reported in Table 1,2 and 3. While these variables are usually studied separately, the objective of our approach is to confront the business cycle, the housing market and the asset pricing implications of the model to the data. Following the literature on the equity premium puzzle, Table 4 reports a series of empirical evidence on the mean and volatility of financial returns, expressed in annualized percent.

In Table 1, the volatility of output is denoted σ_y. The relative standard deviation of variable x with respect to output is denoted σ_x/σ_y. Market consumption, which in the data corresponds to the consumption of non-durable goods and of services, is denoted c_M. Market investment, which corresponds to investment in equipment and software, is denoted i_M. Residential investment is denoted i_H. Hours worked and real wages in the market sector are denoted N_M and w_M and correspond to an index of total employment and earnings in the private sector. The series on output, investment, employment and wages are taken from the online database of the St-Louis Fed[2].

Table 1: Business Cycle Variables, USA

σ_y	σ_{c_M}/σ_y	σ_{i_M}/σ_y	σ_{N_M}/σ_y	σ_{i_H}/σ_y
1.65	0.47	3.31	0.98	6.01

Table 2: Relative Prices, USA

σ_{w_M}/σ_y	σ_{p_H}/σ_y	$\sigma_{p_H/r_H}/\sigma_y$	σ_{p_E}/σ_y	σ_{r_f}/σ_y
0.42	1.63	1.52	5.65	0.91

Table 3: Correlation of Relative Prices with Output

$\rho(w_{Mt}, y_{Mt})$	$\rho(p_{Ht}, y_{Mt})$	$\rho(p_E, y_{Mt})$	$\rho(r_{ft}, y_{Mt})$
- 0.24	0.586	0.44	-0.20

Except for the real risk-free rate, the series presented in these three tables have been expressed in logs. The cyclical component is then extracted using a HP-Filter.

As for the volatility of asset prices reported in Table 2, the relative standard deviation of house prices and equity prices are denoted σ_{p_H}/σ_y and σ_{p_E}/σ_y. The relative standard deviation of the house price to rent ratio is denoted $\sigma_{p_H/r_H}/\sigma_y$. The house price and house price to rent ratio series are taken from the study of Davis, Lehnert and Martin (2008)[3]. Equity prices are taken from the online database of Shiller[4]. The risk-free rate series, r_f, is computed using the 3 months Treasury Bill secondary market rate and realized CPI inflation. Both series are taken from the online database of the St-Louis Fed.

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[2] Data available online on a quarterly basis for the period 1947-2008. The series on real wage is only available for the period 1964-2008.

[3] These series are available on a quarterly basis for the period 1960-2007. House prices are expressed in real terms and are deflated using CPI inflation.

[4] Based on Shiller (2001) and updated.

As can be seen from Table 3, there are important differences in the cyclical behavior of wages, house prices, equity prices and the real risk-free rate. While equity and house prices are procyclical, real wages and the risk-free rate are countercyclical. The correlation of output and of the house price to rent ratio is 0.42. The small difference between house prices and the house prices to rent ratio illustrates that the dynamics of this ratio is mostly driven by movements in house prices.

Following the literature on the equity premium puzzle, the key financial moments which must be explained are the high risk premium, the low mean risk-free rate and the low Sharpe Ratio. As illustrated in Table 4, which shows the empirical facts reported by several different studies, to be successful, the candidate model will have to generate an equity premium, $E(r_m - r_f)$, of at least 6.18%, a mean risk-free rate, $E(r_f)$, of about 1%. The predicted Sharpe Ratio, $\frac{E(r_m - r_f)}{\sigma(r_m)}$, where $\sigma(r_m)$ denotes the standard deviation of realized equity returns should be between 0.3 and 0.4.

Table 4: Financial Returns USA, Annualized %

	$E(r_m - r_f)$	$E(r_f)$	$\sigma(r_f)$	$\frac{E(r_m - r_f)}{\sigma(r_m)}$
Jermann (1998)	6.18	0.80	5.67	0.37
Boldrin and al. (2001)	6.63	1.19	5.27	0.34
Campanale and al. (2008)	7.57	1.01	1.67	0.49

3 The Environment

To simplify the exposition, we present the social planner's problem. We then use the equivalence between the centralized problem and the competitive equilibrium to derive the asset pricing formulae describing the evolution of equity and house prices.

Preferences

Following King, Plosser and Rebelo (2002), preferences are specified so that the economy is compatible with balanced growth. The standard functional form with non-separability between consumption and leisure is adopted and lifetime utility is given by:

$$U = E_0 \left\{ \sum_{t=0}^{\infty} \beta^{*t} \frac{1}{1-\sigma} \left[C_t v(L_t) \right]^{1-\sigma} \right\}$$

where β^* is the modified discount factor[5]. Consumption, C_t, and the total disutility of working, N_{Tt}, are assumed to have both a market and a non-market component:

$$C_t = c_{Mt}^{\kappa} h_t^{1-\kappa}$$

$$N_{Tt} = N_{Mt}^{\phi} N_{Ht}^{1-\phi}$$

where c_{Mt} and h_t denote market consumption and the stock of housing. Market hours are denoted N_{Mt} and home hours N_{Ht}. The introduction of differences in the disutility of working implies that L_t measures a subjective notion of leisure[6]. At this stage, postulating a negative relationship between L_t and N_{Tt} is enough. A particular functional form will however be needed to calibrate the model (see section 4).

Our specification reduces to the standard real business cycle model when κ and ϕ are set to 1. This property will be exploited when these parameters will be estimated in order to assess to what extent introducing home production can help to explain asset pricing puzzles.

Budget Constraint

Following the home production literature, market output, y_{Mt}, can be divided between market consumption, c_{Mt}, business or market investment, i_{Mt}, and residential investment, i_{Ht} :

$$y_{Mt} = c_{Mt} + i_{Mt} + i_{Ht} \tag{1}$$

Market production has the standard Cobb-Douglas characterization:

$$y_{Mt} = A_t k_{Mt}^{\alpha} N_{Mt}^{1-\alpha}$$

where A_t, k_{Mt} and N_{Mt} denote total factor productivity, business capital and hours worked in the market sector. When it comes to capital accumulation, we start with the standard specification adopted by Greenwood and Hercowitz (1991):

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[5] where $\beta^* = \widetilde{\beta}\gamma^{1-\sigma}$ and where γ denotes the growth rate of the economy along the balanced growth path and σ is the coefficient of relative risk aversion.

[6] The effective number of hours spent on leisure activities is given by:

$$L^{eff} = T - N_H - N_M$$

where T is agents' total endowment of time.

$$k_{Mt+1} = (1 - \delta_M)k_{Mt} + i_{Mt}$$

$$k_{Ht+1} = (1 - \delta_{KH})k_{Ht} + i_{Ht}$$

where the stock of residential capital or structures is denoted k_{Ht}, and where δ_M and δ_{KH} denote the depreciation rates of business and residential capital.

Home Production

Following Davis and Heathcote (2005), a stock of effective housing, h_t, is introduced into the analysis. The stock of effective housing evolves according to the following law of motion:

$$\gamma h_{t+1} - (1 - \delta_H)h_t = y_{Ht} + l_t \tag{2}$$

The stock of effective housing is influenced by two components: the amount of home produced good, y_{Ht}, and agents' endowment of land, l_t[7]. The production function of home output, y_{Ht}, has the standard Cobb-Douglas characterization:

$$y_{Ht} = k_{Ht}^{\varphi} N_{Ht}^{1-\varphi}$$

where N_{Ht} denotes hours worked at home, k_{Ht} the stock of residential capital or structures. This home production constraint introduces a distinction between residential capital, k_{Ht}, and the stock of effective housing, h_t. While residential structures need to be combined with home hours to produce the home output good, residential structures do not directly enter the utility function of the representative agent.

Compared to Davis and Heathcote (2005), to keep the analysis tractable, we abstract from the construction sector. In our economy, the representative agent can engage in home improvement activities by increasing his or her number of hours worked at home. While home improvement activities will generate an increase in the housing stock, our analysis does not include any notion of new house built. In addition, the endowment of land is held

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[7] In Greenwood and Hercowitz (1991), home output is used to produce a service flow of consumption which is a component of utility. Their setting does not include a notion of effective housing stock and therefore cannot be used to study the determination of house prices.

constant and the asset pricing implications of introducing land into the analysis are not investigated[8].

3.1 Asset Prices

Using the equivalence between the centralized and the competitive equilibrium allows us to firstly derive the standard asset pricing formula describing the dynamics of equity prices, p_{Et}. Equity prices can be expressed as the infinite discounted sum of future dividends, or equivalently, as an intertemporal arbitrage equation where the cost of buying the asset today and tomorrow's expected future gain have to be equalized:

$$p_{Et} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[d_{t+1} + p_{Et+1} \right] \tag{3}$$

where $\beta = \widetilde{\beta}\gamma^{-\sigma}$[9]. As in Rouwenhorst (1995) and Jermann (1998), this asset pricing formula corresponds to a competitive equilibrium where market output is produced by a representative firm owning the stock of business capital. Investment is financed via retained earnings and managers maximize the value of the firm by solving the following maximization problem :

$$Max\ E_0 \sum_{t=0}^{\infty} \beta^{*t} \frac{\lambda_t}{\lambda_0} d_t$$

where:

$$d_t = y_{Mt} - W_{Mt} N_{Mt} - i_{Mt}$$

and where W_{Mt} is the market real wage. Managers discount the flow of future dividends, d_t, using the discount factor of the representative agent, who is the owner of the firm. The Lagrange multiplier associated to the budget constraint, λ_t, is determined by agents' marginal utility of consumption:

$$\lambda_t = U_{c_M}(c_{Mt}, h_t, L_t) \tag{4}$$

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[8] See Davis and Heathcote (2007) for a discussion of the implications of introducing land.

[9] The discount factor is modified to take into account that the stock of asset is growing along the balanced growth path at rate γ.

3.1.1 House Prices

In our economy, house prices can be characterized by a similar intertemporal arbitrage equation linking prices to fundamentals. Expressing house prices as an infinite discounted sum of future expected cash-flows allows us to derive the following asset pricing formula linking house prices, p_{Ht}, to the rental rate of housing r_{Ht}:

$$p_{Ht} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[r_{Ht+1} + (1 - \delta_H) p_{Ht+1} \right] \tag{5}$$

where:

$$r_{Ht} = \frac{U_h(c_{Mt}, h_t, L_t)}{U_{c_M}(c_{Mt}, h_t, L_t)}$$

According to this asset pricing formula, the payoff associated with owning the housing stock is given by r_{Ht}, where U_h, and U_{c_M} denote the marginal utilities of housing and of consumption. As noted by Davis and Heathcote (2005), r_{Ht} would correspond to the rental rate of housing in a decentralized equilibrium populated by home owners and renters.

In the centralized equilibrium described in the previous section, this asset pricing formula is derived by comparing the shadow benefit of owning a house with the shadow cost of raising residential capital. Given that the stock of housing enters the utility function, this shadow benefit is given by the marginal utility of owning the housing stock. This sum of future expected benefits is then discounted by the shadow cost of residential capital.

The shadow benefit of owning the housing stock, which is denoted μ_t, is given by the Lagrange multiplier associated with the home production constraint (2). From the first-order condition with respect to h_{t+1}, μ_t can be expressed as:

$$\mu_t = \beta E_t U_h(c_{Mt+1}, h_{t+1}, L_{t+1}) + \beta E_t \mu_{t+1} (1 - \delta_H) \tag{6}$$

While in the case of a financial asset, this flow of future expected benefits takes the form of a financial payoff such as dividends, in the case of housing, this gain is measured by the marginal utility of owning the asset.

Similarly, the shadow cost of residential capital, λ_t, is determined by the first-order condition with respect to k_{Ht+1}, and in the case without adjustment costs, is given by:

$$\lambda_t = \beta E_t \lambda_{t+1} (1 - \delta_{KH}) + \beta E_t \mu_{t+1} \varphi \frac{y_{Ht+1}}{k_{Ht+1}} \tag{7}$$

where $\varphi \frac{y_{Ht+1}}{k_{Ht+1}}$ is the marginal productivity of residential structures. The asset pricing formula (5) linking house prices to the rental rate of housing can then be obtained by combining equations (4) and (6), where house prices, p_{Ht}, are determined by the ratio of the two shadow prices:

$$p_{Ht} = \frac{\mu_t}{\lambda_t}$$

In the case without adjustment costs, the shadow cost of residential capital is equal to the marginal utility of consumption. The benefits from investing in equity and in housing are therefore both discounted at the risk-free rate. In the next section, the introduction of physical adjustment costs in residential capital will create a wedge between the discount factor used by homeowners and equity holders.

4 Simulating the Baseline Model

As documented by many studies, the baseline version presented above cannot be expected to explain asset pricing facts such as the high equity premium or the high volatility of house prices. The objective of this section is firstly to identify the reasons of this failure and secondly to propose a series of modifications that could potentially help resolving the puzzle.

4.1 Parameter Selection

The calibration procedure is carried out in two steps. A first set of parameters is chosen based on National Income Account data, following the standard in the business cycle literature. A second set of parameters, for which a priori knowledge is weak, is chosen to maximize the model's ability to replicate a set of asset pricing moments.

- **Market Sector**

The quarterly trend growth rate γ is set to 1.005 and the constant capital share in the Cobb-Douglas production function, α, is 0.34. These are standard values used in the literature. The depreciation rate of business capital, δ_M, is set to 0.0136. According to Davis and Heathcote (2005), this value corresponds to the depreciation rate for appropriately measured capital between 1948 to 2001.

- **Home Production**

Following Davis and Heathcote (2005), the depreciation rate of residential structure, δ_{k_H}, and the depreciation rate of the housing stock, δ_H, are set to 0.0039 and 0.0035. Given that our production function of the home output good depends on labor and residential capital, the estimated values reported by Jin and Zeng (2004) are used, and the residential capital share φ is set to 0.13. Since land, l, is in fixed supply, it only affects the home production constraint in the steady state of the model. To find an equivalent in the data, we assume that in the steady state land is equal to a fixed fraction of the home output, y_H, where:

$$\eta = \frac{l}{y_H}$$

Following the empirical evidence reported by Davis and Heathcote (2005) on the share of raw land, we set η to 0.106.

- **Labor Market**

As far as ϕ is concerned, the steady state of the model can be used to restrict this parameter value. In the steady state, we have that:

$$\frac{\phi}{(1-\phi)} = \frac{[1-\beta(1-\delta_H)]}{\beta} \frac{\kappa}{(1-\kappa)} \frac{(1-\alpha)}{(1-\varphi)} \frac{y_M}{c_M} \frac{h}{y_H}$$

where the analytical expressions of $\frac{y_M}{c_M}$ and $\frac{h}{y_H}$ are given in the appendix. This steady state restriction implies a relationship that is tying the two home production parameters ϕ and κ. Given values for the other remaining parameters of the model, choosing κ therefore directly gives a value for ϕ. This steady state restriction also implies that when κ is set to 1, ϕ has to be equal to 1, which corresponds to the case where the model reduces to the standard business cycle model without home production.

As far as labor supply is concerned, the following functional form for $v(L_t)$ is adopted:

$$v(L_t) = \log(\xi L_t)$$

where ξ is pinned down by the usual steady state restriction on $v'(L)L/v(L)$ [see the technical appendix, equation (2S")]. This assumption also implies that in the steady state:

$$\frac{v''(L)L}{v'(L)} = -1$$

Given that ϕ is pinned down by the home production parameter κ, adopting this functional form allows to limit the number of degrees of freedom. The only parameter that has to be exogenously specified is L.

The introduction of differences in the disutility of working implies that L measures a subjective notion of leisure. The effective number of hours spent on leisure activities is given by $L^{eff} = T - N_H - N_M$, where T is agents' total endowment of time. In order to add some discipline to the analysis, we propose the following steady state relationship between L and $N_M^{\phi} N_H^{1-\phi}$:

$$L = \Psi - N_M^{\phi} N_H^{1-\phi}$$

where Ψ is a preference shifter that we normalize to 1. Following Greenwood and Hercowitz (1991), we then propose to set N_M to 0.33 and N_H to 0.25. Given that ϕ is endogenously determined, this allows to pin down L.

- **Productivity Shock**

Following the real business cycle literature, we assume that technology shocks are the only source of business cycle fluctuations. Total factor productivity, A_t, has the usual autoregressive characterization:

$$A_t = \rho A_{t-1} + \varepsilon_t$$

Compared to Davis and Heathcote (2005) and Greenwood and Hercowitz (1991), the number of degrees of freedom is reduced by considering an economy where business fluctuations are entirely driven by a single exogenous shock.

The calibration of the Solow Residuals has always been a sensitive issue. Many authors have argued that the success of the real business cycle literature relies on the introduction of implausibly large and volatile technology shocks [see Mankiw (1989) for instance]. Asset pricing implications such as the equity premium and the mean risk-free rate are also very sensitive to the assumed volatility of exogenous shocks.

To make sure that the conclusions of this study do not rely on some implausible calibration of the driving process, we choose to set the shock standard deviation σ_ε to 0.0036, a value twice smaller than the one usually used in the real business cycle literature [see King and Rebelo (1999)]. As for the persistence parameter, we set ρ to 0.979, which is a standard value used in the literature.

- **Home Production, Curvature Coefficient and Subjective Discount Factor**

The three remaining parameters are: (1) the home production parameter, κ, (2) the subjective discount factor, β where $\beta = \widetilde{\beta}\gamma^{-\sigma}$, and (3) the curvature parameter σ. Following Jermann (1998), this second set of parameter is picked, within a range of plausible values, to maximize the model's ability to match a set of moments of interest. Let θ denote the vector of the 3 model parameters:

$$\theta = [\kappa \ \beta \ \sigma]$$

θ is then chosen in order to minimize the following loss function:

$$L = [\varphi - f(\theta)]'\Omega[\varphi - f(\theta)]$$

where φ is the vector of empirical moments to match, and where $f(\theta)$ denotes the theoretical moments generated from the model, and Ω^{10} is the weighting matrix. The loss function L is computed for a grid of values for θ :

$$\kappa = [0.01 : 1], \ \beta = [0.95 : 0.999], \ \sigma = [1 : 10]$$

These three parameters are then estimated to maximize the model's ability to explain a set φ of empirical moments of interest. Following the literature on the equity premium puzzle, the asset pricing moments to match are the equity premium and the mean risk-free rate. The only business cycle moments that is included in the loss function is the output volatility.

4.2 Results

The loss function is minimized for the following parameter values:

$$\kappa = 1, \ \beta = 0.998 \ , \ \sigma = 5$$

As expected and as illustrated by the following Table comparing the model prediction with a few basic empirical facts, this baseline version is widely rejected:

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[10] Since we have as many moments as parameters to estimate, we use the identity matrix.

Table 4: **Baseline Model**

	σ_y	$E(r_m - r_f)$	$E(r_f)$
Data	**1.65**	**6.18**	**0.80**
Baseline[11]	**0.53**	**0.015**	**0.80**

Less than one third of the volatility of output can be accounted for. In addition, the model generates an equity premium of 0.015%[12]. The fact that the model can explain the low mean risk-free rate is misleading. With this value of β, in the non-stochastic steady state, the risk-free rate is equal to 0.80%. So the fact that adding uncertainty does not allow to reduce this value illustrates that the model fails to produce any precautionary savings.

The model also fails on many other asset pricing dimensions. Less than 20% of the volatility of house prices and less than 5% of the volatility of equity prices can be explained. This version also shares a series of other shortcomings that have been reported in the literature. In particular, a negative correlation between residential investment and output is predicted while in the data residential investment is procyclical.

As it is often the case in this class of models, the problem comes from the labor market. In this economy, agents are reluctant to increase market hours in response to a positive technology shock. Less than 10% of the actual volatility of hours worked in the market sector can be accounted for. The lack of volatility of market hours implies that the dynamics of real wages is almost entirely driven by the technology shock[13]. This generates another counterfactual implication. The correlation between real wages and output generated by the model is close to one while in the data real wages are acyclical.

4.3 Discussion

Increasing the curvature parameter, σ, does not resolve the problem. In a model with endogenous labor supply, increasing curvature leads to a coun-

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[11] The output volatility is obtained by generating 1000 observations that are then HP-filtered. The mean risk-free rate is computed using the closed form solution derived in Jermann (1998). The equity premium is obtained by taking the average of 100 simulations, each 800 periods long and computed as in Jermann (1998).

[12] The moments that are targeted in the empirical procedure described above are emphasized in bold.

[13] The real wage is given by:

$$w_M = (1-\alpha)Ak_M^{\alpha}N_M^{-\alpha}$$

where the capital stock, k_M, is a predetermined variable.

terfactual reduction in the volatility of market hours, which in turn, gives rise to a decline in the volatility of output[14]. The problem is due to the fact that increasing risk aversion gives rise to a stronger wealth effect, due to the resulting increase in the volatility of marginal utility. This negative wealth effect, in turn, reduces the incentive to work by offsetting the positive substitution effect induced by the increase in real wages. This result illustrates that in a model with endogenous labor supply, attempts to explain asset pricing facts by simply increasing risk aversion are bound to fail. While the increase in curvature helps to make marginal utility more volatile, this improvement comes at the cost of generating a counterfactual reduction in the volatilities of market hours and output.

It is also interesting to note that the empirical procedure leads to a value for κ that eliminates home production from the analysis[15]. This confirms that explaining asset pricing facts is easier in a model where the set of choices is restricted. Adding home production increases the potential for intertemporal smoothing and therefore reduces the amount of risk faced by agents, which is exactly the opposite from what is needed in order to explain asset pricing puzzles. Reintroducing home production by lowering κ from 1 to 0.50 would decrease the equity premium by more than half[16].

5 Introducing Real Rigidities

As shown by Jermann (1998), in a more general asset pricing environment the key to obtain empirically plausible asset pricing implications is to combine two set of frictions. The first central ingredient is to introduce a friction such as habit formation that induces a strong willingness to smooth consumption[17]. To make the model predictions robust to the introduction of production, the key element is to combine this friction with a rigidity that reduces the potential for intertemporal smoothing, such as capital adjustment costs.

Following Jermann (1998), we propose to introduce habit formation and adjustment costs into the home production economy described in the previous section. Our objective is to assess whether this strategy could be used

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[14] Increasing σ from 5 to 10 would lead to a reduction in the volatilty of hours worked from 0.11 to 0.065 and thus reduce further the volatility of output.

[15] The case $\kappa = 1$, implies $\phi = 1$, which corresponds to the case without home production.

[16] From 0.015% to 0.006%.

[17] In Campanale, Castro and Clementi (2007), this effect is obtained by introducing Chew-Dekel preferences.

to explain key asset market facts within a class of model whose success at reproducing many business cycle aspects has already been demonstrated [see Davis and Heathcote (2005)].

5.1 Capital Adjustment Costs

The accumulation of residential and business capital is subject to the kind of adjustment costs proposed by Baxter and Crucini (1993) and used by Jermann (1998) in the context of asset pricing models. This general specification simply makes large changes in the capital stock more costly than smaller ones, and only requires the introduction of one single parameter. We also assume that the accumulation of business and residential capital are subject to the same type of adjustment costs. This assumption ensures that the differences in dynamics between the home and the business sectors will not rely on the introduction of a particular functional form.

The accumulation of residential capital, k_{Ht} is governed by the following law of motion:

$$(1-\delta_{k_H})k_{Ht} + \Phi_H\left(\frac{i_{Ht}}{k_{Ht}}\right)k_{Ht} = \gamma k_{Ht+1}$$

and similarly, the law of motion of the stock of business capital, k_{Mt} is given by:

$$(1-\delta_{k_M})k_{Mt} + \Phi_M\left(\frac{i_{Mt}}{k_{Mt}}\right)k_{Mt} = \gamma k_{Mt+1}$$

The parameters of the capital adjustment costs functions $\Phi(\cdot)$ are set so that the model with adjustment costs has the same steady state as the model without adjustment costs and it is assumed that near the steady state point: $\Phi(\cdot) > 0$, $\Phi'(\cdot) > 0$ and $\Phi''(\cdot) < 0$.

The introduction of adjustments costs in business and in residential capital adds two additional parameters. For each capital stock, the degree of adjustment costs is captured by a single elasticity parameter:

$$\varepsilon = \frac{\Phi_j''\left(\frac{i_j}{k_j}\right)\frac{i_j}{k_j}}{\Phi_j'\left(\frac{i_j}{k_j}\right)}$$

where $1/\varepsilon$ can be interpreted as the elasticity of the investment to capital ratio to changes in Tobin's Q[18].

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[18] So the case $1/\varepsilon = \infty$ corresponds to the case without adjustment costs while the case $1/\varepsilon = 0$ corresponds to the case with infinite adjustment costs.

5.1.1 The Impact of Residential Adjustment Costs on House Prices

Adjustment costs in residential capital have a direct impact on the dynamics of house prices that works through the discount factor. The value of the housing stock is obtained by discounting the flow of future expected cash-flows (rents) by the cost of raising capital. As in the previous section, the flow of future expected benefits is determined by the shadow value of the housing stock, μ_t, and is not directly affected by the introduction of adjustment costs. The rate at which these cash-flows are discounted is however affected by the introduction of adjustment costs.

Using the notation of the previous section, house prices can firstly be expressed in compact form as:

$$p_{Ht} = \frac{\mu_t}{\tau_t \lambda_t}$$

where $\tau_t = 1/\Phi'_H\left(\frac{i_{Ht}}{k_{Ht}}\right)$ and where $\Phi'_H\left(\frac{i_{Ht}}{k_{Ht}}\right)$ denotes the first derivative of the adjustment cost function[19].

Compared to the previous section, the presence of real rigidities introduces a wedge, τ_t, capturing the impact of adjustment costs on the shadow cost of residential capital. Adjustment costs therefore create an investment wedge that makes it more expensive to raise residential capital. This reflects that, when evaluating the flow of expected benefits from investing in housing, the fact that the opportunity cost of capital is now higher has to be integrated.

As in the previous section, house prices can equivalently be expressed as an intertemporal asset pricing equation relating house prices to the rental rate of housing:

$$p_{Ht} = \beta E_t \frac{\lambda_{t+1}\tau_{t+1}}{\lambda_t \tau_t}\left[p_{Ht+1}(1-\delta_H) + \frac{r_{Ht+1}}{\tau_{t+1}}\right] \tag{8}$$

The case $\tau_t = \tau_{t+1} = 1$ corresponds to the baseline version studied in the previous section and is obtained as a special case, when the adjustment costs channel is switched off.

5.2 Habit Formation

To overcome the difficulties that have been mentioned in the previous section, we propose to introduce a more general specification of habit formation.

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[19] In terms of the notation used in the appendix $\tau_t \lambda_t = \omega_t$.

Given the structure of our model, it seems natural to assume that the habit stock, which measures agents' level of addiction, does not only depend on market consumption but also on the other components of utility such as the housing stock and leisure.

In our case, given that utility is composed of 4 different components, introducing a separate notion of habit for each variable would considerably increase the number of degrees of freedom. To minimize the number of free parameters, we propose to introduce a single notion of habit formation that directly depends on the utility level provided by the composite of consumption and leisure. This implies that lifetime utility is now given by:

$$U = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma} \left[C_t v(L_t) - x_t \right]^{1-\sigma} \right\}$$

where x_t is the habit stock or reference level. Net utility, $C_t v(L_t) - x_t$, is given by the difference between the composite good or (instantaneous) utility level, $C_t v(L_t)$, and the reference level, x_t. As before, we have that:

$$C_t = c_{Mt}^{\kappa} h_t^{1-\kappa}$$

$$N_{Tt} = N_{Mt}^{\phi} N_{Ht}^{1-\phi}$$

As regards the law of motion for the habit stock, the general specification proposed by Constantinides (1990) is adopted:

$$\gamma x_{t+1} = m x_t + (1-m) \left[C_t v(L_t) \right]$$

where m captures the rate at which the habit stock depreciates[20]. To restrict the number of degrees of freedom, we assume that the parameter measuring the impact of current utility on the habit stock is given by $1-m$. This specification of habit formation, therefore, only requires the introduction of one additional parameter.

Compared to the standard case where the habit stock only depends on consumption, this specification creates a strong incentive to smooth changes in utility, and c_{Mt}, h_t, N_{Ht} and N_{Mt} will be chosen accordingly. Introducing memory effects by relaxing the assumption that $m = 0$ amplifies this incentive to make the composite good, and no longer consumption, as smooth as possible.

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[20] and where γ is the growth rate of the economy along the balanced growth path.

The other important implication of this form of habit formation is also to introduce a concept of risk aversion which depends on this composite good. It can easily be shown that, with this specification of *internal* habit formation, even in the case $m > 0$, in the steady state, the coefficient of relative risk aversion in the composite good is exactly given by the curvature parameter σ.

5.3 Parameter Selection

To limit the number of degrees of freedom, we fix the coefficient of relative risk aversion, σ. Values for the coefficient of relative risk aversion, σ, ranging from 1 to 10 are usually considered plausible [see Mehra and Prescott (1985)]. Following Jermann (1998), and our result from the previous section, this parameter is set to 5.

With the introduction of habit formation and capital adjustment costs, the 5 remaining parameters to estimate are: (1) the home production parameter, κ, (2) the habit parameter, m, (3) the subjective discount factor, β, (4) the business capital adjustment costs parameter, ε_M and (5) the residential capital adjustment costs parameter, ε_H. Let θ denote the vector of the 5 model parameters:

$$\theta = [\kappa \;\; m \; \beta \; \varepsilon_M \;\; \varepsilon_H]$$

The loss function L is computed for the following grid of values for θ :

$$\kappa = [0.01 : 1],\ m = [0.01 : 1],\ \beta = [0.95 : 0.999],\ \varepsilon_M = [0.01 : 3],\ \varepsilon_H = [0.01 : 3]$$

The 5 parameters are then estimated using the standard deviation of output, as the only business cycle moment, and 4 asset pricing moments: the equity premium, the mean risk-free rate, the relative standard deviation of equity prices, and the relative standard deviation of house prices.

5.4 Results

The loss function is minimized for the following parameter values:

$$\kappa = 0.86,\ m = 0.37\ ,\ \beta = 0.987,\ 1/\varepsilon_M = 0.41,\ 1/\varepsilon_H = 1.38$$

The results comparing the model predictions with the empirical facts are reported in the following Tables[21], where the targeted moments are emphasized in bold:

Table 5: Business Cycle, Benchmark vs Data

	σ_y	σ_{c_M}/σ_y	σ_{i_M}/σ_y	σ_{N_M}/σ_y	σ_{i_H}/σ_y
Data	**1.65**	0.47	3.31	0.98	6.0
Benchmark	**1.40**	0.30	3.15	1.02	10.6

Table 6: Relative Prices, Benchmark vs Data

	σ_{w_M}/σ_y	σ_{p_H}/σ_y	$\sigma_{p_H/r_H}/\sigma_y$	σ_{p_E}/σ_y	σ_{r_f}/σ_y
Data	0.42	**1.63**	1.52	**5.67**	0.91
Model	0.06	**1.60**	1.24	**5.69**	0.81

Table 7: Correlation of Relative Prices with Output

	$\rho(w_{Mt}, y_{Mt})$	$\rho(p_{Ht}, y_{Mt})$	$\rho(p_{Et}, y_{Mt})$	$\rho(r_{ft}, y_{Mt})$
Data	-0.24	0.59	0.44	-0.20
Model	-0.24	0.92	0.99	-0.99

Table 8: Financial Returns, Benchmark vs Data, Annualized %

	$E(r_m - r_f)$	$E(r_f)$	$\frac{E(r_m-r_f)}{\sigma(r_m)}$
Data	**6.50**	**1.00**	0.30
Benchmark	**6.48**	**0.93**	0.21

- Output Volatility and the Labor Market

As illustrated in Table 5, compared to the previous section, the first important difference is that more than 80% of the volatility of output, σ_y, can be explained. This result is obtained using a shock standard deviation twice smaller than what is usually used in the literature. This illustrates that the mechanism embedded into the model amplifies the effects of technology shocks by generating a strong response of market hours. The high volatility of hours worked that is generated also enables to decrease the volatility of real wages. As can be seen from the impulse response analysis presented in the appendix, in response to a technology shock, the strong response

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[21] The mean risk-free rate is computed using the closed form solution derived in Jermann (1998). The equity premium is obtained by taking the average of 1000 simulations, each 1000 periods long and is computed as in Jermann (1998). The remaining simulated moments are obtained by generating 5000 observations that are then HP-filtered.

of hours worked more than offsets the effect of the shock on the marginal productivity of labor. This leads to a gradual and hump-shaped response of real wages, which in turn allows the model to match the correlation between real wages and output.

Explaining the high volatility of market hours together with the acyclicality of real wages has always been a challenge for this class of models [see King and Rebelo (1999)]. It is interesting to note that this result can be obtained in a model abstracting from wage rigidities and where technology shocks are the only source of business cycle fluctuations.

- Asset Pricing Implications

Compared to standard business cycle models, the main difference is that the equity premium and the low mean risk-free rate can be explained. It is also possible to generate the high volatility of equity prices and of equity returns. Compared to the literature on the equity premium puzzle, these financial market facts can be reproduced within a framework also able to capture additional asset pricing facts such as the high volatility of house prices and of the house price to rent ratio.

- Additional Implications

As discussed in the previous section, the introduction of residential investment adjustment costs creates a wedge between the risk-free rate, r_{ft}, used to discount dividends:

$$\frac{1}{1+r_{ft}} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t}$$

and the discount rate used by homeowners. Denoting this discount rate r_t^M, equation (8) implies that[22]:

$$\frac{1}{1+r_t^M} = \beta E_t \frac{\lambda_{t+1}\tau_{t+1}}{\lambda_t \tau_t}$$

The model predicts a value for $E(r_t^M)$ of 4.48% per annum. The introduction of real rigidities affecting residential investment generates a spread between the short term rate at which residential structures can be borrowed and the risk-free rate of: 4.48-0.93=3.55%.

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[22] In the case wihtout adjustment costs, house prices are given by equation (5) and there is no difference between r_{Mt} and the risk-free rate r_{ft}.

To obtain an approximation of the predicted 30 years borrowing rate, we propose to compute the return of a 30 years zero coupon bond. The predicted return is then compared to the actual 30 years mortgage rate. The price of a one period bond is equal to the inverse of the short term borrowing rate:

$$p^1_{B,H} = \frac{1}{1 + r^M_t} = \beta E_t \frac{\lambda_{t+1}\tau_{t+1}}{\lambda_t \tau_t}$$

The 30 years return can then be computed by deriving the term structure corresponding to the short term borrowing rate, r_{Mt}. The price of a 30 years (120 quarters) zero coupon bond is given by:

$$p^{120}_{B,H} = E_t \sum_{k=1}^{120} \beta^k \frac{\lambda_{t+k}\tau_{t+k}}{\lambda_t \tau_t}$$

The corresponding return on this financial asset, r^{30}_{Mt}, can then be derived and compared to the actual 30 years mortgage rate[23]:

	$E(r_{Mt})$	$E(r^{30}_{Mt})$
Data	-	4.52
Model	4.48	4.66

- Asset Prices and Investment Dynamics

As can be seen from the 2 figures presented in the annex (see section 9), the model generates significant differences in the dynamics of equity and house prices. While, on impact, a positive technology shock generates a sharp increase in equity prices, the response of house prices is more gradual and hump-shaped.

The combination of strong adjustment costs in the market sector and habit formation increases the persistence of market investment, which in turn increases the persistence of market capital and therefore of market output. The fact that small technology shocks generate large and persistent increases in output illustrates that, compared to a standard business cycle model, both the amplification and the propagation mechanisms embedded into this model are considerably stronger.

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[23] Source: St-Louis Fed. The real reate is computed by deflating the nominal 30 years mortgage rate using CPI realized inflation.

6 Discussion

In contrast to the previous section, with the introduction of habit formation and capital adjustment costs, the loss function is minimized for a value of κ that gives a role to home production[24]. Compared to the previous section, the modified model generates large and procyclical fluctuations in market hours, and the fact that market hours are as volatile as output can be well captured.

This illustrates that, with this specification of habit formation, the introduction of home production gives rise to two opposite effects. First, as shown in the previous section, expanding the set of choices facilitates intertemporal smoothing and thus reduces the risk faced by households. On the other hand, introducing home production leads to a stronger response of market hours which amplifies the effects of technology shocks on output, and therefore makes the whole economy riskier. As illustrated by our results, with habit formation and adjustment costs, the effect induced by the endogenous increase in the volatility of output dominates and has dramatic asset pricing implications.

Why does the introduction of home production generates an increase in the volatility of market hours? The introduction of home production makes utility depend on 2 additional components: h_t and N_{Ht}. If c_{Mt}, h_t and N_{Ht} were fixed, agents would be reluctant to increase (decrease) market hours in good (bad) times because this would generate undesirable fluctuations in the composite good. The main contribution of introducing home production therefore comes from the fact that N_{Ht} can be instantaneously adjusted in response to a shock[25] and used to smooth the composite good. In good (bad) times, the negative (positive) impact on the composite good of an increase (decrease) in market hours can be neutralized by simultaneously decreasing (increasing) the number of hours worked in the home sector.

The fact that, with this specification of habit formation, an increase in the volatility of market hours, and thus output, is not necessarily associated with an increase in the volatility of the composite good is therefore a key element. In this economy, insuring themselves against fluctuations in the composite good becomes agents' main priority. The introduction of a home component in the disutility of working enables them to achieve this objective without generating a counterfactual reduction in the volatility of market hours.

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[24] $\kappa = 0.86$ implies that $\phi = 0.93$.

[25] h_t is a predetermined variable

7 Conclusion

Despite a series of improvements with respect to the literature, some aspects of the model remain unsatisfactory. For instance, this study has failed to provide an explanation for the fact that residential investment leads business investment [Fisher (2007)]. The results reported by Gomme, Kydland and Rupert (2001) suggest that introducing time-to-build into the analysis could potentially solve the problem without compromising the model's ability to explain asset market puzzles. In this study, we have proposed to adopt a general specification of adjustment costs. One interesting direction would be to relax the assumption that both sectors are subject to the same type of adjustment costs.

8 Bibliography

Abel, Andrew B, (1990). "Asset Prices under Habit Formation and Catching Up with the Joneses," American Economic Review, vol. 80(2), pages 38-42, May.

Aguiar, Mark and Hurst, Erik, (2005). "Consumption versus Expenditure," Journal of Political Economy, vol. 113(5), pages 919-948, October.

Bansal, Ravi & Yaron, Amir (2004). "Risks for the Long Run: A Potential Resolution of Asset Pricing Puzzles" Journal of Finance, vol. 59(4), pages 1481-1509, 08.

Baxter, Marianne & Crucini, Mario J, (1993). "Explaining Saving-Investment Correlations," American Economic Review, vol. 83(3), pages 416-36, June.

Baxter Marianne & Jermann, Urban J. (1999). "Household Production and the Excess Sensitivity of Consumption to Current Income," American Economic Review, vol. 89(4), pages 902-920, September.

Benhabib, Jess & Rogerson, Richard & Wright, Randall, (1991). "Homework in Macroeconomics: Household Production and Aggregate Fluctuations," Journal of Political Economy, vol. 99(6), pages 1166-87, December.

Blankenau, William and Kose, M. Ayhan (2007). "How different is the cyclical behavior of home production across countries?," Macroeconomic Dynamics, 11, 2007, 56-78.

Boldrin, Michele & Christiano Lawrence J. & Fisher Jonas D. M., (2001). "Habit Persistence, Asset Returns, and the Business Cycle," American Economic Review, vol. 91(1), pages 149-166, March.

Campbell John Y. & Cochrane John, (1999). "Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior," Journal of Political Economy, vol. 107(2), pages 205-251, April.

Campanale Claudio & Castro Rui & Clementi Gian Luca, (2007). "Asset Pricing in a Production Economy with Chew-Dekel Preferences," Working Papers 07-13, New York University, Leonard N. Stern School of Business

Christiano, Lawrence J & Eichenbaum, Martin, (1992). "Current Real-Business-Cycle Theories and Aggregate Labor-Market Fluctuations," American Economic Review, vol. 82(3), pages 430-50, June.

Cochrane, John (2008). "Financial Markets and the Real Economy," R. Mehra (ed.), Handbook of the Equity Risk Premium, edition 1, chapter 7, p.237-322

Constantinides, George M, (1990). "Habit Formation: A Resolution of the Equity Premium Puzzle," Journal of Political Economy, vol. 98(3), pages 519-43, June.

Danthine Jean-Pierre & Donaldson John B. & Siconolfi, Paolo (2008). "Distribution Risk and Equity Returns," R. Mehra (ed.), Handbook of the Equity Risk Premium, edition 1, chapter 10, p.415-460

Davis Morris A. & Heathcote Jonathan, (2005). "Housing And The Business Cycle," International Economic Review, Department of Economics, vol. 46(3), pages 751-784, 08.

Davis, Morris A. & Heathcote, Jonathan, (2007). "The price and quantity of residential land in the United States," Journal of Monetary Economics, vol. 54(8), pages 2595-2620, November.

Davis Morris A. & Lehnert Andreas & Martin Robert F., (2008). "The Rent-Price Ratio For The Aggregate Stock Of Owner-Occupied Housing," Review of Income and Wealth, vol. 54(2), pages 279-284, 06.

Flavin Marjorie & Shinobu Nakagawa, (2004). "A Model of Housing in the Presence of Adjustment Costs: A Structural Interpretation of Habit Persistence," NBER Working Papers 10458

Fisher, Jonas D. M. (2007). "Why Does Household Investment Lead Business Investment over the Business Cycle?," Journal of Political Economy, vol. 115, pages 141-168.

Glaeser Edward L. & Gyourko Joseph & Saiz Albert, (2008). "Housing Supply and Housing Bubbles," NBER Working Papers 14193.

Glaeser Edward L. & Gyourko Joseph & Saks Raven E., (2005). "Why Have Housing Prices Gone Up?," American Economic Review, vol. 95(2), pages 329-333, May.

Greenwood, Jeremy & Hercowitz, Zvi, (1991). "The Allocation of Capital and Time over the Business Cycle," Journal of Political Economy, vol. 99(6), pages 1188-214, December.

Greenwood, Jeremy & Hercowitz, Zvi & Huffman, Gregory W, (1988). "Investment, Capacity Utilization, and the Real Business Cycle," American Economic Review, vol. 78(3), pages 402-17, June.

Greenwood, J. & Rogerson, R. & Wright, R., (1995)."Household Production in Real Business Cycle Theory," in "Frontiers of Business Cycle Research", chapter 6. T. F. Cooley, Editor.

Gomme Paul & Kydland Finn E. & Rupert, Peter (2001). "Home Production Meets Time to Build," Journal of Political Economy, vol. 109(5), pages 1115-1131, October.

Iacoviello, Matteo (2005). "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle," American Economic Review, vol. 95(3), pages 739-764, June.

Jaccard, Ivan (2008). "Asset Pricing, Habit Memory, and the Labor Market," Swiss Finance Institute Research Paper Series 07-23.

Jaimovich, Nir & Rebelo, Sérgio, (2009). "Can News About the Future Drive the Business Cycle?," CEPR Discussion Papers 5877, (American Economic Review, forthcoming).

Jermann, Urban J., (1998). "Asset pricing in production economies," Journal of Monetary Economics, vol. 41(2), pages 257-275, April.

Jin, Yi & Zeng, Zhixiong, (2004), "Residential Investment and House Prices in a Multi-sector Monetary Business Cycle Model ", Journal of Housing Economics 13 (2004) 268-286.

King, Robert G. & Rebelo, Sergio T., (1999). "Resuscitating real business cycles," Handbook of Macroeconomics, J. B. Taylor & M. Woodford (ed.), edition 1, volume 1, chapter 14, pages 927-1007

King, Robert G & Plosser, Charles I & Rebelo, Sergio T, 2002. "Production, Growth and Business Cycles: Technical Appendix," Computational Economics, vol. 20(1-2), pages 87-116, October.

King, Robert G & Watson, Mark W, (2002). "System Reduction and Solution Algorithms for Singular Linear Difference Systems under Rational Expectations," Computational Economics, vol. 20(1-2), pages 57-86, October.

Kydland, Finn E & Prescott, Edward C, (1982). "Time to Build and Aggregate Fluctuations," Econometrica, vol. 50(6), pages 1345-70

Lettau, Martin & Uhlig, Harald (2000). "Can Habit Formation be Reconciled with Business Cycle Facts?," Review of Economic Dynamics, vol. 3(1), pages 79-99, January.

Leung, Charles, (2004). "Macroeconomics and housing: a review of the literature," Journal of Housing Economics, vol. 13(4), pages 249-267, December.

Leung, Charles (2007). "Equilibrium Correlations of Asset Price and Return," The Journal of Real Estate Finance and Economics, vol. 34(2), pages 233-256, February.

Lucas, Robert E, Jr, (1978). "Asset Prices in an Exchange Economy," Econometrica, vol. 46(6), pages 1429-45, November.

Mankiw, N Gregory, (1989). "Real Business Cycles: A New Keynesian Perspective," Journal of Economic Perspectives, vol. 3(3), pages 79-90, Summer.

Mehra, Rajnish & Prescott, Edward C., (1985). "The equity premium: A puzzle," Journal of Monetary Economics, vol. 15(2), pages 145-161, March.

Ortalo-Magne Francois & Rady Sven, (2006). "Housing Market Dynamics: On the Contribution of Income Shocks and Credit Constraints," Review of Economic Studies, vol. 73(2), pages 459-485, 04.

Piazzesi, Monika & Schneider, Martin & Tuzel, Selale, (2007). "Housing, consumption and asset pricing," Journal of Financial Economics, vol. 83(3), pages 531-569, March.

Rouwenhorst, K. Geert, (1995). "Asset Pricing Implications of Equilibrium Business Cycle Models", in "Frontiers of Business Cycle Research", chapter 10. T. F. Cooley, Editor.

Shiller, Robert J, (1981). "Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?," American Economic Review, vol. 71(3), pages 421-36, June.

Uhlig, Harald (2007). "Explaining Asset Prices with External Habits and Wage Rigidities in a DSGE Model," American Economic Review, vol. 97(2), pages 239-243, May.

Uhlig, Harald (2007b). "Macroeconomics and Asset Markets: some Mutual Implications", Manuscript, University of Chicago

Van Nieuwerburgh Stijn, & Weill Pierre-Olivier, (2006). "Why Has House Price Dispersion Gone Up?," NBER Working Papers 12538, National Bureau of Economic Research

9 Impulse Response Analysis