LABOR MARKET SEARCH, HOUSING PRICES AND BORROWING CONSTRAINTS[*]

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D-2010-09

December, 2010

1

Abstract

Mortgage market deregulation in the early 1980s coincided in time with a sharp break in the cyclical behavior of many variables related to housing and to the labor market. This paper analyses the joint dynamics of labor market variables, output and housing prices in a search model with efficient bargaining and financial frictions. In a setting of household heterogeneity, only mortgaged-backed loans are available for impatient households, whose borrowing cannot exceed a proportion of the expected value of their real estate holdings. This feature of the credit market, together with search and matching frictions in the labor market, establish a strong link between credit constraints and consumption that significantly affects labor market outcomes: hours, wages and vacancies. The model is also able to explain the comovements of housing prices with output, productive investment and consumption. Our analysis confirms that the response of labor market variables to technology shocks has been substantially affected by the changes in the nature and tightness of imperfections in credit markets that occurred in the early 1980s. Allowing for a housing price shock, in addition to the technology shock, the model is also able to explain the observed reduction in the correlation of housing prices with both output and private investment.

Keywords: general equilibrium, borrowing constraints, search frictions, housing prices.
JEL Classification: E24, E32, E44

1. Introduction

The prolonged period of rapid and stable growth, accompanied by the availability of a large amount of funds, has brought real interest rates down to historically low levels, with the natural consequence of huge increases in the degree of indebtedness in advanced economies. Against this background the financial crisis has developed a common pattern in highly leveraged economies characterized by rising unemployment, falling housing prices and a massive slump in consumption. These features are all endogenous responses to shocks and reinforce each other to amplify the size of output fluctuations. The common link among these phenomena can be found in some peculiarities in the financial market, among which the fact that mortgage-backed borrowing is in general cheaper than other forms of borrowing figures prominently. This establishes a potentially strong link between housing prices and private spending that is also reflected in sizable unemployment fluctuations.

In this paper we analyze the joint dynamics of labor market variables, housing prices and consumption. To that end we blend two strands of the literature that have had fairly separate lives so far. We set up a model of the business cycle with search and matching frictions and negotiation of wages and hours between firms and workers in the spirit of Merz (1995), Andolfatto (1996), or den Haan et al. (2000). In addition, we allow for some degree (albeit very limited) of heterogeneity among households regarding their participation in the financial market. Following Iacoviello (2005), we shall assume that some households are more patient than others and that the more impatient ones face a limit on the amount of borrowing they can take, given by the expected value of their only pledgeable asset: real estate (Kiyotaki and Moore, 1997).

Allowing for the presence of constrained consumers helps the search model to account for some important correlations among labor market variables: for example, between hours and labor productivity, or between hours and real wages. Chéron and Langot (2004) show that the basic models must be augmented by a particular set of non-separable preferences as developed in Rogerson and Wright (1988) to fit these features of the data. A recent paper Boscá et al. (2009) further improves the empirical performance of the basic model by incorporating some Keynesian features, such as a substantial proportion of non optimizing (Rule-of-thumb) consumers and habits in consumption.

Rule-of-Thumb consumers provide a very useful device to bring the empirical implications of search-based business cycle models in line with their empirical counterparts, but the fact that these households do not participate in financial markets makes this assumption less useful when it comes to understanding the link between spending and unemployment through housing prices. In such a scenario, frictions in the financial market are virtually irrelevant: optimizing consumers participate in a perfect capital market,

whereas non-optimizing households do not make any relevant financial decisions at all.

In this paper we assume an alternative form for the financial friction so that in our setup all households are engaged in some form of intertemporal substitution. Patient households, savers, will usually accumulate wealth to increase their steady-state consumption, whereas the impatient ones will be inclined to borrow. Due to imperfections in monitoring in the credit market we shall assume that all (one-period, nominal non-indexed) debt should be backed by the value of real estate holdings and that such a constraint is always binding. Andrés and Arce (2008), Andrés, Arce and Thomas (2009) and Aoki, Proudman and Vlieghe (2004) also find that collateral constraints provide a powerful augmenting device for some shocks and a natural framework in which to study the interaction between consumption and housing prices.

Our motivation is driven by a set of observations regarding the evolution of the business cycle in the US. Thus, we analyze first the cyclical properties of main labor market aggregates, key macroeconomic variables (output, consumption and private investment) and the price index for housing in the US economy. We split the whole sample from 1966 to 2008 into two sub periods with the year 1982 as a cut-off point. The reason for this is that in the early 1980's an important reorganization of the housing finance system took place, as a consequence of the Monetary Control Act of 1980 and the Garn-St. Germain Act of 1982. In terms of our modeling strategy, the first period characterizes an economy with a low loan-to-value ratio and the second period represents an economy with a high leverage ratio. The data seem to support the idea that differences in the tightness of financial friction lead to sizable differences in the cyclical behavior of the labor market and house prices.

Our simulation result will show that the behavior of credit constrained consumers interacts with the process of vacancy creation to create a powerful transmission mechanism of technology and housing shocks. Thus, moderation in output is partially explained by the relaxation of collateral constraints caused by positive shocks, which in turn induces lower hours and a more modest output reaction. This process is exacerbated in economies with high loan-to-value ratios. However, the blend of search and matching frictions in the labor market with collateral constraints and constrained consumers in the mortgage market renders the model capable of accounting for a number of less well known features, such as those related to the changing pattern of some labor market flows (for a technology shock) and financial variables (when the sources of stochastic fluctuations also include a housing price shock).

The paper is organized as follows. Section 2 details the theoretical model. Section 3 contains the empirical facts as well as the calibration of the model. Section 4 presents the simulation results for a technology shock. In section 5 a shock affecting house prices is added to the technology shock to help the model explain some facts. Finally, section 6

offers the main conclusions.

2. Theoretical framework

We model a decentralized, closed economy where households and firms interact each period by trading one final good and two production factors. In order to produce output, firms employ physical capital and labor. While private physical capital is exchanged in a context of perfect competition, the labor market is not Walrasian. Households possess the available production factors. They also own all the firms operating in the economy. In such a scenario, each representative household rents physical capital and labor services out to firms, for which they are paid income in the form of interest and wages. New jobs are created after investing in searching activities. The fact that exchange in the labor market is resource and time-consuming generates a monopoly rent associated with each job match. It is assumed that workers and firms bargain over these monopoly rents in Nash fashion.

Each household is made up of working-age agents who may be either employed or unemployed. If unemployed, agents are actively searching for a job. Firms' investment in vacant posts is endogenously determined and so are job inflows. Finally, job destruction is taken as exogenous.

Patient and impatient consumers are incorporated into the standard labor market search model as in Kiyotaki and Moore (1997) and Iacoviello (2005). Patient households are characterized by having a lower discount rate than impatient ones. This ensures under some conditions that in the steady-state equilibrium patient households are net lenders, while impatient households become net borrowers. There are, hence, two types of representative households. A patient household of size N_t^l, which is the sole owner of physical capital, and an impatient household of size N_t^b. Both have access to capital markets where they can lend and borrow up to a certain borrowing constraint. This constraint is related to the value of houses, whose services provide them with utility, and act as a collateralizable asset.

The size of the working-age population is given by $N_t = N_t^l + N_t^b$. Let $1 - \lambda^b$ and λ^b denote the fractions in the working-age population of lenders and borrowers households, which are assumed to be constant over time. For simplicity, we assume no growth in the working-age population.

Both types of households maximize intertemporal utility by selecting streams of consumption, leisure and housing services. Household members may be either employed or unemployed, but are able to fully insure each other against fluctuations in employment, as in Andolfatto (1996) or Merz (1995).

2.1 Patient households

Patient households in our economy are characterized by discounting the future less heavily than impatient ones. They face the following maximization program:

$$
\max_{c_t^l, k_t^l, j_t^l, b_t^l, x_t^l} E_t \sum_{t=0}^{\infty} (\beta^l)^t \left[\begin{array}{c} \ln\left(c_t^l - h^l c_{t-1}^l\right) + \phi_x \ln\left(x_t^l\right) + n_{t-1}^l \phi_1 \frac{(1-l_{1t})^{1-\eta}}{1-\eta} \\ + (1-n_{t-1}^l)\phi_2 \frac{(1-l_2)^{1-\eta}}{1-\eta} \end{array} \right] \tag{1}
$$

subject to

$$
c_t^l + j_t^l \left(1 + \frac{\phi}{2}\left(\frac{j_t^l}{k_{t-1}^l}\right)\right) + q_t\left(x_t^l - x_{t-1}^l\right) - b_t^l = n_{t-1}^l w_t l_{1t} + r_{t-1}k_{t-1}^l - (1+r_{t-1}^n)\frac{b_{t-1}^l}{\pi_t} - \zeta_t^l \tag{2}
$$

$$
k_t^l = j_t^l + (1-\delta)k_{t-1}^l \tag{3}
$$

$$
n_t^l = (1-\sigma)n_{t-1}^l + \rho_t^w(1 - n_{t-1}^l) \tag{4}
$$

All lower case variables in the maximization problem above are normalized by the working-age population (N_t). In our notation, variables and parameters indexed by b and l respectively denote impatient and patient households. Non-indexed variables apply indistinctly to both types of households. Thus, c_t^l, x_t^l, n_{t-1}^l and $(1-n_{t-1}^l)$ represent, consumption, housing holdings, the employment rate and the unemployment rate of patient households. The time endowment is normalized to one. l_{1t} and l_2 are hours worked per employee and hours devoted to job seeking by the unemployed. Note that while the household decides over l_{1t}, time dedicated to job search (l_2) is assumed to be exogenous, so that individual households take it as given.

Several parameters are present in the utility function of Ricardian households. Future utility is discounted at a rate of $\beta^l \in (0, 1)$. The parameter $-\frac{1}{\eta}$ measures the negative of the Frisch elasticity of labor supply. As consumption is subject to habits, the parameter h^l takes a positive value. ϕ_x is the housing weight in life-time utility. In general $\phi_1 \neq \phi_2$, i.e., the subjective value of leisure imputed by workers may vary across employment statuses[1].

Maximization of (1) is constrained as follows. First, the budget constraint (2) describes the various sources and uses of income. The term $w_t n_{t-1}^l l_{1t}$ captures net labor income earned by the fraction of employed workers, where w_t stands for hourly real wages.

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[1] Notice, that there are two differences in the utility function with respect to a standard search model as in Andolfatto (1996); the presence of habits in consumption and the presence of housing services.

There are three assets in the economy. First, private physical capital (k_t^l), which is owned solely by patient households. Return on capital is captured by $r_{t-1}k_{t-1}^l$, where r_t represents the gross return on physical capital. Second, there are loans/debt in the economy. Thus, patient households lend in real terms $-b_t^l$ (or borrow b_t^l) and receive back $-(1+r_{t-1}^n)b_{t-1}^l$, where r_{t-1}^n is the nominal interest rate on loans between $t-1$ and t. Notice that in the budget constraint (2), the gross inflation rate between $t-1$ and t (π_t) in the term $(1+r_{t-1}^n)\frac{b_{t-1}^l}{\pi_t}$ reflects the assumption that debt contracts are set in nominal terms. Third, there is a fixed amount of real estate in the economy[2], although housing investment can be performed by both patient and impatient households. The term $q_t\left(x_t^l - x_{t-1}^l\right)$ denotes housing investment by patient households, where q_t is the real housing price.

Consumption and investment are respectively given by c_t^l and $j_t^l\left(1+\frac{\phi}{2}\left(\frac{j_t^l}{k_{t-1}}\right)\right)$. Note that total investment outlays are affected by increasing marginal costs of installation. There are also adjustment costs stemming from changing the housing stock that we model as:

$$\zeta_t^l = \phi_h\left(\left(x_t^l - x_{t-1}^l\right)/x_{t-1}^l\right)^2 q_t x_{t-1}^l/2$$

The remaining constraints faced by Ricardian households concern the laws of motion for capital and employment. Each period private capital stock k_{t-1}^l depreciates at the exogenous rate δ and is accumulated through investment, j_t^l. Thus, it evolves according to (3). Employment obeys the law of motion (4), where n_{t-1}^l and $(1-n_{t-1}^l)$ respectively denote the fraction of employed and unemployed optimizing workers in the economy at the beginning of period t. Each period, jobs are lost at the exogenous rate σ. Likewise, new employment opportunities come at the rate ρ_t^w, which represents the probability that one unemployed worker will find a job. Although the job-finding rate ρ_t^w is taken as exogenous by individual workers, at aggregate level it is endogenously determined according to the following Cobb-Douglas matching function[3]:

$$\rho_t^w(1-n_{t-1}) = \chi_1 v_t^{\chi_2}\left[(1-n_{t-1})l_2\right]^{1-\chi_2} \tag{5}$$

where v_t stands for the number of active vacancies during period t.

Given the recursive structure of the above problem, it may be equivalently rewritten in terms of a dynamic program. Thus, the value function $W(\Omega_t^l)$ satisfies the following Bellman equation:

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[2]   As in Iacoviello (2005), the assumption of an aggregate fixed housing stock is not crucial to the propagation mechanism of shocks in the economy.

[3]   This specification presumes that all workers are identical to the firm.

$$W(\Omega_t^l) = \max_{c_t^l, k_t^l, j_t^l, b_t^l, x_t^l} \left\{ \begin{array}{l} \ln\left(c_t^l - h^l c_{t-1}^l\right) + \phi_x \ln\left(x_t^l\right) + n_{t-1}^l \phi_1 \frac{(1-l_{1t})^{1-\eta}}{1-\eta} \\ +(1-n_{t-1}^l)\phi_2 \frac{(1-l_2)^{1-\eta}}{1-\eta} + \beta^l E_t W(\Omega_{t+1}^l) \end{array} \right\} \tag{6}$$

where maximization is subject to constraints (2), (3) and (4).

The solution to the optimization program above generates the following first-order conditions for consumption, capital stock, investment, loans and the holdings of housing:

$$\lambda_{1t}^l = \left(\frac{1}{c_t^l - h^l c_{t-1}^l} - \beta^l \frac{h^l}{c_{t+1}^l - h^l c_t^l} \right) \tag{7}$$

$$\frac{\lambda_{2t}^l}{\lambda_{1t}^l} = \beta^l E_t \frac{\lambda_{1t+1}^l}{\lambda_{1t}^l} \left\{ r_t + \frac{\phi}{2} \frac{j_{t+1}^{l2}}{k_t^{l2}} + \frac{\lambda_{2t+1}^l}{\lambda_{1t+1}^l}(1-\delta) \right\} \tag{8}$$

$$\lambda_{2t}^l = \lambda_{1t}^l \left[1 + \phi\left(\frac{j_t^l}{k_{t-1}^l}\right) \right] \tag{9}$$

$$1 = \beta^l E_t \frac{\lambda_{1t+1}^l}{\lambda_{1t}^l} \left\{ \frac{r_t^n + 1}{\pi_{t+1}} \right\} \tag{10}$$

$$\lambda_{1t}^l q_t \left[1 + \phi_h\left(\frac{x_t^l}{x_{t-1}^l} - 1\right) \right] = \frac{\phi_x}{x_t^l}$$
$$+ \beta^l E_t q_{t+1} \lambda_{1t+1}^l \left[1 + \frac{1}{2}\phi_h\left(\frac{x_{t+1}^l}{x_t^l} - 1\right)\left(\frac{x_{t+1}^l}{x_t^l} + 1\right) \right] \tag{11}$$

According to condition (7) the current marginal utility of consumption depends on both past and expected future consumption due to the presence of habits. Expression (8) ensures that the intertemporal reallocation of capital cannot improve the household's utility. Equation (9) states that investment is undertaken to the extent that the opportunity cost of a marginal increase in investment in terms of consumption is equal to its marginal expected contribution to the household's utility. First-order condition (10) means that variations across periods in the marginal utility of consumption are coherent with the discount rate and existing real interest rates. Finally, expression (11) makes it possible to obtain optimal housing demand.

Now it is convenient to derive the marginal value of employment for a worker ($\frac{\partial W_t^l}{\partial n_{t-1}^l} \equiv \lambda_{ht}^l$), given that later we will use this to obtain the wage and hours equation in the bargaining process.

$$\lambda_{ht}^l = \lambda_{1t}^l w_t l_{1t} + \left(\phi_1 \frac{(1 - l_{1t})^{1-\eta}}{1 - \eta} - \phi_2 \frac{(1 - l_2)^{1-\eta}}{1 - \eta} \right) + (1 - \sigma - \rho_t^w)\beta^l E_t \frac{\partial W_{t+1}^l}{\partial n_t} \quad (12)$$

where λ_{ht}^l measures the marginal contribution of a newly created job to the household's utility. The first term captures the value of the cash-flow generated by the new job in t, i.e. the labor income measured according to its utility value in terms of consumption (λ_{1t}^l). The second term on the right-hand side of (12) represents the net utility arising from the newly created job. Finally, the third term represents the "capital value" of an additional employed worker, given that the employment status will persist into the future, conditional to the probability that the new job will not be lost.

2.2 Impatient households

Impatient households discount the future more heavily than patient ones so their discount rate satisfies $\beta^b < \beta^l$. We will also assume that these households do not hold physical capital, so they face the following maximization program:

$$\max_{c_t^b, b_t^b, x_t^b} E_t \sum_{t=0}^{\infty} (\beta^b)^t \left[\begin{array}{c} \ln \left(c_t^b - h^b c_{t-1}^b \right) + \phi_x \ln \left(x_t^b \right) + n_{t-1}^b \phi_1 \frac{(1-l_{1t})^{1-\eta}}{1-\eta} \\ + (1 - n_{t-1}^b)\phi_2 \frac{(1-l_2)^{1-\eta}}{1-\eta} \end{array} \right] \quad (13)$$

subject to the specific liquidity constraint, a borrowing limit and the law of motion of employment, as reflected in:

$$c_t^b + q_t \left(x_t^b - x_{t-1}^b \right) - b_t^b = n_{t-1}^b w_t l_{1t} - (1 + r_{t-1}^n)b_{t-1}^b / \pi_t - \zeta_t^b \quad (14)$$

$$b_t^b \le m^b E_t \left(\frac{q_{t+1}\pi_{t+1}x_t^b}{1 + r_t^n} \right) \quad (15)$$

$$n_t^b = (1 - \sigma)n_{t-1}^b + \rho_t^w (1 - n_{t-1}^b) \quad (16)$$

where $\zeta_t^b = \phi_h \left(\left(x_t^b - x_{t-1}^b \right) / x_{t-1}^b \right)^2 q_t x_{t-1}^b / 2$ denotes the housing adjustment cost. As can be appreciated, parameter ϕ_x that accounts for housing weight in life-time utility is

the same as for patient households. Later we will allow for random shocks to this parameter that in turn can be interpreted as disturbances to the marginal utility of housing that directly affect housing demand. In this way, we will be able to capture the effects of shocks on house prices.

Notice that restrictions (14) and (16) are analogous to those for patient individuals (with the exception that impatient households do not accumulate physical capital). With respect to the borrowing constraint (15), parameter m^b is the loan-to-value ratio. As is well known in the mortgage market the amount lent by an individual is limited to a fraction of the value of the asset. If, for example, m^b takes a value of 1, this means that the whole value of the house acts as collateral. However, if $m^b = 0$ this implies a situation where housing is not collaterizable at all, meaning that the household is excluded from the financial market. As shown in Iacoviello (2005), without uncertainty the assumption $\beta^b < \beta^l$ guarantees that the borrowing constraint holds with equality.

In the case of impatient households, the value function $W(\Omega_t^b)$ satisfies the following Bellman equation:

$$
W(\Omega_t^b) = \max_{c_t^b, b_t^b, x_t^b} \left\{
\begin{array}{l}
\ln\left(c_t^b - h^b c_{t-1}^b\right) + \phi_x \ln\left(x_t^b\right) + n_{t-1}^b \phi_1 \frac{(1-l_{1t})^{1-\eta}}{1-\eta} \\
+ (1 - n_{t-1}^b)\phi_2 \frac{(1-l_2)^{1-\eta}}{1-\eta} + \beta^b E_t W(\Omega_{t+1}^b)
\end{array}
\right\} \tag{17}
$$

where maximization is subject to constraints (14), (15) and (16).

The solution to the optimization program is characterized by the following first-order conditions:

$$
\lambda_{1t}^b = \left(\frac{1}{c_t^b - h^b c_{t-1}^b} - \beta^b \frac{h^b}{c_{t+1}^b - h^b c_t^b} \right) \tag{18}
$$

$$
\lambda_{1t}^b = \beta^b E_t \lambda_{1t+1}^b \left(\frac{1 + r_t^n}{\pi_{t+1}} \right) + \mu_t^b (1 + r_t^n) \tag{19}
$$

$$
\lambda_{1t}^b q_t \left[1 + \phi_h \left(\frac{x_t^b}{x_{t-1}^b} - 1 \right) \right] = \frac{\phi_x}{x_t^b} + \mu_t^b m^b q_{t+1} \pi_{t+1}
$$
$$
+ \beta^b E_t q_{t+1} \lambda_{1t+1}^b \left[1 + \frac{1}{2}\phi_h \left(\frac{x_{t+1}^b}{x_t^b} - 1 \right) \left(\frac{x_{t+1}^b}{x_t^b} + 1 \right) \right] \tag{20}
$$

where μ_t^b is the Lagrange multiplier of the borrowing constraint.

The marginal value of employment for an impatient household worker ($\frac{\partial W_t^b}{\partial n_{t-1}^b} \equiv \lambda_{ht}^b$)

can be obtained as,

$$\lambda_{ht}^b = \lambda_{1t}^b w_t l_{1t} + \left(\phi_1 \frac{(1 - l_{1t})^{1-\eta}}{1 - \eta} - \phi_2 \frac{(1 - l_2)^{1-\eta}}{1 - \eta} \right) + (1 - \sigma - \rho_t^w) \beta^b E_t \frac{\partial W_{t+1}^b}{\partial n_t} \quad (21)$$

which can be interpreted in the same way as that of patient households.

2.3 Aggregation

Aggregate consumption and employment are a weighted average of the corresponding variables for each household type:

$$c_t = \left(1 - \lambda^b \right) c_t^l + \lambda^b c_t^b \quad (22)$$

$$n_t = \left(1 - \lambda^b \right) n_t^l + \lambda^b n_t^b \quad (23)$$

$$\lambda^b b_t^b + (1 - \lambda^b) b_t^l = 0 \quad (24)$$

$$\lambda^b x_t^b + (1 - \lambda^b) x_t^l = X \quad (25)$$

where λ^b represents the share of impatient households in the economy and X is the fixed stock of real estate in the economy.

For the variables that exclusively concern patient households, aggregation is merely performed as:

$$k_t = \left(1 - \lambda^b \right) k_t^l \quad (26)$$

$$j_t = \left(1 - \lambda^b \right) j_t^l \quad (27)$$

In addition, we consider an aggregator (trade union) that puts together the surpluses from employment, in terms of consumption, of both types of households and use this aggregate in the negotiation of hours and wages:

$$\lambda_{ht} = \left(1 - \lambda^b \right) \frac{\lambda_{ht}^l}{\lambda_{1t}^l} + \lambda^b \frac{\lambda_{ht}^b}{\lambda_{1t}^b} \quad (28)$$

2.4 Factor demands

Factor demands are obtained by solving the cost minimization problem faced by each competitive producer (for simplicity, we drop the firm index i)

$$\min_{k_t, v_t} E_t \sum_{t=0}^{\infty} (\beta^l)^t \frac{\lambda^l_{1t+1}}{\lambda^l_{1t}} \left(r_{t-1} k_{t-1} + w_t n_{t-1} l_{1t} + \kappa_v v_t \right) \tag{29}$$

subject to

$$y_t = z_t k_{t-1}^{1-\alpha} (n_{t-1} l_{1t})^\alpha \tag{30}$$

$$n_t = (1-\sigma) n_{t-1} + \rho^f_t v_t \tag{31}$$

where, in accordance with the ownership structure of the economy, future profits are discounted at the patient household's relevant rate $\left((\beta^l)^t \frac{\lambda^l_{1t+1}}{\lambda^l_{1t}} \right)$ .Producers use two inputs, private capital and labor, so technological possibilities are given by a standard Cobb-Douglas constant-returns-to-scale production function where z_t stands for a technology shock $\ln z_t = (1-\rho_z) \ln A + \rho_z \ln z_{t-1} + \varepsilon_t$ where A represents the long-run level of total factor productivity and $\varepsilon_t \sim N(0, \sigma_z)$. ρ^f_t is the probability that a vacancy will be filled in any given period t. It is worth noting that the probability of filling a vacant post ρ^f_t is exogenous from the firm's perspective. However, from the perspective of the overall economy, this probability is endogenously determined according to the following Cobb-Douglas matching function:

$$\rho^w_t (1 - n_{t-1}) = \rho^f_t v_t = \chi_1 v_t^{\chi_2} \left[(1 - n_{t-1}) l_2 \right]^{1-\chi_2} \tag{32}$$

Proceeding in the same manner we did with households, we can express the maximum expected value of the firm in state Ω^f_t as a function $V(\Omega^f_t)$ that satisfies the following Bellman equation:

$$V(\Omega^f_t) = \max_{k_t, v_t} \left\{ y_t - r_{t-1} k_{t-1} - w_t n_{t-1} l_{1t} - \kappa_v v_t + \beta^l E_t \frac{\lambda^l_{1t+1}}{\lambda^l_{1t}} V(\Omega^f_{t+1}) \right\} \tag{33}$$

The solution to the optimization program above generates the following first-order conditions for private capital and the number of vacancies

$$r_t = (1-\alpha) \frac{y_{t+1}}{k_t} \tag{34}$$

$$\frac{\kappa_v}{\rho_t^f} = \beta E_t \frac{\lambda_{1t+1}^l}{\lambda_{1t}^l} \frac{\partial V_{t+1}}{\partial n_t} \tag{35}$$

where the demand for private capital is determined by (34). It is positively related to the marginal productivity of capital $(1-\alpha)\frac{y_{t+1}}{k_t}$ which, in equilibrium, must equate the gross return on physical capital.

Expression (35) reflects that firms choose the number of vacancies in such a way that the marginal recruiting cost per vacancy, κ_v, is equal to the expected present value of holding it, $\beta^l E_t \frac{\lambda_{1t+1}^l}{\lambda_{1t}^l} \rho_t^f \frac{\partial V_{t+1}}{\partial n_{t+1}}$.

Using the Bellman equation the marginal value of an additional employment in t for a firm ($\lambda_{ft} \equiv \frac{\partial V_t}{\partial n_{t-1}}$) is,

$$\lambda_{ft} = \alpha \frac{y_t}{n_{t-1}} - w_t l_{1t} + (1-\sigma)\beta^l E_t \frac{\lambda_{1t+1}^l}{\lambda_{1t}^l} \frac{\partial V_{t+1}}{\partial n_t} \tag{36}$$

where the marginal contribution of a new job to profits equals the marginal product net of the wage rate, plus the capital value of the new job in t, corrected for the probability that the job will continue in the future.

Now using (36) one period ahead, we can rewrite condition (35) as:

$$\frac{\kappa_v}{\rho_t^f} = \beta^l E_t \left[\frac{\lambda_{1t+1}^l}{\lambda_{1t}^l} \left(\alpha \frac{y_{t+1}}{n_t} - w_{t+1} l_{1t+1} + (1-\sigma) \frac{\kappa_v}{\rho_{t+1}^f} \right) \right] \tag{37}$$

2.5   Trade in the labor market: the labor contract

The key departure of search models from the competitive paradigm is that trading in the labor market is subject to transaction costs. Each period, unemployed engage in search activities in order to find vacant posts spread over the economy. Costly search in the labor market implies that there are simultaneous flows into and out of the state of employment, so an increase (reduction) in the stock of unemployment results from the predominance of job losses (creation) over job creation (losses). Stable unemployment occurs whenever inflows and outflows cancel out one another, i.e.,

$$\rho_t^f v_t = \rho_t^w (1 - n_{t-1}) = \chi_1 v_t^{\chi_2} \left[(1 - n_{t-1}) l_2 \right]^{1-\chi_2} = \sigma n_{t-1} \tag{38}$$

Because it takes time (for households) and real resources (for firms) to make profitable contacts, some pure economic rent emerges with each new job, which is equal to

the sum of the expected transaction (search) costs the firm and the worker will further incur if they refuse to match. The emergence of such rent gives rise to a bilateral monopoly framework.

Once a representative job-seeking worker and vacancy-offering firm match, they negotiate a labor contract in hours and wages. There is risk-sharing at household level but not between households. Although patient and impatient households have a different reservation wage, they delegate the bargain process with firms to trade unions. This trade union maximizes the aggregate marginal value of employment for workers (28)[4] and distributes employment according to their shares in the working-age population. The implication of this assumption is that all workers receive the same wages, work the same number of hours, and suffer the same unemployment rates. Thus, following standard practice, the Nash bargain process maximizes the weighted product of the parties' surpluses from employment.

$$
\max_{w_t, l_{1t}} \left(\left(1 - \lambda^b\right) \frac{\lambda^l_{ht}}{\lambda^l_{1t}} + \lambda^b \frac{\lambda^b_{ht}}{\lambda^b_{1t}} \right)^{\lambda^w} \left(\lambda_{ft}\right)^{1-\lambda^w} = \max_{w_t, l_{1t}} \left(\lambda_{ht}\right)^{\lambda^w} \left(\lambda_{ft}\right)^{1-\lambda^w}
\tag{39}
$$

where $\lambda^w \in [0,1]$ reflects the workers's bargaining power. The first term in brackets represents the worker surplus (as a weighted average of borrowers and lenders workers' surpluses) while the second is the firm surplus. More specifically, $\lambda^l_{ht}/\lambda^l_{1t}$ and $\lambda^b_{ht}/\lambda^b_{1t}$ respectively denote the earning premium (in terms of consumption) of employment over unemployment for a patient and an impatient worker. Notice that both earning premia are weighted according to the share of borrowers in the population (λ^b).

The solution of the Nash maximization problem gives the optimal real wage and hours worked (see Boscá, Doménech and Ferri, 2009 for further details):

$$
w_t l_{1t} = \lambda^w \left(\alpha \frac{y_t}{n_{t-1}} + \frac{\kappa_v v_t}{(1 - n_{t-1})} \right)
\tag{40}
$$

$$
+(1 - \lambda^w) \left(\frac{(1 - \lambda^b)}{\lambda^l_{1t}} + \frac{\lambda^b}{\lambda^b_{1t}} \right) \left(\phi_2 \frac{(1 - l_2)^{1-\eta}}{1 - \eta} - \phi_1 \frac{(1 - l_{1t})^{1-\eta}}{1 - \eta} \right)
$$

$$
+(1 - \lambda^w)(1 - \sigma - \rho^w_t) \lambda^b E_t \frac{\lambda^b_{ht+1}}{\lambda^b_{1t+1}} \left(\beta^l \frac{\lambda^l_{1t+1}}{\lambda^l_{1t}} - \beta^b \frac{\lambda^b_{1t+1}}{\lambda^b_{1t}} \right)
$$

$$
\alpha \frac{y_t}{n_{t-1} l_{1,t}} = \left[\frac{1 - \lambda^b}{\lambda^l_{1t}} + \frac{\lambda^b}{\lambda^b_{1t}} \right] \phi_1 (1 - l_{1t})^{-\eta}
\tag{41}
$$

---

[4]   This is a shortcut to circumvent problems associated with incentives to reveal preferences by workers and to perform screening by firms.

Unlike the Walrasian outcome, the wage prevailing in the search equilibrium is related (although not equal) to the marginal rate of substitution of consumption for leisure and the marginal productivity of labor, depending on worker bargaining power λ^w. Putting aside the last term on the right hand side, the wage is a weighted average between the highest feasible wage (i.e., the marginal productivity of labor plus hiring costs per unemployed worker) and the outside option (i.e., the reservation wage as given by the difference between the utility of leisure of an unemployed person and an employed worker). This reservation wage is, in turn, a weighted average of the lowest acceptable wage of both type of workers. They differ in the marginal utility of consumption (λ^l_{1t} and λ^b_{1t}). If the marginal utility of consumption is high, the workers are ready to accept a relatively low wage.

The third term on the right hand side of (40) is part of the reservation wage that depends only on the existence of impatient workers (only if $\lambda^b > 0$ this term is different from zero). It can be interpreted as an inequality term in utility. The economic intuition is as follows: impatient consumers are constrained by their collateral requirements, so that they are not allowed to use their entire wealth to smooth consumption over time. However, they can take advantage of the fact that a match today continues with some probability $(1 - \sigma)$ in the future, yielding a labor income that in turn will be used to consume tomorrow. Therefore, they use the margin that hours and wage negotiation provide them to improve their lifetime utility, by narrowing the gap in utility with respect to patient consumers. In this sense, they compare the discounted intertemporal marginal rate of substitution had they not been income constrained $\left(\beta^l \frac{\lambda^l_{1t+1}}{\lambda^l_{1t}} \right)$ with the expected rate given their present rationing situation $\left(\beta^b \frac{\lambda^b_{1t+1}}{\lambda^b_{1t}} \right)$. For example if, *caeteris paribus*,$\beta^l \frac{\lambda^l_{1t+1}}{\lambda^l_{1t}} > \beta^b \frac{\lambda^b_{1t+1}}{\lambda^b_{1t}}$ all the third term in (40) is positive, which indicates that impatient workers put additional pressure on the average reservation wage as a way to ease their period-by-period constraint in consumption. The importance of this inequality term is positively related to the earning premium of being matched next period $\left(\frac{\lambda^b_{ht+1}}{\lambda^b_{1t+1}} \right)$, because it increases the value of a match to continue in the future, and negatively related to the job finding probability (ρ^w_t), that reduces the loss of breaking up the match. Finally, notice that when $\lambda^b = 0$, all consumers are patient and, therefore, the solutions for the wage rate and hours simplify to the standard ones (see Andolfatto, 2004).

2.6 Interest rate rule and the accounting identity

We assume the existence of a central bank in our economy that follows a Taylor's interest rate rule:

$$1 + r_t^n = \left(1 + r_{t-1}^n\right)^{r_R} \left((\pi_{t-1})^{1+r_\pi} \left(\frac{y_{t-1}}{\bar{y}}\right)^{r_y} \bar{rr}\right)^{1-r_R} \tag{42}$$

where $\bar{y}$ and $\bar{rr}$ are steady-state levels of output and the real interest rate, respectively. The parameter r_R captures the extent of interest rate inertia, and r_π and r_y represent the weights given by the central bank to inflation and output objectives.

Finally, to close the model, output is defined as the sum of demand components:

$$y_t = c_t + j_t \left(1 + \frac{\phi}{2} \left(\frac{j_t}{k_{t-1}}\right)\right) + \kappa_v v_t \tag{43}$$

3.   Evidence and calibration

3.1   Stylized facts

In table 1 column (A) we display the cyclical properties of some macroeconomic variables, including the main labor market aggregates and the price index for housing in the US economy from 1964:1 to 2008:4. Data come from different sources (see table A1 in the Appendix). All series have been HP filtered (with a smoothing parameter of 1600) to obtain their trend and cyclical components. Some of the US cyclical features we document have been already previously established in the literature[5], whereas others are less known. They can be summarized as follows:

1.   Total hours are as volatile as output and highly procyclical.
2.   Labor productivity is less volatile than output and procyclical.
3.   Wages are less volatile than output and slightly procyclical.
4.   The labor share is less volatile than output and acyclical.
5.   Vacancies are eight times more volatile than output and highly procyclical.
6.   Total employment is less volatile than output and procyclical.
7.   Real housing prices are more volatile than output and procyclical.
8.   Total hours and labor productivity are not correlated.
9.   Total hours and wages are not correlated.
10. Hours per employee are four times less volatile than output and procyclical.
11. The correlation of housing prices and consumption is positive.
12. The correlation of housing prices and non-residential investment is positive.

---

[5]   See Cheron and Langot (2004), Shimer (2005) or Ravn and Simonelli (2008), for labor market aggregates, or Aoki et al. (2004), for housing prices.

TABLE 1 — STYLIZED FACTS

Variable x	(A) 64-08		(B) 64-82		(C) 83-08	
Period	64-08		64-82		83-08	
$\sigma(y)$	1.54		2.02		1.17	
ρ_y	0.91		0.91		0.91	
Variable x	(1)	(2)	(1)	(2)	(1)	(2)
c_t	0.52	0.93	0.52	0.95	0.51	0.90
j_t	2.56	0.90	2.22	0.90	2.83	0.92
$l_{1t}n_t$	1.12	0.82	1.05	0.83	1.27	0.81
$\frac{y_t}{l_{1t}n_t}$	0.68	0.44	0.66	0.66	0.69	-0.01
w_t	0.61	0.30	0.41	0.68	0.88	0.04
v_t	8.54	0.88	8.07	0.90	9.29	0.86
q_t	1.37	0.59	1.14	0.80	1.76	0.40
$corr(l_{1t}n_t, \frac{y_t}{l_{1t}n_t})$	0.00		0.28		-0.48	
$corr(l_{1t}n_t, w_t)$	-0.04		0.37		-0.33	
$corr(q_t, c_t)$	0.52		0.73		0.31	
$corr(q_t, j_t)$	0.48		0.79		0.20	

Column (1): $\sigma(x)/\sigma(y)$, Column (2): $corr(x,y)$.

In the early 1980's an important reorganization of the housing finance system took place, as a consequence of the Monetary Control Act of 1980 (President Carter) and the Garn-St. Germain Act of 1982 (President Reagan). In particular, this new system along with the progressive deepening in the financial market triggered a substantial increase in indebtedness. In this section we discuss to what extent this increase in leverage may be behind a substantial alteration in the dynamic pattern of most macroeconomic and labor market variables. In columns (B) and (C) of the table we augment the evidence presented by Campbell and Hercowitz (2009) regarding changes occurred in those data moments across two subsamples: 1964:1-1982:4 and 1983:1-2008:3, to include the most important labor market flows as well as correlations among housing prices and other aggregate series. The first period characterizes an economy with tight constraints in the financial market (low loan-to-value ratios), whereas the second period represents an economy with higher leverage ratios. The following features stand out from this comparison:

1. There is a fall in the volatility of output between the first and the second period (what has been called great moderation).
2. The relative volatility of investment increases.
3. There is an increase in the relative volatility of total hours.
4. The relative volatility of wages doubles in the second period with respect to the first. Conversely, the correlation with output changes from positive in the first period to zero in the second one.
5. The relative volatility of vacancies increases slightly across periods.
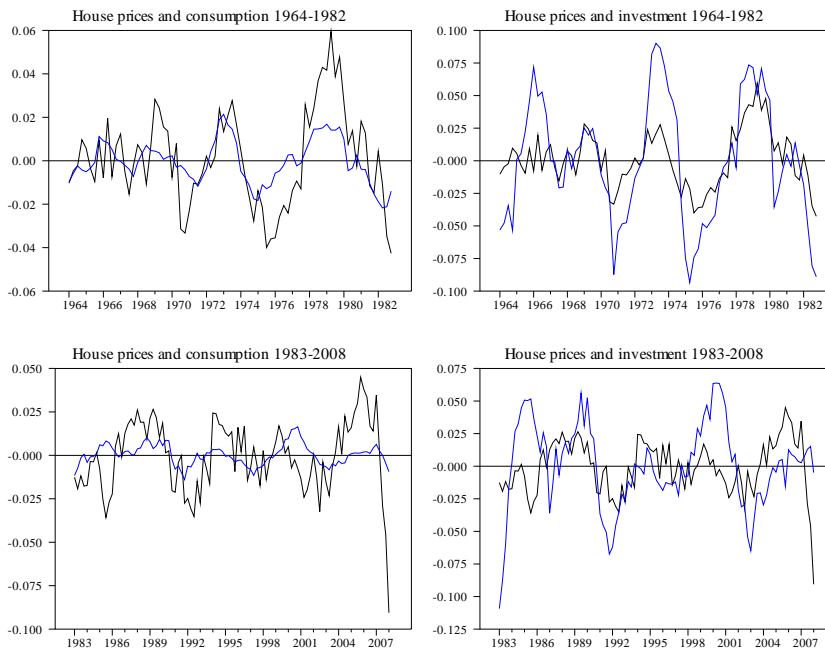
Figure 1: *Cyclical components of housing prices, consumption and investment*

6. The relative volatility of employment increases slightly.
7. The correlations of total hours with labor productivity and with wages change from moderately procyclical to moderately countercyclical.
8. The relative volatility of real housing prices increases.
9. The correlation between real housing prices and consumption decreases.
10. The correlation between real housing prices and non-residential investment falls significantly.

Given the extensive use of housing as collateral, the last two correlations, in particular that between the cyclical components of housing prices and consumption, might be counterintuitive. However, as figure 1 makes clear these two comovements have indeed weakened since the early 80's.

3.2 Model parameterization

The calibration strategy follows three steps. First, some model parameters have been set

to some consensus values drawn from related papers in the literature. Second, some other parameters have been obtained from the steady state relationships in the model. Finally, the parameter m^b is supposed to differ across scenarios to capture the two indebtedness regimes that exist behind the two sub-samples in which we split up the data.

Parameters from previous studies

From Iacoviello (2005) we choose values for the subjective intertemporal discount rate of patient households, $\beta^l = 0.99$, the subjective discount rate of impatient households, $\beta^b = 0.95$, the depreciation rate of physical capital, $\delta = 0.03$, and the adjustment cost for housing capital $\phi_h = 0.0$. From Campbell and Hercowitz (2005 and 2008) we take the Cobb-Douglas parameter $\alpha = 0.7$. With respect to labor market parameters, and following Andolfatto (1996) and Cheron and Langot (2004), we set the exogenous transition rate from employment to unemployment, $\sigma = 0.15$, and the elasticity of matchings to vacant posts, $\chi_2 = 0.6$. From these authors we also pick up some average steady-state values, as the probability of a vacant position becoming a productive job, which is assumed to be $\bar{\rho}^f = 0.9$, is consistent with a vacancy being opened 45 days on average. The long run employment ratio and the fraction of time spent working are computed to be $\bar{n} = 0.57$ and $\bar{l}_1 = 1/3$, and the fraction of time households spent searching is half the time spent working, $l_2 = 1/6$. Also, we assume that equilibrium unemployment is socially-efficient (see Hosios, 1990) and, as such $\lambda^w = 0.4$ is equal to $1 - \chi_2$. For the intertemporal labor elasticity of substitution, η, we rely on Andolfatto (1996) and consider $\eta = 2$ implying that average individual labor supply elasticity is equal to 1. The adjustment costs parameter, $\phi = 5.95$, is taken from QUEST II, which considers the same function as ours for capital installation costs. The external habits parameters in consumption, $h^l = h^b = 0.7$, are between the low (*0.36*) and the high (*0.81*) values estimated by Liu *et al.* (2009) and in the upper bound of a 95 probability interval for impatient household habits estimated by Iacoviello and Neri (2010). We choose a value $\lambda^b = 0.36$ for the fraction of impatient consumers in the economy as the one estimated by Iacoviello (2005).

Calibrated parameters from steady-state relationships

We normalize both steady-state output ($\bar{y}$) and real housing prices ($\bar{q}$) to one. From (38) we obtain the long-run value for vacancies $\bar{v} = \sigma\bar{n}/\bar{\rho}^f$. Then, we calibrate the ratio of recruiting expenditures to output ($\kappa_v \bar{v}/\bar{y}$) to represent 0.5 percentage points of output, as in Cheron and Langot (2004), to obtain a value of $\kappa_v = 0.053$. In order to obtain A, we first use (3) and (9) to ascertain the steady-state value of Tobin's q ($\frac{\bar{\lambda}_2^l}{\bar{\lambda}_1^l}$). Hence, we gain the return on capital ($\bar{r}$) using (8) and this allows us to compute the steady-state value for the

capital stock ($\bar{k}$) from (34). Therefore the long run value of total factor productivity, $A = 1.801$, is calibrated from the production function (30). The steady-state value of matching flows in the economy equals the flow of jobs that are lost ($\sigma \bar{n}$) and we use the equality ($\sigma \bar{n} = \chi_1 \bar{v}^{\chi_2} [(1 - \bar{n}) l_2]^{1 - \chi_2}$) to solve for the scale parameter of the matching function, $\chi_1 = 1.007$.

Using equation (37), we can solve for the steady-state value of wages ($\bar{w}$). The steady-state value of the nominal interest rate, $\bar{r}^n$, is related to the intertemporal discount rate of lenders through equation (10). Let γ_l be the ratio of assets of patient households in the steady state to total output ($\bar{b}^l = \gamma_l \bar{y}$). From equation (24) we obtain $\bar{b}^b$ conditional to the value of γ_l. Next, we can compute the steady-state level of consumption of borrowers, $\bar{c}^b$, from the budget restriction (14) and the consumption level of lenders, $\bar{c}^l$, from the aggregation equation (22). Our next step consists in calibrating steady-state levels of the marginal utilities of consumption of both types of consumers, $\bar{\lambda}_1^l$ and $\bar{\lambda}_1^b$, from their respective first-order conditions in equations (7) and (18). We can now obtain the steady-state holdings of housing of these types of agents, $\bar{x}^b$, from the borrowing restriction of impatient households (equation (15)). The long-run equilibrium value for the multiplier of impatient households' borrowing constraint, $\bar{\mu}^b$, can now be computed directly from the first-order condition (19). This makes it possible to compute the parameter that accounts for the housing weight in life-time utility, ϕ_x, from the last first-order condition of borrowers' optimization program (equation (20)). The value of the parameter ϕ_x enables us to compute the steady-state holdings of housing for lenders, $\bar{x}^l$, from first order condition (11), and the fixed stock of real estate in the economy, X, from the aggregation rule (25). Notice that the value we will obtain for ϕ_x and X depends on the value we assign to the ratio of assets of patient households in the steady state to total output, γ_l. In order to produce a sensible calibration of this parameter and the steady-state level of the variables, we follow Iacoviello (2005) and choose a value for γ_l, such that the total stock of housing over yearly output is 140 per cent. The resulting value for ϕ_x is 0.097.

As regards preference parameters in the household utility function, $\phi_1 = 2.221$ is calculated from the steady-state version of expression (41). A system of three equations implying the steady state of expressions (12) (21) and (40) is solved for ϕ_2, $\bar{\lambda}_h^b$ and $\bar{\lambda}_h^l$. The resulting value for ϕ_2 is 1.420. Therefore the calibrated values for ϕ_1 and ϕ_2 are similar to those in Andolfatto (1996) and other related research in the literature. Such values imply that the imputed value for leisure by an employed worker is situated well above the imputed value for leisure by an unemployed worker.

Shocks and policy rule parameters

The parameters $r_R = 0.73$ and $r_\pi = 0.27$ in the interest rate rule are taken from Iacoviello

TABLE 2 — PARAMETER VALUES

β^l	0.99	η	2.00
β^b	0.95	$h^l = h^b$	0.70
α	0.70	ϕ	5.95
δ	0.03	λ^b	0.36
κ_v	0.053	ϕ_h	0.00
σ	0.15	m^b	0.775
χ_1	1.007	ϕ_x	0.088
χ_2	0.60	r_R	0.73
λ^w	0.40	r_π	0.27
l_2	1/6	r_y	0.0
ϕ_1	2.22	ϕ_2	1.42

(2005). For the parameter measuring the interest rate reaction to output, r_y, we choose a value of 0. Regarding the productivity shock, we have chosen a high value for the autocorrelation parameter for technology shocks ($\rho_z = 0.95$) as in Campbell and Hercowitz (2005) and Cheron and Langot (2004), whereas the standard deviation of the shock σ_z has been calibrated so that the standard deviation of output matches its actual value in the 1964:1-1982:4 subsample. In some simulations we also activate a shock affecting housing preferences. The behavior of this shock and its calibration will be explained further below.

Parameter changes across periods

We only use one adjusting parameter, the loan-to-value ratio, to characterize the two periods of interest. The two concrete values for m^b are taken directly from Iacoviello and Neri (2010). So, for the first subperiod 1964:1-1982:4, we set $m^b = 0.775$ as implying a low indebtedness regime. Because we calibrate our parameters to normalize output and housing prices to one, and to match the volatility of output during the first subperiod, we consider this calibration our baseline (what we will call the low indebtedness regime, or *LI* model). Then, we relax the collateral restriction by setting $m^b = 0.925$, the rest of parameters characterizing the different equations and shocks of the models being constant. This calibration is assumed to represent a high indebtedness regime during the second period (what we will call *HI* model). The steady-state value for the leverage ratio $\frac{b^b}{qx^b}$ implied by our two regimes (*HI* and *LI* models) rises from 77 per cent in the first case to 91 per cent in the second. All the results characterizing changes between the two regimes, which are introduced below, are only conditional to these two values for m^b. A summary of the parameters of the model and the steady-state values of the endogenous variables implied by the model solution for the baseline calibration are given in tables 2 and 3.

LABOUR MARKET SEARCH, HOUSING PRICES AND BORROWING CONSTRAINTS 21

<div align="center">

TABLE 3 — STEADY STATE

Search model with borrowing constraints and housing					
c_t	0.77	n_t	0.57	b_t^b	2.15
c_t^l	0.83	n_t^l	0.57	r_t^n	0.01
c_t^b	0.67	n_t^b	0.57	q_t	1.00
j_t	0.20	r_t	0.04	x_t^l	7.19
j_t^l	0.32	v_t	0.095	x_t^b	2.80
k_t	6.78	w_t	3.66	X	5.61
k_t^l	10.59	y_t	1.00		
l_{1t}	0.33	b_t^l	-1.21		

</div>

4. Results: technology shocks

4.1 Impulse response functions

In figure 2 we depict impulse-response functions to a one-percentage-point transitory increase in total factor productivity. This graph illustrates to what extent the presence and the degree of credit constraints can affect the dynamics of the real economy after a technology shock. In particular, we concentrate on the dynamic effects on key labor market variables and housing prices, which crucially shape the dynamics of output and its components.

As commented previously when discussing the stylized facts, the US economy has undergone two different periods characterized by very different indebtedness facilities of households. To account for the changes observed in the US economy, as regards indebtedness facilities for households, we consider three possible scenarios. The first (column 1 of figure 2) features an economy without financial restrictions in which all households have the same time discount rate; the economy with a loan-to-value ratio $m^b = 0.775$ represents the *LI* scenario, in which the level of indebtedness was relatively low (second column in figure 2); finally the high-indebtedness regime in the third column features a higher m^b (0.925) to capture the increase in the leverage ratio that took place during the second sub period (1983:1-2008:3). Our simulations will show that some of the changes observed in the cyclical pattern of the US labor market might have been triggered by the increasing access to capital markets due to looser borrowing requirements.

According to the impulse-response functions depicted in the first column, a transitory positive technological shock increases output and total consumption on impact. It also positively affects the extensive (employment) and the intensive (hours) margins in the labor market and augments real wages. Looking now across columns, significant differences appear in the behavior of the labor market depending on household borrowing
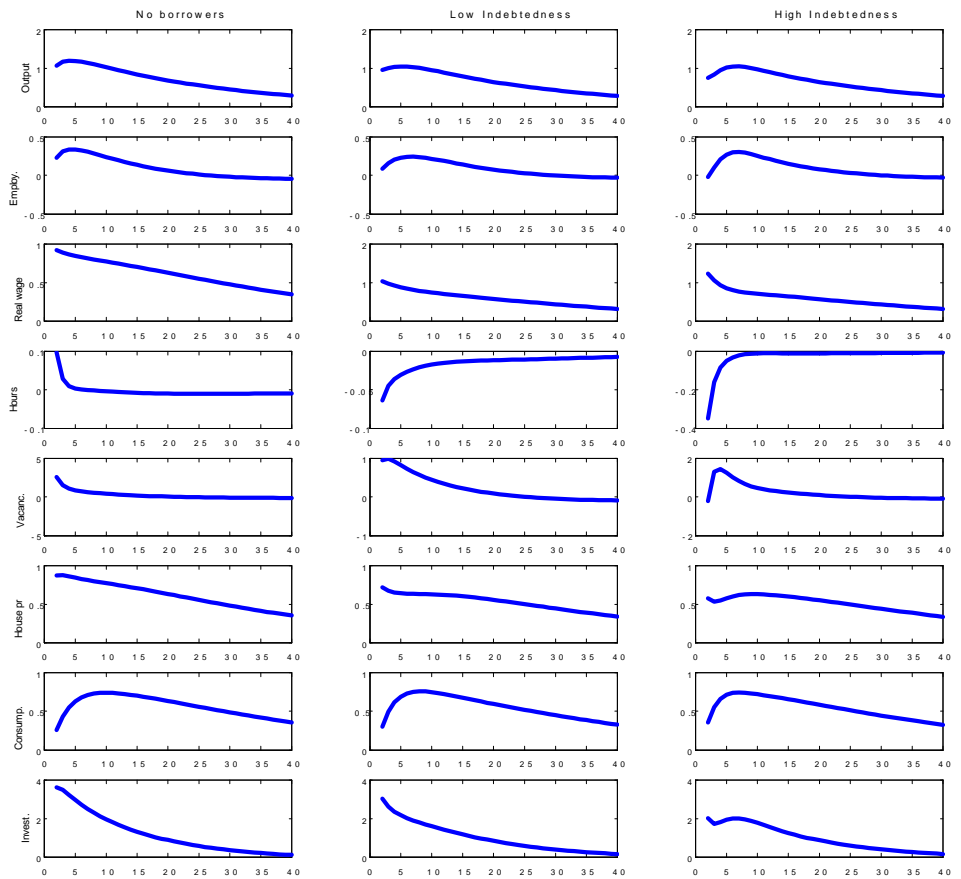
Figure 2: *IRF for a technological shock*

capacity. In particular, the easier it is for the economy to become indebted (i.e. the higher m^b is), the weaker the effects on employment, hours and vacancies and the stronger the effects on wages.

The intuition of these changes in dynamic responses can be better grasped by focusing on the response of the weighted average of the inverse marginal utilities of consumption of both types of households in the economy, $\left[\frac{1-\lambda^b}{\lambda^l_{1t}} + \frac{\lambda^b}{\lambda^b_{1t}} \right]$, which depends directly on the number of impatient households λ^b, and indirectly on the loan-to-value ratio, m^b, through its impact on λ^b_{1t}. The term $\left[\frac{1-\lambda^b}{\lambda^l_{1t}} + \frac{\lambda^b}{\lambda^b_{1t}} \right]$ is crucial to determine the effect of a technological shock on hours worked (see equation 41). The reaction, to a positive technology shock, of the marginal utility of consumption of heavily leveraged constrained consumers is stronger than that of lenders, as the shock not only increases their current income, but also the value of their collateral (due to both the increase in the relative price of houses and the fall in the real interest rate) making their access to credit easier. Thus, as m^b increases, a positive technology shock reduces households' marginal utility of consumption on impact by more, which in turn pushes the (optimally chosen) level of working hours down (equation 41), increasing both the reservation wage (equation 40) as well as the real market wage.[6] Finally, less hours and higher market wages act as a disincentive to post vacancies thus reducing matching activity in the labor market.[7] As a result, employment falls, along with capital and output, dampening the positive output effect of the shock itself. Notice additionally that all these effects would be strengthened when the weight of λ^b_{1t} increases in the term $\left[\frac{1-\lambda^b}{\lambda^l_{1t}} + \frac{\lambda^b}{\lambda^b_{1t}} \right]$. Thus, they would be more pronounced in economies with a higher proportion of borrowers.[8]

4.2 Simulated moments

Next we assess to what extent the model captures the most salient features of the change in financial structure from the early eighties onwards. In table 4 we present the simulations on labor market moments of a technological shock that hits the two different calibrations of our economy (*LI* and *HI* models). Let us recall that the standard deviation of the shock σ_z has been calibrated so that the *LI* model's standard deviation of output matches its actual value in first period sample. We will assume that the autocorrelation and standard

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[6] Notice that this fall in hours worked following a technology shock is obtained without relying on price stickiness as is common in the literature.

[7] A complete set of graphs representing impulse-response functions for all the variables is available upon request.

[8] We have also simulated other different scenarios in which λ^b also increases across regimes. The results are very similar to those obtained in this paper and are available on request.

deviation of the shocks remain constant across periods. Thus, the intertemporal empirical comparison we carry out below is conditional only to the change in the parameter m^b.

In order to facilitate comparisons, the first two columns of table 4 reproduce the relative (to output) standard deviations and relevant correlations of observed US labor market variables and other macroeconomic aggregates. Some of the moments in the US economy we focus on have been extensively analyzed in the literature. Some examples are, Hagedorn and Manovskii (2008), Gertler and Trigari (2009), Mortensen and Nagypal (2007) and Andrés et al (2007) who, among others, have studied the volatility of vacancies and labor productivity in depth; Cheron and Langot (2004) and Boscá et al (2009) who look at the correlation of hours with productivity and wages; Iacoviello (2005) and Iacoviello and Neri (2010), who have analyzed the volatility of real housing prices and their correlation with output and consumption[9] and finally Liu et al. (2009), who focus their analysis on the correlation between housing prices and productive investment. We use a theoretical framework that blends financial and labor market frictions, aimed at explaining a broader set of empirical features. The range of second moments we considers include those related to macroeconomic aggregates, labor market flows and housing prices; besides we are primarily interested in the changing pattern associated with financial deepening in the mortgage market in the vein of Campbell and Hercowitz (2005).[10]

The first noteworthy result that emerges from the sub-sample comparison in the table is that switching from a low to a high-indebtedness economy, all the other things equal, generates a decrease in the volatility of output (from 2.02 to 1.87). These figures account for 36 per cent of the observed reduction in the standard deviation. Thus, our model helps to explain one of the key features of the so-called great moderation. This result was already explained by Campbell and Hercowitz (2005) in a model with a perfectly competitive labor market and financial frictions, where collateral requirements are relaxed. More interestingly, with respect to labor market variables, our model also does a good job in capturing other dimensions of the business cycle across the two sample periods. With respect to relative (output) volatilities, the model over-accounts for the observed increase in the relative volatility of total hours (the observed rate of increase being 21 per cent and the simulated augment 109 per cent). This result is guided by the low simulated standard deviation for hours in the first period, but points to the importance of financial restrictions in the cyclical behavior of total hours. Also, the significant growth rate in the observed relative volatility of wages is partially explained (a 37 per cent) by the model, once we account for looser financial restrictions. Finally, and starting from a much lower than

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[9]   Aoki, Proudman and Vlieghe (2004) conduct a similar analysis for the UK.

[10]   Also Iacoviello and Neri (2010) devote a subsection to estimating their model with data before and after 1982:4.

Table 4 — Cyclical Properties

	US		US		LI model		HI model	
	(1)		(2)		(3)		(4)	
Period	64-82		83-08		$m = 0.775$		$m = 0.925$	
$\sigma(y)$	2.02		1.17		2.02		1.87	
ρ_y	0.91		0.91		0.78		0.84	
Variable x	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
c_t	0.52	0.95	0.51	0.90	0.59	0.90	0.65	0.98
j_t	2.22	0.90	2.83	0.92	2.60	0.95	2.15	0.98
$l_{1t}n_t$	1.05	0.83	1.27	0.81	0.23	0.49	0.48	0.20
$\frac{y_t}{l_{1t}n_t}$	0.66	0.66	0.69	-0.01	0.91	0.98	1.02	0.89
w_t	0.41	0.68	0.88	0.04	0.92	0.97	1.08	0.86
v_t	8.07	0.90	9.29	0.86	0.99	0.94	1.50	0.73
q_t	1.14	0.80	1.76	0.40	0.63	0.98	0.58	0.97
$corr(l_{1t}n_t, \frac{y_t}{l_{1t}n_t})$	0.28		-0.48		0.29		-0.28	
$corr(l_{1t}n_t, w_t)$	0.37		-0.33		0.28		-0.33	
$corr(q_t, c_t)$	0.73		0.31		0.83		0.93	
$corr(q_t, j_t)$	0.79		0.20		0.98		0.98	

Column (a): $\sigma(x)/\sigma(y)$, Column (b): $corr(x, y)$.

observed simulated standard deviation of vacancies in the first period, the change in the level of indebtedness also approximates the simulated moment during the second period to that observed (in fact, the observed rate of growth in the observed volatility is 29 per cent of that simulated).

Regarding other labor market statistics, an interesting pattern arises in the observed cross correlations of total hours with labor productivity and wages. These correlations have drawn some attention recently given the difficulty of accounting for the fact that they are non significantly different from zero for the whole sample 1964:1-2008:4.[11] Our sample decomposition shows that these correlations do actually experience a striking variation from positive to negative across periods, a pattern that is very well captured by our model conditioned on the change in financial market parameters. While it is not remarkable that technology shocks generate positive comovement between hours and productivity (or wages), as in the *LI* scenario, it is more encouraging that the model accounts for the opposite sign as in the *HI* economy. The sharp fall in hours worked that occurs in highly leveraged economies is not offset by the increase in the numbers of employed workers. As a result, total hours fall in the short run inducing a negative correlation with rising volatility.

Turning to the financial side of our economy, the model accounts fairly well for the degree of housing price volatility (explaining 55%), as well as the correlation among

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[11]   This null correlation is the main object of study in Cheron and Langot (2004) and Boscá et al (2009).

housing prices, consumption and investment; among these results the positive and strong comovement between housing prices and investment deserves a more detailed scrutiny. In a recent paper, Liu, Wang and Zha (2009) find that a productivity shock and credit frictions are not enough to deliver such correlation. The search and matching frictions is the key channel here. Even in the unconstrained household version of the model (column 1 of figure 2), a positive realization of the technology shock causes a simultaneous increase in both variables. As houses are in fixed supply, the increase in demand by all consumers drives its relative price up, as compared with the rest of consumer goods. The fall in real interest rates raises the supply of labor and the number of hours worked, which in turn make vacancy posting much more attractive thus increasing matching activity, the marginal product of capital and investment.

A closer look at the results in table 4 reveals, however, that the model is not so successful in explaining the time pattern of some of these statistics. As the data show, the sharp fall observed in the correlations of total hours with both productivity and wages was driven by labor productivity and wages becoming acyclical in the second period, while the correlation of total hours with output remained unchanged. This is something that our model does not capture well. Instead we obtain that the first correlations indeed weaken (but only slightly so), whereas total hours become almost acyclical, which is not in the data.

On the financial side, the increase in housing price volatility from the first to the second period is not captured by the model. In a more leveraged economy, the expansionary effects of the shock on permanent income are more quickly transmitted into higher consumption with the corresponding fall in marginal propensity to consume, hours and real wages. This mutes the response of employment, output, housing demand and, hence, of q_t. Also, neither the observed reduction in the comovement of housing prices with output, nor the fall in the correlation of q_t with consumption and investment are captured in the *HI* version of the model (column 4, table 4).

There are several avenues that could be pursued to overcome this model's shortcomings. First we limit the fast response of housing purchases by introducing non-zero adjustment costs in housing investment ($\phi_h = 0.06$). This modification changes the results, accommodating some, though not all, of the model's predictions to empirical regularities. As shown in table A2 in the Appendix, columns (1) and (2), the observed fall in $corr(l_{1t}n_t, \frac{y_t}{l_{1t}n_t})$ and $corr(l_{1t}n_t, w_t)$ across periods is still present. Now, however, the model predicts that total hours maintain a highly positive correlation with output throughout the sample period and that the procyclicality of productivity and wages is significantly reduced across periods. The presence of adjustment costs in housing introduces an additional cost which despite increasing their effective price adds nothing to their value as

collateral. Thus, in a highly leveraged economy in which borrowers have a large stock of dwellings, the relative weight of these adjustment costs is larger and the consumption reaction to the technology shock smaller. The marginal utility of consumption falls less and so the negative reaction of hours worked is also smaller. Thus, total hours increase and maintain the positive correlation with total output (0.40 vs 0.45). This stronger increase in total hours also explains why the reaction of labor productivity is much smaller significantly reducing its procyclicality in the *HI* economy.

We do not pursue this line further though, as this modification does not correct the predictions on the financial side and, most importantly, does not capture the great moderation as the volatility of output remains almost unchanged across periods.

An alternative approach is summarized in columns (3) and (4) of table A2. In this case we assume that the stochastic structure of the two economies (*LI* and *HI*) is different. In particular we assume that over and above the technology shock, the economy is hit, in the second subsample only, by a shock to preferences representing the worldwide reduction in the real interest rate that has taken place over the last twenty years or so (Borio, 2008). This demand shock easily explains the substantial weakening of the procyclicality of productivity (and wages), while maintaining that of total hours. Thus again, the time pattern of the cyclical behavior of labor market variables ($corr(l_{1t}n_t, y_t)$, $corr(\frac{y_t}{l_{1t}n_t}, y_t)$, $corr(l_{1t}n_t, \frac{y_t}{l_{1t}n_t})$, etc.) is well accounted for and now consistently.

Although this approach also explains the moderation of macroeconomic aggregates, we chose not to pursue this line further. Changing the stochastic structure of the model across periods blurs the role of the theoretical structure in accounting for the empirical evidence. Nevertheless, these results are very informative of the difficulty involved in reproducing observed facts without taking into account a major change in the structure of shocks that have driven macroeconomic fluctuations over the entire period.

5.   Shock to housing preferences

The literature on the macroeconomic effects of housing has paid attention to an additional source of fluctuations without which it is difficult to understand some of the correlations discussed above: shocks to house prices. Next we consider a positive shock to the marginal rate of substitution ϕ_x between housing and consumption, common to both impatient and patient households. Because this shock is common to both impatient and patient households it can proxy for changes in, for instance, tax advantages for housing investment or an increase in demand fed by optimistic household expectations (see Iacoviello, 2005). The parameter ϕ_x is allowed to change over time according to the following model,

$$\ln \phi_{xt} = (1 - \rho_{\phi_x}) \ln \phi_x + \rho_{\phi_x} \ln \phi_{xt-1} + \xi_t$$

where ξ_t is an independent normally distributed variable with zero mean and standard deviation σ_{ϕ_x}. We calibrate σ_{ϕ_x} such that when both shocks, productivity and housing prices happen together, we replicate the observed relative volatility of housing prices during the first period with the *LI* model, whereas ρ_{ϕ_x} is set to 0.85, the estimated value of Iacoviello (2005).

Let us focus first on the pure shock to house prices. Figure 3 shows the simulated impulse-response functions to this shock for aggregate consumption, which increases housing prices on impact by roughly 1 per cent in the two borrowing regimes, as well as for the reference economy with no borrowers. According to our simulations, the impact elasticity of consumption to housing prices varies between a negative value of -0.02 for a low indebtedness regime and 0.06 for a high indebtedness regime. These values are fairly similar to other estimations in the literature. For instance, Ludwig and Slok (2004) estimate (significant) elasticities of consumption to housing prices in the range of -0.054 and -0.028 for the sample period 1960-1984 and between 0.015 and 0.040 for the 1985-2000 period. Using a BVAR model, Liu et al (2009) estimate the impact elasticity of aggregate consumption to house prices is positive and around 0.03 (Liu et al, figure 7).[12] Iacoviello (2005) also finds that a high loan-to-value ratio is required in order to obtain positive impact elasticity, although he recognizes that the simulated point elasticity of 0.2 he obtains in the impulse-response functions is higher than those estimated in the literature.[13]

The model also captures the response of investment to housing prices fairly well, a finding that has deserved some attention in the literature.[14] Liu, Wang and Zha (2009) report a positive empirical value of this elasticity that ranges approximately from 0.2 to 0.8, depending on the nature of the shocks considered in their estimated BVAR. The interplay among borrowers' consumption, hours and vacancy posting that occurs in our model makes this elasticity weaken as the leverage ratio increases. The impact elasticity becomes negative in the *HI* economy, which is compatible with low but positive elasticity, as the one present in the data, for some degree of indebtedness between the two considered.

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[12] Aoki, Proudman and Vlieghe (2004) also report a similar pattern of response to a monetary shock. The elasticity of consumptions with respects to the price of houses increases with financial developments in the mortgage market sector in the UK.

[13] This discrepancy can also be explained in our model by the presence of habits. When the habit parameter is set to zero we obtain more pronounced impact effect of the housing prices shock on consumption (elasticities -0.2 and 0.16 respectively) in line with those estimated by Iacoviello (2005, Figure 3).

[14] This is related to the finding by Aoki, Proudman and Vlieghe (2004) who report a positive response of housing investment to a monetary shock that, nevertheless, falls as the reforms in the mortgage market permit a higher level of indebtedness.
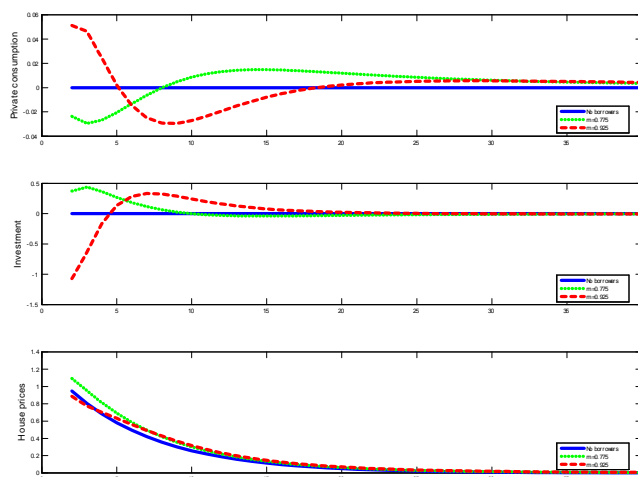
Figure 3: *Model responses to a housing preference shock*

Results in table 5 contain both shocks: technology and house prices. Importantly, as in the case of the productivity shock, we fix the same value for σ_{ϕ_x} and ρ_{ϕ_x} across the two calibrated models, so that changes in the simulated moments cannot be attributed to the characteristics of the shocks, but to the change in the degree of indebtedness of the economy. As table 5 makes clear, the model with two sources of fluctuations is now capable of reproducing the changing pattern of the correlation between housing prices and investment that goes from very high in the first subsample to very small in the recent period. In fact, the decrease in the cross correlation of housing prices with output is also matched by our simulated moments. However, as can be appreciated, the model with two shocks fails to capture the observed increase in the relative volatility of housing prices across periods. Given that this is an important fact characterizing recent developments in some advanced economies, we believe it is worth investigating the reasons behind this result further. In order to do so, we have performed a sensitivity analysis (figure 4) on the response of the simulated relative volatility of housing prices to changes in both the loan-to-value ratio and the share of borrowers in the economy. As the graph shows, for any given share of borrowers, increasing the leverage ratio causes always a drop in the relative standard deviation. However, augmenting the share of impatient households at the same time produces ambiguous responses given the clear non-linearities visible in the plot. In order to generate a rise in observed volatility when m^b increases, it should be necessary

TABLE 5 - CYCLICAL PROPERTIES

	US		US		LI model		HI model	
Period	64-82		83-08		$m = 0.775$		$m = 0.925$	
$\sigma(y)$	2.02		1.17		2.03		1.90	
ρ_y	0.91		0.91		0.78		0.83	
Variable x	(1)	(2)	(1)	(2)	(a)	(b)	(a)	(b)
c_t	0.52	0.95	0.51	0.90	0.59	0.89	0.64	0.94
j_t	2.22	0.90	2.83	0.92	2.64	0.95	2.33	0.95
$l_{1t}n_t$	1.05	0.83	1.27	0.81	0.26	0.47	0.55	0.26
$\frac{y_t}{l_{1t}n_t}$	0.66	0.66	0.69	-0.01	0.91	0.97	1.01	0.85
w_t	0.41	0.68	0.88	0.04	0.92	0.96	1.07	0.81
v_t	8.07	0.90	9.29	0.86	1.14	0.84	1.65	0.66
q_t	1.14	0.80	1.76	0.40	1.14	0.67	1.01	0.45
$corr(l_{1t}n_t, \frac{y_t}{l_{1t}n_t})$	0.28		-0.48		0.23		-0.29	
$corr(l_{1t}n_t, w_t)$	0.37		-0.33		0.21		-0.35	
$corr(q_t, c_t)$	0.73		0.31		0.40		0.56	
$corr(q_t, j_t)$	0.79		0.20		0.67		0.30	

Column (1): $\sigma(x)/\sigma(y)$, Column (2): $corr(x,y)$.

to also increase λ^b, starting from low values of this share. Interestingly, the preferences shock has a negligible effect on the computed moments of the other labor market variables included in the tables. A decomposition of the variance confirms this finding, given that this shock on housing prices has very low explanatory power with respect to labor market aggregates, while it represents more than 85% of the explanation of the variance of housing prices. Thus, this version of the model with a richer stochastic structure improves the fit of the model as regards financial variables and does not significantly alter the pattern of labor market variables.

6.   Conclusions

In this paper we have considered a standard DSGE model with flexible prices, augmented with two important real frictions aimed at accounting for the dynamics of macroeconomic aggregates. The model contributes to explaining the substantial reduction in the volatility of output that has taken place since the early eighties. The presence of constrained consumers intertwines with the process of vacancy creation to deliver a powerful transmission mechanism of technology and housing shocks. The great moderation in output is (partially) explained on the basis of innovations in the mortgage markets that relax the collateral constraints. Following a positive technology shock, households resort to a combination of longer working hours and heavier borrowing against future income. Impatient consumers compensate a tight borrowing constraint with a substantial increase in their labor supply that leads to a strong output increase today. Higher loan-to-value ra-
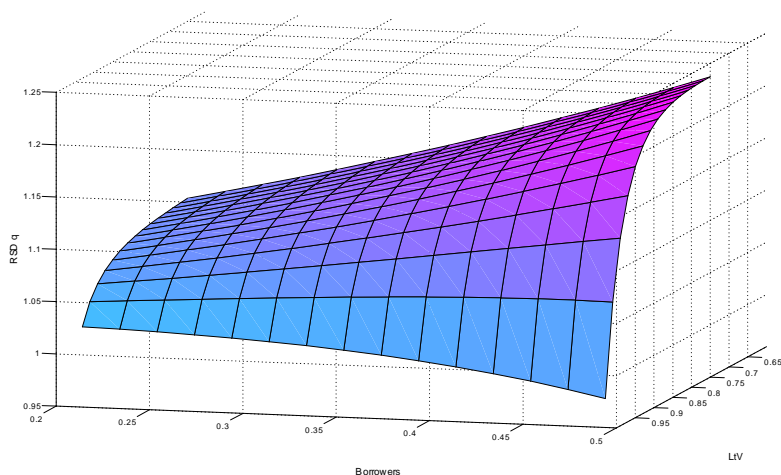
Figure 4: *Relative standard deviation of house prices depending on m^b and λ^b*

tios dampen the response of the labor supply and contribute to moderating the impact response of output to technology shocks.

However, the blend of search and matching frictions in the labor market with collateral constraint and constrained consumers in the mortgage market, renders the model capable of accounting for a number of less well known features, such as those related to the changing pattern of some labor market flows and financial variables associated to the great moderation. Thus, with technology shocks as the only source of fluctuations, the model explains the following facts: the great moderation and the time pattern of the volatilities of hours, productivity, wages and vacancies, the correlation of consumption and investment with output and those between productivity and wages with total hours.

When the sources of stochastic fluctuations include a housing price shock, the model also predicts the fall (from the *LI* to the *HI* economy) of the correlation of housing prices with output, as well as the correlation of housing prices with consumption and investment and the time evolution of the latter.

Finally there are some empirical facts that our model cannot explain. These include the time pattern of the correlations between hours, productivity and wages with output, that of the volatility of investment and the correlation between housing prices and consumption. We suggest some avenues to overcome these limitations that, while empirically satisfactory, do not seem sufficiently appealing on theoretical grounds. Explaining these puzzles is the next item on the research agenda.

Appendix   1:

TABLE A1 - DATA

Variable	Data	Source
Consumption	Real consumption of non durable goods +	FRED
	Real consumption of services	FRED
Investment	Real private nonresidential fixed investment +	FRED
	Real consumption of durable goods	FRED
Total Hours	Nonfarm Business Sector: Hours of All Persons	FRED
Labor productivity	Nonfarm Business Sector: Output Per Hour of All Persons	FRED
Wages	Nonfarm Business Sector: Real Compensation Per Hour	FRED
Vacancies	Help wanted index	Conference Board
Housing price	Real Constant Quality House Price Index (New Houses Sold)	US Census and FRED

TABLE A2 - LABOR MARKET CYCLICAL PROPERTIES

	Technology shock with adjustment cost in housing[1]				Technology shock with a demand shock[2]			
	LI model		HI model		LI model		HI model	
	(1)		(2)		(3)		(4)	
	$m = 0.775$		$m = 0.925$		$m = 0.775$		$m = 0.925$	
$\sigma(y)$	2.00		2.03		2.02		1.56	
ρ_y	0.82		0.85		0.78		0.88	
Variable x	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
$l_{1t}n_t$	0.29	0.40	0.85	0.45	0.23	0.49	1.20	0.79
$\frac{y_t}{l_{1t}n_t}$	0.92	0.96	0.98	0.63	0.91	0.98	0.74	0.08
w_t	0.94	0.95	1.03	0.58	0.92	0.97	0.80	0.10
$corr(l_{1t}n_t, \frac{y_t}{l_{1t}n_t})$	0.12		-0.41		0.29		-0.55	
$corr(l_{1t}n_t, w_t)$	0.10		-0.47		0.28		-0.52	

Column (a): $\sigma(x)/\sigma(y)$, Column (b): $corr(x, y)$.

Notes:

(1) Parameter $\phi_h = 0.06$.

(2) The technology shock applies to both models and has the same characteristics as in Table 4 when using with LI model. The demand shock only applies to HI model, in addition to the technology shock. In order to exactly replicate the great moderation in output, it is assumed that both shocks have the same high persistence parameter (0.95), whereas the corresponding standard deviations have been modified such that the demand shock contributes to explaining 65% of the variance of output.

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