BANCA D'ITALIA

EUROSISTEMA

Temi di discussione

(Working papers)

Housing market spillovers: Evidence from an estimated DSGE model

by Matteo Iacoviello and Stefano Neri

January 2008

Number 659

HOUSING MARKET SPILLOVERS: EVIDENCE FROM AN ESTIMATED DSGE MODEL

by Matteo Iacoviello* and Stefano Neri†

Abstract

The ability of a two-sector model to quantify the contribution of the housing market to business fluctuations is investigated using US data and Bayesian methods. The estimated model, which contains nominal and real rigidities and collateral constraints, displays the following features: first, a large fraction of the upward trend in real housing prices over the last 40 years can be accounted for by slow technological progress in the housing sector; second, residential investment and housing prices are very sensitive to monetary policy and housing demand shocks; third, the wealth effects from housing on consumption are positive and significant, and have become more important over time. The structural nature of the model allows us to identify and quantify the sources of fluctuations in house prices and residential investment and to measure the contribution of housing booms and busts to business cycles.

JEL Classification: E32, E44, E47, R21, R31.

Keywords: house prices, collateral constraints, Bayesian methods, two-sector models.

---

* Boston College.

† Bank of Italy, Economics and International Relations.

Contents

1 Introduction[1]

Two of the defining characteristics of the U.S. economy at the turn of the 21st century were fast growth in housing prices and strong residential investment. This has led many to raise the specter that imbalances are being created in the housing sector that will produce macroeconomic strains once they are reversed, causing spillover effects not only in the housing market itself but also in other sectors of the economy. To understand whether these concerns are justified, it is crucial to answer two questions: (1) What is the nature of the shocks hitting the housing market? (2) How big are the spillovers from the housing market to the wider economy?

In this paper, we address these questions using a quantitative model. We develop and estimate, using a Bayesian likelihood approach, a dynamic stochastic general equilibrium model of the U.S. economy that explicitly models the price and the quantity side of the housing market. We do so with two goals in mind. First, we want to understand the extent to which a model with nominal and real rigidities and credit frictions can explain the dynamics of residential investment and housing prices that are observed in the data. Second, to the extent that the model can reproduce some key features of the data, we want to measure the spillovers from the housing market to the wider economy.

Our starting point is a variant of many dynamic equilibrium models with nominal and real frictions that have become popular in monetary policy analysis (see Christiano, Eichenbaum and Evans, 2005 and Smets and Wouters, 2007). It features sticky nominal prices and wages and indexation, habit formation in consumption, capital adjustment costs and variable capital utilization. We add two main features to this framework. On the supply side, the model is characterized by heterogeneity across sectors, as in Davis and Heathcote (2005): the non-housing sector produces consumption and business investment using capital and labor; and the housing sector produces residential investment using capital, labor and land. On the demand side, both housing and consumption enter households' utility, and housing can be used as collateral for loans, as in Iacoviello (2005). Since housing and

[1] We thank Richard Arnott, Peter Ireland, Michel Juillard, Lisa Lynch, Caterina Mendicino, Fabio Schiantarelli, Livio Stracca, Karl Walentin and seminar participants at the Bank of Canada, Bank of Italy, Bank of Sweden, Boston College, CEPR, European Central Bank, HEC Montreal and UPF for comments and suggestions. A technical appendix containing additional results, a computational appendix and replication files are available at the following webpage: `http://www2.bc.edu/~iacoviel/research.htm`

consumption goods are produced using different technologies, the model generates heterogeneous dynamics both in residential vis-à-vis business investment and in the price of housing. At the same time, fluctuations in house prices affect the borrowing capacity of a fraction of households, on the one hand, and the relative profitability of producing new homes, on the other: these mechanisms generate feedback effects for the expenditure of households and firms.

1.1 Findings

We estimate the model on quarterly data over the period 1965:I-2006:IV. The dynamics of the model are driven by nine orthogonal structural shocks. In addition to productivity shocks (non-housing technology shocks, housing technology shocks and investment specific shocks), the model includes two monetary shocks (a transitory "monetary policy" shock, and a persistent inflation objective shock), a price-markup shock, a discount factor shock and a labor supply shock. The remaining disturbance is a housing preference shock, an exogenous shift in the marginal rate of substitution between housing and non-housing goods that (unlike the housing technology shock) generates positive comovement of housing prices and housing investment. Our estimated model accounts well for several features of the data. At cyclical frequencies, it matches the observation that both housing prices and housing investment are strongly procyclical, volatile, and very sensitive to monetary shocks. Over longer horizons, the model accounts extremely well for the rise in real house prices over the last four decades, and views such increase as the consequence of slower technological progress in the housing sector, and the presence of land (a fixed factor) in the production function for new homes.

What drives the housing market? In terms of the first question outlined at the start of our introduction, we find that three main factors drive the housing market. Housing demand shocks and housing technology shocks account for roughly one quarter each of the cyclical volatility of housing investment and housing prices. Monetary shocks account for between 15 and 20 percent. Over the sample period we examine, we find that, housing demand shocks aside, the housing price boom of the 1970s was mostly the consequence of faster technological progress in the non-housing sector. Instead, the boom in housing prices and residential investment at the turn of the 21st century (and its reversal in 2005 and 2006) was driven, in non-negligible part, by monetary factors.

How big are the spillovers from the housing market? To answer our second question, we must first characterize the nature of the spillovers. From an accounting standpoint, fluctuations in housing investment directly affect GDP, holding everything else constant. We define the spillovers by considering what our estimated nominal, real and financial frictions add to this mechanism. We find that wage and price rigidities more than double the response of GDP to shifts in housing preferences, by increasing the sensitivity of housing investment itself to changes in housing demand. Over and above this effect, collateral effects on household borrowing amplify the response of non-housing consumption to given changes in, say, housing demand and interest rates, thus altering the propagation mechanism: we quantitatively document these effects in the last part of the paper, by focusing on how fluctuations in the housing market have affected consumption dynamics. In doing so, we estimate our model over two subsamples, a period before financial liberalization in the mortgage market (1965-1982), and a period after mortgage market liberalization (1989-2006): using the subsample estimates, we conclude that fluctuations in the housing market have contributed around 2 percent of the total variance of consumption growth in the early period, and around 15 percent in the late period. Hence, the average spillovers from the housing market to the rest of the economy are non-negligible and, if anything, they have become more important in the last two decades.

1.2 Related approaches

Our analysis combines four main elements: (1) a multi-sector structure with housing and non-housing goods; (2) nominal rigidities; (3) financing frictions in the household sector; (4) a rich set of shocks, which are essential to take the model to the data.

Greenwood and Hercowitz (1991), Benhabib, Rogerson and Wright (1991), Davis and Heathcote (2005) and Fisher (2006) deal with (1), but they only consider technology shocks as sources of business fluctuations. Davis and Heathcote (2005), in particular, use a multisector model with intermediate goods production in which construction, manufacturing and services are combined, in different proportions, to produce consumption, business investment, and residential structures. Residential structures are then combined with land to produce new homes. On the supply side, we follow their lead, so that our setup shares some features with theirs. However, since our goal is to take the model to the data and to assess the role of monetary and real factors in affecting housing market dynamics, we allow additional (real and nominal) frictions, and a larger set of shocks.

Edge, Kiley and Laforte (2005) integrate (1), (2) and (4). They distinguish between two production sectors, which (as in our paper) differ in their long-run growth rates of technological progress. They also distinguish between several categories of household expenditure, namely consumption of nondurables and services, investment in durables and investment in residences. Bouakez, Cardia and Ruge-Murcia (2005) estimate a model with heterogenous production sectors that differ in price stickiness, capital adjustment costs and production technology, and use output from each other as material and investment inputs. None of these papers deals explicitly with housing prices and housing investment, which are, instead, our focus of analysis.[2]

Several papers have studied housing in models with incomplete markets and financing frictions by combining elements of (1) and (3). Most of these papers abstract from aggregate shocks:[3] Gervais (2002), Peterson (2004) and Diaz and Luengo-Prado (2005) look at housing investment in models in which housing is illiquid and can be used as collateral but do not consider house prices. Lustig and Van Nieuwerburgh (2005) study the asset pricing implications of these models.[4]

Section 2 lays out the model. Section 3 presents data and parameter estimates. Section 4 presents the properties of the estimated model. In Section 5 we use the estimated model to discuss a number of issues related to the role of the housing market in the business cycle. Section 6 concludes.

---

[2] Aoki, Proudman and Vlieghe (2004) integrate features of (1), (2) and (3) in a calibrated model with financing frictions for household. Campbell and Hercowitz (2005) study the role of financial liberalization in explaining changes in aggregate volatility in an RBC-style model with durables, aggregate shocks and heterogenous agents.

[3] Campbell and Hercowitz (2005) study the role of mortgage market liberalization in explaining changes in aggregate volatility in a one-sector growth model with housing, aggregate shocks and heterogenous agents.

[4] Topel and Rosen (1988) build a neoclassical model of residential investment. In their setup, housing demand is infinitely elastic at the market interest rate, and the housing supply curve is upward sloping, with different short and long run price elasticities.

2 The Model

The model features sectoral heterogeneity, heterogeneity in households' discount factors and collateral constraints tied to a fraction of housing values. On the demand side, there are two types of households, patient (lenders) and impatient (borrowers). Patient households work, consume and accumulate housing:[5] they own the productive capital of the economy, supply funds to firms on the one hand, and to impatient households on the other. Impatient households work, consume and accumulate housing: because of their high impatience, they only accumulate the required net worth to finance the down payment on their home and are up against their housing collateral constraint in equilibrium.

On the supply side, there are two sectors. The consumption sector combines capital and labor to produce consumption and business capital for both sectors. The housing sector produces new homes, combining business capital with labor and land. Each household works in both sectors. We allow for Calvo-style price rigidities in the non-housing sector and wage rigidities in both sectors. The price of housing is, instead, assumed to be fully flexible. In addition, we allow for the share of impatient households to take on any value on the unit interval: when this share approaches zero, our model boils down to a representative agent model without financing frictions.

2.1 Households

There is a continuum of measure 1 of agents in each of the two groups. The economic size of impatient households is measured by their wage share which, as we will see, is assumed to be constant through a unit elasticity of substitution production function. Within each group, a representative household maximizes the expected present value of lifetime utility as given by:

$$E_0 \sum_{t=0}^{\infty} (\beta G_C)^t \, \mathsf{z}_t \left(\Gamma_c \log \left(c_t - \varepsilon c_{t-1} \right) + \mathsf{j}_t \log h_t - \frac{\tau_t}{1+\eta} \left(n_{c,t}^{1+\xi} + n_{h,t}^{1+\xi} \right)^{\frac{1+\eta}{1+\xi}} \right) \quad (1)$$

$$E_0 \sum_{t=0}^{\infty} (\beta' G_C)^t \, \mathsf{z}_t \left(\Gamma'_c \log \left(c'_t - \varepsilon' c'_{t-1} \right) + \mathsf{j}_t \log h'_t - \frac{\tau_t}{1+\eta'} \left(\left(n'_{c,t} \right)^{1+\xi'} + \left(n'_{h,t} \right)^{1+\xi'} \right)^{\frac{1+\eta'}{1+\xi'}} \right) \quad (2)$$

[5] We rule out a rental market for housing. In the United States, homeownership rates have been around 65 percent in the postwar period, so that ruling out a rental market appears to us, as a first pass, a good approximation. Allowing for renters in our model would be an interesting extension, but is beyond the scope of this paper.

where variables without a prime refer to the patient households and those with a prime to the impatient ones; c, h, n_c, n_h represent consumption, housing, hours in the consumption sector and hours in the housing sector.[6] The discount factors are β and β' ($\beta' < \beta$), E is the expectation operator and G_C is the gross growth rate of consumption along the balanced growth path. Random variations in z_t, j_t and τ_t capture respectively shocks to intertemporal preferences, to the demand for housing and to the supply of labor. These shocks follow stationary autoregressive processes of order one:

$$\begin{aligned}
\ln \mathsf{z}_t &= \rho_z \ln \mathsf{z}_{t-1} + u_{z,t}, u_{z,t} \sim N(0, \sigma_z) \\
\ln \mathsf{j}_t &= (1-\rho_j) \ln j + \rho_j \ln \mathsf{j}_{t-1} + u_{j,t}, u_{j,t} \sim N(0, \sigma_j) \\
\ln \tau_t &= \rho_\tau \ln \tau_{t-1} + u_{\tau,t}, u_{\tau,t} \sim N(0, \sigma_\tau).
\end{aligned}$$

The parameter ε measures the degree of habit formation in consumption[7] and the scaling factors $\Gamma_c = \frac{G_C-\varepsilon}{G_C-\beta\varepsilon G_C}$ and $\Gamma'_c = \frac{G_C-\varepsilon'}{G_C-\beta'\varepsilon' G_C}$ are simple normalizations that ensure that the marginal utilities of consumption are equal to $1/c$ and $1/c'$ in the nonstochastic steady state.

The specification of preferences for consumption and housing reconciles the trend in the relative housing prices and the stable nominal share of expenditures on household investment goods, as in Davis and Heathcote (2005) and Fisher (2006). The specification of the disutility of labor ($\xi, \eta \geq 0$) follows Horvath (2000) and implies that households have a preference for differentiating labor across the two sectors. If ξ and ξ' equal zero, hours worked across the two sectors are perfect substitutes, both sectors pay the same wage in equilibrium, η measures the inverse Frisch elasticity of labor supply, and labor is perfectly mobile across sectors. Positive values of ξ and ξ' allow capturing some degree of sector specificity and imply that relative hours respond less to sectoral wage differentials.[8] Several two-sector models display the so-called comovement puzzle,[9] in that they predict that employment across sectors tends to be negatively correlated, something that seems

[6]We assume a cashless limit in the sense of Woodford (2003), so that the transaction role of money is negligible, but the price level is still meaningful as a rate of exchange between interest bearing private debt and real goods.

[7]We assume habits only in non-durable consumption. We have also experimented with habits in housing, and found no substantial differences in our results. Using Spanish panel data, Carrasco, Labeaga and López-Salido (2005) find high habits only at the level of food consumption, and virtually no habits for expenditure in services.

[8]It is easy to show that, so long as ξ is greater than η, hours are complements, in that hours in one sector will increase following an increase in the wage in the other sector, keeping everything else constant.

[9]See for instance the discussion in Hornstein and Praschnik (1997).

at odds with the data: complementarity across hours worked slows down reallocation of labor across sectors.

We use a decentralization of our model with the following features. Patient households save by accumulating capital and houses and make loans to impatient households. They rent capital to firms, choose the capital utilization rate and sell the remaining undepreciated capital; in addition, there is joint production of consumption and business investment goods. Patient households maximize their lifetime utility subject to the budget constraint (using consumption as the numeraire):

$$c_t + \frac{k_{c,t}}{\mathsf{A}_{k,t}} + k_{h,t} + k_{b,t} + q_t h_t + p_{l,t} l_t - b_t = \frac{w_{c,t}}{X_{wc,t}} n_{c,t} + \frac{w_{h,t}}{X_{wh,t}} n_{h,t}$$
$$+ \left(R_{c,t} z_{c,t} + \frac{1-\delta_{kc}}{\mathsf{A}_{k,t}} \right) k_{c,t-1} + \left(R_{h,t} z_{h,t} + 1 - \delta_{kh} \right) k_{h,t-1} + p_{b,t} k_{b,t} - \frac{R_{t-1} b_{t-1}}{\pi_t}$$
$$+ \left(p_{l,t} + R_{l,t} \right) l_{t-1} + q_t \left(1 - \delta \right) h_{t-1} + Div_t - \phi_t - \frac{a\left(z_{c,t}\right)}{\mathsf{A}_{k,t}} k_{c,t-1} - a\left(z_{h,t}\right) k_{h,t-1}. \quad (3)$$

Patient agents choose plans for consumption c_t, capital in the consumption sector $k_{c,t}$, capital $k_{h,t}$ and intermediate inputs $k_{b,t}$ (priced at $p_{b,t}$) in the housing sector, housing h_t (priced at q_t), land holdings l_t (priced at $p_{l,t}$), hours $n_{c,t}$ and $n_{h,t}$, capital utilization rates $z_{c,t}$ and $z_{h,t}$, and one-period borrowing b_t (loans if b_t is negative) to maximize their utility subject to the constraint above. The term $\mathsf{A}_{k,t}$ captures investment-specific technological shocks, thus representing the relative marginal cost (in terms of consumption) of producing capital used in the non-housing sector.[10] Loans are set in nominal terms and yield a gross, riskless nominal return of R_t. Real wages in each sector are denoted by $w_{c,t}$ and $w_{h,t}$, real rental rates by $R_{c,t}$ and $R_{h,t}$, depreciation rates by δ_{kc} and δ_{kh}. The terms $X_{wc,t}$ and $X_{wh,t}$ denote the markup (due to monopolistic competition in the labor market) between the wage paid by the wholesale firm and the wage paid to the households, which accrues to the labor unions (we discuss below the details of nominal rigidities in the labor market). Finally, $\pi_t = P_t/P_{t-1}$ is the gross money inflation rate in the consumption sector, Div_t are lump-sum profits from final good firms and from labor unions, ϕ_t denotes convex adjustment costs for capital, z is the capital utilization rate that transforms physical capital k into effective capital zk and $a\left(\cdot\right)$ is the convex cost of setting the capital utilization rate to z. We discuss the properties of ϕ_t, $a\left(\cdot\right)$ and Div_t

[10] We assume that investment-specific technological change applies only to the capital used in the production of consumption goods, k_c, since investment-specific technological progress mostly refers to information technology (IT) and construction is a non-IT-intensive industry.

in Appendix B.[11]

Impatient households maximize utility subject to two constraints. Their flow of wealth constraint is analogous to that of the patient agents with the exception that they do not accumulate capital and do not own finished good firms nor land (their dividends come only from labor unions). In addition, the maximum amount they can borrow, b'_t, is given by the expected present value of their home, times the loan-to-value (LTV) ratio m:

$$c'_t + q_t h'_t - b'_t = \frac{w'_{c,t}}{X'_{wc,t}} n'_{c,t} + \frac{w'_{h,t}}{X'_{wh,t}} n'_{h,t} + q_t \left(1 - \delta_h\right) h'_{t-1} - \frac{R_{t-1}}{\pi_t} b'_{t-1} + Div'_t \tag{4}$$

$$b'_t \leq m E_t \left(q_{t+1} h'_t \pi_{t+1} / R_t\right). \tag{5}$$

The assumption $\beta' < \beta$ implies that for small shocks the borrowing constraint (5) will hold with equality in a neighborhood of the steady state. In other words, as long as β' is lower than β, impatient agents decumulate wealth quickly enough to some lower bound, and, for small fluctuations around the steady state, the lower bound is always binding.[12] It then follows that patient agents own and accumulate all the capital in a neighborhood of the steady state, whereas impatient agents' only form of wealth will be their home, and they will borrow the maximum possible amount against it. Along

[11] We do not allow for adjustment costs for housing on the demand side. Housing investment is, obviously, lumpy at the individual level and home purchases are subject to readily identifiable transaction costs, which do not seem convex in nature: in most cases, in fact, these costs involve a fixed fee and a cost that is proportional to the market value of the house. While these features are important at the individual level, it is hard to say whether microeconomic lumpiness has important implications for aggregate residential investment. Our hypothesis is that such lumpiness is not crucial and is based on two observations: first, Thomas (2002) finds that large and infrequent microeconomic adjustment at the plant level has negligible implications for the behavior of aggregate investment; second, a sizeable fraction (25 percent in 2006) of residential investment in the National Income and Product Accounts (NIPA) consists of home improvements where the lumpiness argument is less likely to apply.

[12] The extent to which the borrowing constraint holds with strict equality in equilibrium mostly depends on the degree of impatience, as measured by the difference between the discount factors of the two groups, and on the degree of uncertainty that economic agents face, as measured by the variance of the shocks hitting the economy. We have developed algorithms to solve simplified, non-linear versions of two agent models with housing and capital accumulation in presence of aggregate risk that take into account the possibility that the borrowing constraint might not be binding in all states of the world. For discount rate differentials of the magnitude that we assume here, the degree of aggregate uncertainty that is needed to fit the data implies that impatient agents are always arbitrarily close to the borrowing constraint (details are available from the authors upon request). For this reason, we solve the model linearizing the equilibrium conditions of the model around a steady state in which the borrowing constraint is assumed to be binding.

the equilibrium path, fluctuations in housing values will, according to (5), affect the borrowing and the spending capacity of constrained households. The effect will be larger the larger m, since m measures, ceteris paribus, the liquidity of housing wealth.

The first-order conditions for the household problem are in Appendix B.

2.2 Wholesale Goods Firms and Technology

To introduce price rigidity in the consumption sector, we differentiate between competitive flexible price/wholesale firms that produce wholesale consumption goods and housing using two technologies, and a final good firm (described below) that operates in the consumption sector under monopolistic competition. Wholesale firms hire labor and capital services and purchase intermediate goods to produce wholesale goods Y_t and new houses IH_t. They solve the following problem:[13]

$$\max \frac{Y_t}{X_t} + q_t IH_t - \left(\sum_{i=c,h} w_{i,t} n_{i,t} + \sum_{i=c,h} w'_{i,t} n'_{i,t} + R_{c,t} z_{c,t} k_{c,t-1} + R_{h,t} z_{h,t} k_{h,t-1} + R_{l,t} l_{t-1} + p_{b,t} k_{b,t} \right)$$

which, due to the constant-returns-to-scale assumption, delivers zero profits. The markup of final over wholesale goods is denoted with X_t. We assume that the wholesale goods (whose nominal price is P_t^w) are transformed into final goods (priced at $P_t \equiv X_t P_t^w$) by final goods firms.

The two production technologies are:

$$Y_t = \left(\mathsf{A}_{c,t} \left(n_{c,t}^{\alpha} n_{c,t}'^{1-\alpha} \right) \right)^{1-\mu_c} \left(z_{c,t} k_{c,t-1} \right)^{\mu_c} \quad (6)$$

$$IH_t = \left(\mathsf{A}_{h,t} \left(n_{h,t}^{\alpha} n_{h,t}'^{1-\alpha} \right) \right)^{1-\mu_h-\mu_b-\mu_l} \left(z_{h,t} k_{h,t-1} \right)^{\mu_h} k_{b,t}^{\mu_b} l_{t-1}^{\mu_l}. \quad (7)$$

In (6), the consumption sector uses labor and capital to produce the final output. In (7), the housing sector uses labor, capital, land l and the intermediate input k_b produced in the consumption sector. $\mathsf{A}_{c,t}$ is a measure of productivity in the non-housing sector whereas $\mathsf{A}_{h,t}$ is a measure of productivity in the housing sector. We model productivity as trend-stationary.[14] Along the equilibrium path, a rise in $\mathsf{A}_{c,t}$ relative to $\mathsf{A}_{h,t}$ will cause an increase in the price of housing relatively to consumption.

[13] The notation reflects the equilibrium conditions in the markets for n_c, n'_c, n_h, n'_h, k_c, k_h, k_b, l.

[14] Ireland (2001) estimates a prototypical business cycle model under several assumptions about the stochastic process for technology, and concludes that technology shocks are very persistent but still trend stationary. We have estimated a version of our model with unit-root technology shocks: the main results are robust across specifications (see the technical appendix for a comparison of the impulse responses of the two models).

As shown by (6) and (7), we let hours of the two households enter the two production functions in a Cobb-Douglas fashion. This assumption implies complementarity across the labor skills of the two groups and allows obtaining closed form solutions for the steady state of the model. With this formulation, the parameter α measures the labor income share of unconstrained households.[15]

The first order conditions for the firms' problem are standard and are in Appendix B.

2.3 Nominal Rigidities and Monetary Policy

We allow for Calvo-style nominal price rigidities in the consumption sector and for wage rigidities in both sectors. In doing so, we follow the large body of literature that has found that real rigidities alone cannot account for the persistent effects of monetary and other shocks (see for instance Christiano, Eichenbaum and Evans, 2005). However, we rule out price rigidities in the housing market: according to Barsky, House and Kimball (2007) there are several reasons why housing might have flexible prices. First, housing is relatively expensive on a per-unit basis; therefore, if menu costs have important fixed components, there is a large incentive to negotiate on the price of this good. Second, most homes are priced for the first time when they are sold.

Price Stickiness. We introduce sticky prices in the consumption sector by assuming monopolistic competition at the "retail" level and implicit costs of adjusting nominal prices following Calvo-style contracts.[16] Retailers buy wholesale goods Y_t from wholesale firms at the price P_t^w in a competitive market, differentiate the goods at no cost, and sell them at a markup $X_t = P_t/P_t^w$ over the marginal cost. The CES aggregates of these goods are converted back into homogeneous consumption and investment goods by households. In each period, a fraction $1 - \theta_\pi$ of retailers set prices optimally while a fraction θ_π cannot do so, and index prices to the previous period inflation rate with an

[15] We have experimented with an alternative setup in which hours of the groups are perfect substitutes in production. The results were similar to those reported here for the Cobb-Douglas case. The formulation in which hours are substitutes is perhaps more natural, but analytically less tractable: while it implies equal wages across agents, it also implies that hours worked by one group will affect total wage income received by the other group, thus creating a complex interplay between borrowing constraints and labor supply decisions of both groups.

[16] See, for instance, Bernanke, Gertler and Gilchrist (1999).

elasticity equal to ι_π. These assumptions deliver the following consumption-sector Phillips curve:

$$\log \pi_t - \iota_\pi \log \pi_{t-1} = \beta G_C \left(E_t \log \pi_{t+1} - \iota_\pi \log \pi_t \right) - \varepsilon_\pi \log \left(X_t / X \right) + \log u_{p,t} \tag{8}$$

where $\varepsilon_\pi = (1-\theta_\pi)(1-\beta G_C \theta_\pi)/\theta_\pi$. As in Smets and Wouters (2007), we allow for cost-push shocks that affect inflation independently from fluctuations in the real marginal cost. These shocks are assumed to be i.i.d. with zero mean and variance equal to σ_p^2.

Wage Stickiness. We model wage setting in a way that is analogous to the price setting. Patient and impatient households supply homogeneous labor services to unions. The unions differentiate labor services as in Smets and Wouters (2007), set wages subject to a Calvo scheme and offer labor services to wholesale labor packers who reassemble these services into the homogeneous labor composites n_c, n_h, n'_c, n'_h.[17] Wholesale firms hire labor from these packers. Under Calvo pricing with partial indexation to past inflation, the pricing rules set by the union imply four wage Phillips curves that are isomorphic to the price Phillips curve. These equations are in Appendix B.

Monetary Policy. To close the model, we assume that the central bank sets the interest rate R_t according to a Taylor rule that responds gradually to inflation and GDP growth:

$$R_t = R_{t-1}^{r_R} \pi_t^{(1-r_R)r_\pi} \left(\frac{GDP_t}{G_C GDP_{t-1}} \right)^{(1-r_R)r_Y} \overline{rr}^{1-r_R} \frac{u_{R,t}}{\mathsf{s}_t}. \tag{9}$$

where $\overline{rr}$ is the steady-state real interest rate (which we assume to be equal to $1/\beta$, the patient households discount rate), and GDP_t sums all the components of aggregate demand, expressed in units of consumption.[18] The term $u_{R,t}$ captures a zero-mean, i.i.d. monetary policy shock with

[17] We assume that there are four unions, two for each sector, each acting in the interest of either patient or impatient households. While the unions in each sector choose slightly different wage rates reflecting the different consumption profiles of the two household types, we assume that the probability of changing wages in each sector is common to both patient and impatient households.

[18] Our definition of GDP sums the growth rates of consumption, residential investment and business investment by their steady state nominal shares. That is, $GDP_t = C_t + IK_t + \overline{q} IH_t$, where $\overline{q}$ denotes real housing prices along the balanced growth path (following Davis and Heathcote (2005), our GDP definition uses steady-state house prices, so that short-run changes in real house prices do not affect GDP growth). We exclude imputed rents from definition of GDP. We do so because our model implies a tight mapping between house prices and rents at business cycle frequency. Including rents in model definition of GDP would be too close to including house prices themselves in the Taylor rule, and would create a mechanical link between house prices and consumption of housing services.

variance σ_R^2, while s_t is a stochastic process with high persistence introduced in order to implicitly model long-lasting deviations of inflation from its steady state level, for instance due to shifts in the central bank inflation target. That is:

$$\ln \mathsf{s}_t = \rho_s \ln \mathsf{s}_{t-1} + u_{s,t}, u_{s,t} \sim N(0, \sigma_s)$$

where $\rho_s > 0$ (see for instance Adolfson et al., 2007, who adopt a similar formulation).

2.4 Equilibrium

There are three markets in the model. The goods market produces consumption, business investment and intermediate inputs for the housing market. The housing market produces new homes, denoted by IH_t. In the loan market, patient and impatient agents trade one-period collateralized nominal loans. The three market clearing conditions are:

$$C_t + IK_{c,t}/\mathsf{A}_{k,t} + IK_{h,t} + k_{b,t} = Y_t - \phi_t \quad (10)$$

$$H_t - (1-\delta_h) H_{t-1} = IH_t \quad (11)$$

$$b_t + b_t' = 0 \quad (12)$$

where $C_t = c_t + c_t'$ is aggregate consumption, $H_t = h_t + h_t'$ is the aggregate stock of housing and $IK_{c,t} = k_{c,t} - (1-\delta_{kc}) k_{c,t-1}$ and $IK_{h,t} = k_{h,t} - (1-\delta_{kh}) k_{h,t-1}$ are the two components of business investment, expressed in real units.[19] Supply of land l_t is fixed and normalized to one. Supply of land l_t is fixed and normalized to one.

2.5 Trends and Balanced Growth

We assume heterogeneous trends in productivity in the consumption sector, in the nonresidential investment sector, and in the housing sector. Their processes follow:

$$\ln \mathsf{A}_{c,t} = t \ln(1+\gamma_{AC}) + \ln Z_{c,t}, \quad \ln Z_{c,t} = \rho_{AC} \ln Z_{c,t-1} + u_{C,t}$$

$$\ln \mathsf{A}_{h,t} = t \ln(1+\gamma_{AH}) + \ln Z_{h,t}, \quad \ln Z_{h,t} = \rho_{AH} \ln Z_{h,t-1} + u_{H,t}$$

$$\ln \mathsf{A}_{k,t} = t \ln(1+\gamma_{AK}) + \ln Z_{k,t}, \quad \ln Z_{k,t} = \rho_{AK} \ln Z_{k,t-1} + u_{K,t}$$

[19] Aside from the adjustment cost ϕ_t (which is zero in steady state), output Y_t in the consumption sector is a measure of *gross* output since it includes intermediate inputs k_b that do not enter the definition of GDP.

where the innovations $u_{C,t}, u_{H,t}, u_{K,t}$ are serially uncorrelated with mean equal to zero and standard deviations $\sigma_{AC}, \sigma_{AH}, \sigma_{AK}$, and the terms $\gamma_{AC}, \gamma_{AH}, \gamma_{AK}$ denote the net growth rates of technology in each sector. Since preferences and production functions have a Cobb-Douglas form, a balanced growth path exists, along which the gross growth rates of the real variables are:[20]

$$G_C = G_{IK_h} = G_{q\times IH} = 1 + \gamma_{AC} + \frac{\mu_c}{1-\mu_c}\gamma_{AK} \quad (13)$$

$$G_{IK_c} = 1 + \gamma_{AC} + \frac{1}{1-\mu_c}\gamma_{AK} \quad (14)$$

$$G_{IH} = 1 + (\mu_h + \mu_b)\gamma_{AC} + \frac{\mu_c(\mu_h+\mu_b)}{1-\mu_c}\gamma_{AK} + (1-\mu_h-\mu_l-\mu_b)\gamma_{AH} \quad (15)$$

$$G_q = 1 + (1-\mu_h-\mu_b)\gamma_{AC} + \frac{\mu_c(1-\mu_h-\mu_b)}{1-\mu_c}\gamma_{AK} - (1-\mu_h-\mu_l-\mu_b)\gamma_{AH}. \quad (16)$$

We note some interesting properties of these growth rates. First, the trend growth rates of $IK_{h,t}$, $IK_{c,t}/\mathsf{A}_{k,t}$ and $q_t IH_t$ are all equal to G_C, the trend growth rate of real consumption: this growth rate is a combination of the growth rates of consumption and investment-specific technological progress. Second, the growth rate of business investment is the same as the growth rate of consumption when investment is expressed in units of consumption; in real terms, instead, business investment grows faster than consumption, as long as $\gamma_{AK} > 0$.[21] Third, the trend growth rate in real house prices offsets differences in the productivity growth between the consumption and the housing sector: these differences are due to the heterogeneous rates of technological progress in the two sectors and to the presence of land in the production function for new homes.[22]

[20] Given our assumptions about investment specific technological change in the nonresidential investment sector, actual investment will include two components - k_c and k_h - that grow at different rates (in real terms) along the balanced growth path. In the data, we only have a chain-weighted series (non-residential fixed investment) for the aggregate of these two series, since sectoral data on capital held by the construction sector are available only at annual frequency and are not reported in the National Income and Product Accounts. Because, both in our model and in the data, capital held by the construction sector is a very small fraction of non-residential capital (around 5 percent), we assume that the data counterpart of total investment grows at the same rate as the model investment in the consumption-good sector.

[21] This property of the model mirrors the behavior of most NIPA series, which exhibit differential growth rates in real terms, but share a common nominal trend. See Whelan (2003) for a discussion.

[22] Investment-specific technological change $(\gamma_{AK} > 0)$ causes consumption to grow faster than residential investment, since it is assumed to apply only to capital used in the production of consumption goods. If $\gamma_{AK} = 0$, consumption and residential investment grow respectively at rates given by γ_{AC} and $(\mu_h + \mu_b)\gamma_{AC} + (1-\mu_h-\mu_l-\mu_b)\gamma_{AH}$. In this case, consumption grows faster than residential investment even if $\gamma_{AC} = \gamma_{AH}$, if land share μ_l is positive.

3 Parameter Estimates

We linearize the set of equations that describe the equilibrium of our model around the balanced growth path. For given parameter values, the solution to our model takes the form of a state-space model that is used to compute the likelihood function.

The estimation procedure consists of various steps: the transformation of the data into a form suitable for the computation of the likelihood function using the state-space representation of the model; the choice of appropriate prior distributions for the parameters; the estimation of the posterior distribution with Monte Carlo methods. Starting from the joint probability distribution of the data Z and the parameters $\Theta, P\left(Z, \Theta\right)$, one can derive the fundamental relationship between the prior $P\left(\Theta\right)$ and posterior distribution $P\left(\Theta|Z\right)$ of the parameters known as Bayes theorem: P$(\Theta|Z) \propto P\left(Z|\Theta\right) \times P\left(\Theta\right).$

In its essence, this amounts to updating *a priori* distribution using the information (likelihood, $P\left(Z|\Theta\right)$) contained in the data to obtain the conditional *a posteriori* distribution of the structural parameters. The posterior density $P\left(\Theta|Z\right)$ can then be used to draw statistical inference either on the parameters themselves or on any function derived from them.

3.1 Description of the Data

We use ten quarterly series as observables: real consumption,[23] real residential investment, real business fixed investment, real house prices, the 3-month nominal interest rate, inflation, hours in the consumption sector, hours in the housing sector, wage inflation in the consumption sector and wage inflation in the housing sector. Consumption, investment and total hours are expressed in per capita terms (using the civilian noninstitutional population), whereas inflation and the interest

[23]We use total chain-weighted consumption, since our goal is to assess the implications of housing for a broad measure of consumption, and because chained aggregates do not suffer the base-year problem documented and explained in Whelan (2003). NIPA data do not provide a chained series for total consumption excluding housing services and durables, which would correspond to our theoretical definition of consumption. As a robustness check, we have also estimated our model using fixed-weight series for consumption and investment, excluding housing services and durables from our definition of consumption. The results of the estimation were similar and are available from the authors upon request.

rate are expressed on a quarterly basis. We measure house prices using the quality-adjusted Census Bureau house price index, which measures the price of new one-family houses sold including value of lot.[24] We estimate the model over the full sample period from 1965:I to 2006:IV. In Section 5.2, we estimate the model over two subperiods (1965:I to 1982:IV and 1989:I to 2006:IV) in order to investigate the stability of our estimated model. The series (described in Appendix A) are plotted in Figure 1. Real house prices have steadily increased in the sample period.[25] Real business investment has grown faster than real consumption, which has in turn grown faster than real residential investment.

We keep the trend and remove the level information from the series that we use in estimation. In practice, we calibrate depreciation rates, the capital shares in the production functions and the weights in the utility functions in order to match consumption and investment shares and wealth to output ratios, as commonly done in the literature (see for example Smets and Wouters, 2003). We also calibrate the discount factor in order to match the real interest rate and remove the mean from inflation and the nominal interest rate. In a similar vein, we do not use information on steady state hours to calibrate the labor supply parameters since in any multi-sector model the link between value added of the sector, on the one hand, and available measures of total hours worked in the same sector, on the other, is somewhat tenuous.[26] In addition, there are reasons to believe that self-

[24]Another available house price series is the repeat sales Freddie Mac/OFHEO Conventional Mortgage House Price Index (CMHPI), which starts in 1970. At business cycle frequencies, the CMHPI moves together with the Census series (the correlation between year-on-year real growth rates of the two series is 0.70). In the 1970-2006 period, the CMHPI has a stronger upward trend: our Census series grows in real terms by an average of 1.67 percent per year, the CMHPI by 2.38 percent. Being based on repeat sales, the CMHPI is perhaps a better measure of house price appreciation at short-run frequencies; however, several authors have argued that the CMHPI is biased upward (between 0.1 and 0.6 percent per year) because homes that change hands more frequently have greater price appreciation (see Gallin, 2004, for a discussion). We prefer to use the Census series since it starts earlier.

[25]The increase in house prices (90 percent in real terms) has been mirrored by the increase in real rents throughout the same period. Between 1965 and 2006, the shelter component of the CPI has risen by 88 percent in real terms. Shiller (2006) argues that real rents have not increased in the 20th century, but his claims are based on a small fraction of the shelter component of the CPI that includes rent of primary residence but excludes owner's equivalent rent. See Figure D2 in our technical appendix for a graphical comparison.

[26]For instance, available measures of hours and employment in construction are based on the Current Employment Statistics (CES) survey and classify between (1) residential construction workers, (2) nonresidential construction workers and (3) trade contractors, without distinguishing whether trade contractors (like electricians or plumbers) work in

employment in the construction sector varies according to the business cycle, and, for this reason, we allow for measurement error in total hours in this sector.[27]

In equilibrium the transformed variables $\mathsf{C}_t = C_t/G_C^t$, $\mathsf{IH}_t = IH_t/G_{IH}^t$, $\mathsf{IK}_t = IK_t/G_{IK}^t$, $\mathsf{q}_t = q_t/G_q^t$ all remain stationary.[28] In addition total hours in the two sectors $N_{c,t}$ and $N_{h,t}$ remain stationary, as do inflation π_t and the nominal interest rate R_t.[29] The model also predicts that real wages in the two sectors should grow at the same rate as consumption along the balanced growth path. Available industry wage data (such as those provided by the BLS Current Employment Statistics) show a puzzling divergence between real hourly wages and real consumption over the sample in question, with the latter rising twice as fast as the former between 1965 and 2006.[30] Sullivan (1997) argues that the BLS measures of sectoral wages suffer from potential measurement error. For these two reasons, we use demeaned nominal wage inflation in the estimation and we allow for measurement error.[31]

3.2 Calibrated Parameters and Prior Distributions

Calibration. The parameters we calibrate include the discount factors β, β', the weight on housing relative to consumption in the utility function j, the technology parameters μ_c, μ_h, μ_l, μ_b, δ_h, δ_{kc}, δ_{kh}, the steady-state gross price and wage markups X, X_{wc}, X_{wh}, the loan-to-value (LTV) ratio m and the persistence of the inflation objective shock ρ_s. We fix these parameters prior to estimation because they are either notoriously difficult to estimate (in the case of the markups) or because they are better identified using other information (in the case of the factor shares and the discount factors).

the residential or nonresidential sector. Besides this, the CES survey does not include self-employed and unpaid family workers, who account for about one in three jobs in the construction sector itself, and for much less in other sectors.

[27]See for instance the BLS website at `http://www.bls.gov/oco/cg/cgs003.htm`.

[28]In steady state, assets, wages and consumption of each group will all grow at the same rate as aggregate consumption. We scale each variable by its trend growth rate before linearize our model around the steady state.

[29]We define our indexes of total hours as $N_{ct} = n_{ct}^{\alpha}\left(n'_{ct}\right)^{1-\alpha}$ and $N_{ht} = n_{ht}^{\alpha}\left(n'_{ht}\right)^{1-\alpha}$.

[30]See Figure D1 in our technical appendix. The wage series in question measures average hourly earnings of production/nonsupervisory workers from the BLS-CES monthly establishment survey.

[31]We allow for measurement error only on wages in the housing sector. In preliminary estimation attempts, we allowed for measurement error also for wages in the consumption sector: the estimated standard deviation was very close to zero, and all the other parameters very virtually unchanged.

Table 1A summarizes our calibrated parameters and Table 1B displays the steady state moments of the model.[32] We set $\beta = 0.9925$, implying a steady-state real interest rate of 3 percent on an annual basis. We set the discount factor of the impatient households (β') equal to 0.97. This value has a limited effect on the dynamics, but guarantees an impatience motive large enough that the impatient agents are arbitrarily close to the borrowing limit, so that the linearization around a steady state with binding borrowing limit is accurate (see the discussion in Iacoviello, 2005). We fix $X = 1.15$, implying a steady-state markup of 15 percent in the consumption-good sector. Similarly, we also set $X_{wc} = X_{wh} = 1.15$. The steady-state markups have virtually no effect on the model dynamics.

The depreciation rates for housing, capital in the consumption sector and capital in the housing sector are set equal respectively to $\delta_h = 0.01$, $\delta_{kc} = 0.025$ and $\delta_{kh} = 0.03$. The first number (together with j, the weight on housing in the utility function) pins down the ratio of residential investment to total output at around 6 percent, as in the data. The other numbers - together with the capital shares in production - imply a ratio of non-residential investment to GDP around 27 percent. We pick a slightly higher value for the depreciation rate of construction capital on the basis of BLS data on service lives of various capital inputs, that indicate that construction machinery (the data counterpart to k_h) has a lower service life than other types of nonresidential equipment (the counterpart to k_c).[33]

For the capital share in the production function of goods, we choose $\mu_c = 0.35$. In the production function of new homes, we choose a capital share of $\mu_h = 0.10$ and a land share of $\mu_l = 0.10$, following Davis and Heathcote (2005). Together with the other estimated parameters, the choice of the land share implies that the value of residential land is around 50 percent of annual GDP. This happens because the current price of land capitalizes future housing production opportunities.[34]

[32] Some of the parameters that we estimate (namely, trend parameters and the labor income share of unconstrained agents α) also affect some of the steady state ratios that the calibration aims at pinning down (in the case of α, this happens because in steady state the two groups have different marginal propensities to consume and to save). In preliminary estimation attempts, we fine-tuned the calibrated parameters so ensure that our target ratios were roughly as desired given the posterior estimates.

[33] See `http://www.bls.gov/mfp/mprcaptl.pdf` (Table 1, service lives of private nonresidential equipment).

[34] Simple algebra (see equations A.11, A.26 and A.36 in Appendix B) shows that the steady state value of land

We set the intermediate goods share at $\mu_b = 0.10$: data from sectoral input-output tables typically indicate that the share of material costs for most sectors is on the order of 50 percent, which suggests that a calibration for μ_b could be as high as 0.50.[35] We choose to be conservative because our share parameter is only meant to capture the extent to which sticky price, nondurable intermediate inputs are used in housing production. Next, the weight on housing in the utility function is set at $j = 0.12$: together with the technology parameters, these choices imply a ratio of business capital to annual GDP around $2.1,$ whereas the ratio of housing wealth to GDP is around 1.35.

Next, we choose a value for LTV ratio m. This parameter is difficult to estimate unless one uses data on debt and housing holdings of credit constrained households, both of which are clearly unobserved. For this reason, we calibrate m. Our choice is meant to measure the typical LTV ratio applying to homebuyers who are likely to be credit constrained, and borrow the maximum possible against their housing holdings. Between 1973 and 2006, the average LTV ratio was 0.76.[36] Yet it is likely that "impatient" households borrow more as a fraction of the home value: in 2004, for instance, 27 percent of new homebuyers took LTV ratios in excess of 80 percent, with an average ratio (conditional on borrowing more than 80 percent) of 0.94. We choose to be conservative and set $m = 0.85$. It is also conceivable that the assumption of a constant value for m over a 40 year period is too strong, in light of the observation that the mortgage market has become more liberalized over time. We take these considerations into account when we estimate our model across subsamples, calibrating m differently across subperiods.

Finally, we set the correlation of the inflation objective shock at $\rho_s = 0.975,$ as in Adolfson et al. (2007). A high value for ρ_s captures well low-frequency movements in inflation.

Prior Distributions. Our priors are listed in Tables 2A and 2B. Overall, they are either consistent with the previous literature or relatively uninformative. We use uniform priors for the standard

relative to residential investment equals: $\frac{p_l}{qIH} = \mu_l \frac{\beta G_C}{1-\beta G_C}$. In practice, ownership of land entitles the household to the present discounted value of future income from renting land to housing production firms, which is proportional to μ_l. For $\mu_l = 0.10$, $\beta = 0.9925$, $qIH/GDP = 0.06$ and our estimated value of G_C (the gross growth rate of per capita consumption) equal to 1.0047, this yields the value reported in the main text.

[35] See for instance Jorgenson, Gollop and Fraumeni (1987).

[36] The data are from the Federal Housing Finance Board. See "Table 19: Terms on Conventional Single-Family Mortgages, all Homes, by Loan-to-Price Ratio" available at `www.fhfb.gov`.

errors of the shocks. For the persistence, we choose a beta-distribution with a prior mean of 0.8 and standard deviation of 0.1. We set the prior mean of the habit parameters in consumption (ε and ε') at 0.5 (with a standard error of 0.075). For the monetary policy specification, we base our priors on a standard Taylor rule responding gradually to inflation only, so that the prior means of r_R, r_π and r_Y are respectively 0.75, 1.5 and 0. We set a prior on the capital adjustment costs around 10 with a standard error of 2.5.[37] We choose a loose beta prior for the utilization parameter (ζ) between zero (capacity utilization can be varied at no cost) and one (capacity utilization never changes). For the disutility of working, we center the elasticity of the hours aggregator for each agent at 2 (that is, the prior mean for η and η' is 0.5). We select values for ξ and ξ', the parameters describing the inverse elasticity of substitution across hours in the two sectors, around $1,$ as estimated by Horvath (2000). We select the prior mean of the Calvo price and wage parameter θ_π, θ_{wc} and θ_{wh} at 0.667, with a standard deviation of 0.05, values which are close to the estimates of Christiano, Eichenbaum and Evans (2005). The priors for the indexation parameters ι_π, ι_{wc} and ι_{wh} are loosely centered around 0.5, as in Smets and Wouters (2007).

We set the prior mean for the labor income share of unconstrained agents to be 0.65, with a standard error of 0.05. The mean is in the range of comparable estimates in the literature: for instance, using aggregate data, Campbell and Mankiw (1989) estimate a fraction of rule-of-thumb consumers around 40 percent. Using the 1983 Survey of Consumer Finances, Jappelli (1990) estimates 20 percent of the population to be liquidity constrained. Iacoviello (2005), using a limited information approach, estimates a wage share of collateral constrained agents of 36 percent.

3.3 Posterior Distributions

Table 2 reports the posterior mean, median and 95 probability intervals for the structural parameters, together with the mean and standard deviation of the prior distributions. In addition to the structural parameters, we estimate the standard deviation of the measurement error for hours and wage inflation in the housing sector. Draws from the unknown posterior distribution of the parameters are

[37]Given our adjustment cost specification (see Appendix B), the implied elasticity of investment to its shadow value is $1/\left(\phi\delta\right)$. Our prior implies an elasticity of investment to its shadow price around 4.

obtained using the random walk version of the Metropolis algorithm.[38]

We find a faster rate of technological progress in business investment, γ_{AK}, followed by the consumption-good sector, γ_{AC}, and, last, by the housing sector, γ_{AH}. At the posterior median, the long-run quarterly growth rates of real per capita consumption, real per capita housing investment and real house prices (as implied by the values of the γ terms and equations 13 to 16) are respectively 0.47, 0.15 and 0.32 percent. In other words, the trend rise in real house prices observed in the data reflects, according to our estimated model, faster technological progress in the non-housing sector. As shown in Figure 2, our estimated trends fit very well the secular behavior of consumption, investment and house prices.

The slow growth rate of total factor productivity (TFP) in the construction sector is perhaps not surprising nor new, although it has not been cited often as one of the driving forces behind the secular increase in house prices seen in the data.[39] Corrado et al. (2006) construct measures of TFP growth for the period 1987-2004 at the sectoral level and find that the average TFP growth in the construction sector is negative (-0.5 percent, annualized), and that increases in the contribution of labor and purchased inputs more than account for the real output growth in the sector. Stiroh (2002) computes measures of productivity growth across industries and finds small labor productivity growth in the construction sector: in particular, he finds that the productivity gap between housing and other sectors was smallest in the period 1987-1995, when house prices dropped in real terms.[40]

[38]Tables and figures are based on a sample of 250,000 draws (in the computational appendix, we report estimates based on 5,000,000 draws, which were essentially the same). The jump distribution was chosen to be the normal one with covariance matrix equal to the Hessian of the posterior density evaluated at the maximum. The scale factor was chosen in order to deliver an acceptance rate between 25 and 30 percent depending on the run of the algorithm. Convergence of the algorithm was assessed by looking at the plots of the draws, moments (mean, standard deviation, skewness and kurtosis) computed by splitting the draws of the Metropolis into two samples (first and second half). All this information is in a computational appendix available at `http://www2.bc.edu/~iacoviel/research.htm`.

[39]Shiller (2006) has argued, on the basis of longer house price series, that the boom of the late 1990s is unprecedented in history, and that there is no presumption that real house prices should have an upward trend. Shiller bases most of his comments on the Case-Shiller-Weiss home price index, which is flat in real terms even between 1965 and 1997, when both the Census bureau and the OFHEO house price indexes show a clear upward trend.

[40]Gort, Greenwood and Rupert (1999) find a positive rate of technological progress in structures, but they confine themselves to non-residential structures such as roads, bridges and skyscrapers.

One key parameter relates to the labor income share of credit-constrained agents. Our median estimate of α is 0.79. This number implies a share of labor income accruing to credit-constrained agents of 21 percent, a value which is lower than our prior mean. As we document below, this fraction is large enough to generate a positive elasticity of consumption to house prices after a housing preference shock. The dynamic effects of this shock are discussed more in detail in the next section.

We now turn to households' preference parameters. Both agents exhibit moderate-to-high degree of habit formation in consumption and relatively little preference for mobility across sectors, as shown by the positive values of ξ (0.67) and ξ' (0.99). The degree of habits in consumption is larger for the impatient households ($\varepsilon' = 0.58$, as opposed to $\varepsilon = 0.33$ for the patient ones). One explanation may be that since impatient households do not hold capital and they cannot smooth consumption through saving, a larger degree of habits in needed in order to match the persistence of aggregate consumption in the data. Turning to the labor supply elasticity parameters, the posterior distributions of η and η' show that the data do not convey much information on these parameters. In our technical appendix, we performed sensitivity analysis with respect to these parameters, and found that the main findings of the paper are not particularly sensitive for a reasonable range of values of η and η'.

We move now to the parameters measuring nominal rigidities. The estimate of θ_π (0.83) implies that prices are reoptimized infrequently, once every six quarters. However, given the positive value for the indexation parameter ($\iota_\pi = 0.71$), prices change every period, although not in response to changes in marginal costs. The implied slope of the Phillips curve is equal to 0.019, a value that is close to the estimates by Galí and Gertler (1999). As it is well known, the parameter θ_π only enters the coefficient on the markup in the Phillips curve equation: to the extent that inflation is not sensitive to marginal costs, the estimate of θ_π tends towards one. Some real rigidities that we do not consider (fixed costs of production or firm-specific capital) would generate the same reduced form of our model (see Eichenbaum and Fisher, 2004 for a discussion) and would show up as a multiple (larger than one) of θ_π in the inflation equation, thus reducing the implied degree of price rigidity. As for wages, we find that stickiness in the housing sector ($\theta_{wh} = 0.91$) is higher than in the consumption sector ($\theta_{wc} = 0.81$), although wage indexation appears to be larger in the housing sector ($\iota_{wh} = 0.42$ and $\iota_{wc} = 0.08$). Later, we discuss the role that nominal rigidities play in the fit of our model.

Estimates of the parameters of the monetary policy rule are in line with previous evidence. Two facts are worth mentioning: first, we find a relatively large response to output growth, with $r_Y = 0.51$; second, we tightly identify the response to inflation, with an estimated coefficient of $r_\pi = 1.36$. Finally, all shocks are quite persistent, with autocorrelation coefficients ranging between 0.91 and 0.997.

4 Properties of the Estimated Model

4.1 Impulse Responses

In this section, we discuss the main workings of our model. Below, we emphasize housing preference shocks, since they illustrate the role of housing collateral in propagating business cycles; monetary shocks, since they have received a large amount of attention in the literature aimed at discriminating between alternative models of the business cycle; and technology shocks, since they explain a good portion of cyclical movements in housing variables.

The effects of a positive housing preference shock are shown in Figure 3. By shifting preferences towards housing, this shock raises house prices as well as the returns to investing in the construction sector, thus causing residential investment to rise. On the other hand, it increases the value of the collateral of constrained agents thus allowing them to increase borrowing and consumption. Since constrained agents have a high propensity to consume at the margin, the effects on aggregate consumption are positive, even if consumption of the lenders (not shown in the figure) falls.

Figure 4 displays the model responses to an adverse monetary policy shock. Real house prices drop, and remain significantly below the baseline for about six quarters: the quantitative impact of the monetary shock on house prices is similar to what is found in VAR-based studies of the impact of monetary shocks on housing prices, with minor differences driven by the choice of the house price index and by the estimation period (see for instance Del Negro and Otrok, forthcoming). All the components of aggregate demand fall, with residential investment showing the largest drop, followed by business fixed investment and consumption. The large drop in residential investment is a well-documented fact in VAR studies of the monetary transmission mechanism (e.g. Bernanke and Gertler, 1995, and Erceg and Levin, 2006).

Finally, Figure 5 plots the responses of house prices and hours in the two sectors in response to technology shocks in the goods sector and in the housing sector. A productivity shock in the goods sector leads to an increase in house prices and (not shown in the figure) in consumption and both types of investment: because firms in the goods sector are unable to lower their prices, they reduce labor demand in the goods sector, while at the same time increasing labor demand in the housing sector. Instead, a positive technology shock in the housing sector leads to a strong increase in hours in the housing sector, and to a drop in real house prices.

Our technical appendix presents the impulse response functions for all the other shocks.[41]

4.2 Second Moments

In this section, we assess the extent to which our estimated model is capable of accounting for some of business cycle facts regarding the behavior of housing variables. To this end, we compute a set of second moments at business cycle frequency using the draws of the parameters generated by the Metropolis algorithm. Table 3 reports our main results. Overall, the model can match well the second moments of the data: most of the model moments lie within the 95 percent probability interval computed from the data. In particular, the model can replicate the comovement between the components of aggregate demand, the procyclicality of housing prices and housing investment, and the relative volatility of our series.

In order to understand the role of each shock in generating fluctuations in the main variables, we compute their asymptotic variance at business cycle frequencies. Table 4 presents the results. Taken together, demand (housing preference) and supply (housing technology) shocks in the housing market account for about one half of the variance in housing investment and housing prices,

[41] A negative labor supply shock (u_τ) leads to a decline in hours, consumption, investment and house prices. An intertemporal preferences shock (u_z) generates an increase in consumption, and a decline in investment and house prices: house prices fall since the shock tilts preferences towards non-durable goods, reducing relative housing demand.

An adverse cost-push shock (u_p) leads to an increase in inflation and nominal rates and a decline in output. An increase in the inflation objective (u_s) leads to a persistent increase in inflation and the nominal interest rate, and to an increase in consumption, residential and business investment, and house prices. Both shocks primarily affect inflation and interest rates, but the former works like a textbook supply shock, whereas the latter works as a demand shock.

while monetary shocks explain respectively 15 percent and 11 percent**.** The average variance of the forecast error of exogenous shocks in the housing sector to the other components of aggregate demand (consumption and business investment) is instead small: for instance, housing preference shocks appear to explain less than 1 percent of the variance in consumption and business investment.

4.3 Understanding the Key Features of the Model.

The introduction of a large number of nominal and real frictions raises the question as to which role each of them plays in the model. Below, we focus mainly on the role that the collateral constraints and nominal rigidities play in affecting the dynamic responses of our variables to housing preference and monetary shocks. We single these shocks out not because of their relative importance given our parameter estimates, but because they best convey the intuition for the workings of our model. Our technical appendix documents other findings in more detail.

Housing Preference Shocks, and the Role of Collateral Constraints. Figure 6 displays the impulse response functions to a housing preference shock for three alternative versions of the model in which we set $\theta_p = 0$ (flexible prices), $\theta_{wc} = \theta_{wh} = 0$ (flexible wages) and $\alpha = 1$ (no collateral effects), while holding the remaining parameters at the benchmark values. As the top left panel of the figure illustrates, collateral effects are the key feature of the model that generates a positive and persistent response of consumption following an increase in housing demand. Absent this effect, in fact, an increase in the demand for housing would generate an increase in housing investment and housing prices, but a fall in consumption. Quantitatively, the observed impulse response translates into a first-year elasticity of consumption to housing prices around 0.07.

The increase in consumption following an increase in housing demand and prices mirrors the findings of several papers that document positive wealth effects on consumption from changes in housing prices or, more broadly, in housing wealth (see for instance Case, Quigley and Shiller, 2005, and Campbell and Cocco, 2007): it is tempting to quantitatively compare our results with theirs. However, our elasticity is conditional to a particular shock, whereas most microeconometric and time-series studies in the literature try to isolate the elasticity of consumption to housing prices through regressions of consumption on housing wealth, both of which are endogenous variables in our model. Nonetheless, it is possible to reconcile the typical elasticities found in time-series data with the mechanism at work in our model. In our model, for instance, a basic regression of consumption growth on lagged growth in housing wealth[42] yields (standard errors are in parenthesis):

$$\Delta \log C_t = (0.0001)\ 0.0041 + (0.005)\ 0.123 \Delta \log HW_{t-1}.$$

The analogous regression in the data[43] yields:

$$\Delta \log C_t = (0.0006)\ 0.0039 + (0.039)\ 0.122 \Delta \log HW_{t-1}.$$

The coefficients on lagged housing wealth are not statistically different across the two regressions. By comparison, a regression using the simulated model output in absence of collateral effects ($\alpha = 1$) yields a smaller coefficient on housing wealth (0.099), whereas a regression of simulated model setting $\alpha = 0.5$ yields a coefficient of 0.150. Hence our model estimate of α allows capturing the empirical elasticity of consumption to housing wealth extremely well, but it should be remembered that, even without collateral constraints, our model generates a positive correlation between changes in housing wealth and changes in future consumption. This result arises because this equation is obviously misspecified relative to the structural equilibrium relationships involved by our model, thus suggesting that caution should be taken in using evidence from reduced form regression of consumption on housing wealth in order to assess the importance of collateral effects.[44] However, our model is consistent with the idea that the wealth effect on consumption increases with the fraction of households who use their home as collateral.[45]

Next, we consider the sensitivity of residential investment to the model parameters in response to a housing preference shock. At the baseline estimates, a shift in housing demand that generates an increase of real house prices by around 1 percent (bottom left panel of Figure 6) causes residential

[42]The model variables have been generated using the posterior median of the parameters. An artificial sample of 10,000 observations was generated.

[43]The housing wealth series is from the Flow of Funds, Federal Reserve Board, Balance sheet of households and non-profit organizations (B.100, row 4), and corresponds to the market value of household real estate wealth (code FL155035015). The series is deflated with the nonfarm business sector deflator and normalized by civilian noninstitutional population.

[44]Loosely speaking, the correct equilibrium relationship between consumption and housing wealth is an infinite order vector autoregression incorporating the cross-equation restrictions of the model.

[45]See for instance Case, Quigley and Shiller (2005).

investment to rise by around 3.5 percent. As the figure illustrates, sticky wages are crucial here: in particular, the combination of flexible housing prices and sticky wages in construction makes residential investment very sensitive to changes in demand conditions. The numbers here can be related to the findings of Topel and Rosen (1988),[46] who estimate a very elastic supply response of new housing to changes in prices: depending on the specifications, for every 1 percent increase in house prices lasting for two years, they find that new construction rises on impact between 1.5 and 3.15 percent.

In other experiments (reported in our technical appendix), we have found that larger values of m, the loan-to-value ratio, operate in a similar way as smaller values of α. Larger values of m, in particular, work to amplify the response of consumption to monetary and housing preference shocks.

Monetary Shocks, and Role of Wage and Price Rigidities. Figure 7 considers the role of nominal stickiness and collateral constraints in the model's performance in response to a monetary policy shock. As the top left panel of the figure illustrates, both nominal rigidities and collateral effects amplify the response of consumption to monetary shocks. The negative response of real house prices to monetary shocks, instead, mainly reflects nominal stickiness, whereas collateral constraints do not appear to play a major role.

Perhaps the most interesting result comes from looking at the response of residential investment. At the baseline estimates, the response of residential investment is more than five times larger than consumption and twice as large as that of business investment. Here, as shown by the top right panel of Figure 7, it is wage rigidity that plays a crucial role. Absent wage rigidity,[47] residential investment would be isolated from interest rate shocks. When wage rigidity kicks in, housing investment becomes very interest rate sensitive. In particular, housing investment *falls* because housing prices fall relative to wages; housing investment *falls a lot* because the flow of housing investment is small relative to its stock, so that the drop in investment has to be large to restore the desired stock-flow

[46] Obviously, the same caveats of the consumption regressions also apply here.

[47] In experiments not reported in the figure, we have found that it is sectoral wage rigidity rather than overall wage rigidity that matters for this result. That is, sticky wages in the housing sector and flexible wages in the non-housing sector are already sufficient to generate a large response of residential investment to monetary shocks.

ratio. Our findings therefore lend support to the theoretical exercises of Barsky, House and Kimball (2007) and Carlstrom and Fuerst (2006), who have remarked the importance of sticky wages to account for the large negative elasticity of durables following a monetary tightening. They show how models with rigid non-durable prices and flexible durable prices may generate a counterfactual increase in durables following a negative monetary shock.[48]

A natural question to ask is the extent to which one can regard the construction sector as a sector featuring strong wage rigidities. Several pieces of evidence - besides our econometric findings - seem to point in this direction. First, the construction sector has higher than average unionization rates compared to the private sector in general: 15.4 percent vs. 8.6 percent. Second, and most importantly, several state and federal wage laws in the construction industry work to insulate movements in wages from movements in the marginal cost of working. The Davis-Bacon Act, for instance, is a federal law that mandates a prevailing wage standard in publicly funded construction projects; several states have followed with their own wage legislation, and the provisions of the Davis-Bacon Act apply to large firms in the construction sector, even for private projects.

The Role of Real Rigidities, Capacity Utilization, and Land. Like many multi-sector models, our estimated model prefers features that slow down sectoral reallocation of labor and capital in response to changes in demand. In our setup, labor is not perfectly mobile, capital is sector specific and costly to adjust,[49] and the housing sector uses intermediate inputs produced in the other sector. We have explored specifications in which we relax these assumptions (see our technical appendix for additional robustness exercises). While the qualitative findings are largely unchanged, our estimated model with all real rigidities (partial labor mobility, habits and variable capacity) can better explain persistence in most series and comovement across sectors. For instance, by smoothing the response of real marginal costs in response to changes in demand, variable capacity and adjustment costs can

[48]DiCecio (2005) presents a two-sector model where sticky wages can solve the comovement puzzle.

[49]We have explored a version of our model with adjustment costs for the changes in both business and residential investment. The parameter estimates and the implied sensitivity of consumption to housing shocks were similar to those of the version with capital adjustment costs. The main difference is that the investment adjustment cost model delivers a smaller sensitivity of residential investment to monetary shocks (the peak response is three times smaller), and a greater role for housing technology shocks in explaining fluctuations in housing investment. See Figures M1, M2 and M3 in our technical appendix: additional details are available from the authors upon request.

explain the persistence and the sensitivity of aggregate demand in response to shocks.

A final comment concerns the role of land in our model. At secular frequencies, the assumption that land is fixed accounts for a fraction of the long-run increase in real house prices, since land acts as a limiting factor in the production of new homes. Given our estimate of $\gamma_{AH} = 0.08\%$ and the land share in new homes of $\mu_l = 0.10,$ equation 16 attributes around 3 percent of the total increase in real house prices over time to the limiting role of land (the remaining fraction is due to slower technological progress in the housing sector). At business cycle frequencies, instead, land works in a way similar to an adjustment cost on housing investment, since it limits the extent to which the housing stock can be adjusted: larger values of μ_l shift the action from quantities to prices in response to shocks.

5 Applications

Having shown that the estimated model fits the data quite well, we use it to address two crucial questions. First, what are the main driving forces of fluctuations in the housing market? Second, can we quantify the spillover effects from the housing market to the rest of the macroeconomy?

5.1 The Contribution of Various Shocks to Housing Booms and Busts

As our variance decomposition exercise shows, housing technology shocks, housing preference shocks, and monetary factors (the combination of monetary policy shocks and shifts in the inflation objective) account for roughly 75 percent of the fluctuations in residential investment, and 60 percent of the fluctuations in house prices at business cycle frequency. A related question is how these different factors have contributed to the major housing cycles in the United States. Figure 8 provides a visual representation. The solid line displays the detrended historical data, obtained subtracting from the raw series the deterministic trends plotted in Figure 2. The other lines show the historical contribution of these three factors under our estimated parameters.

As the top panel Figure 8 shows, the period 1965-2006 has witnessed two major expansions in real housing prices, the first from 1976 to 1980, and the second from 2000 to the beginning of 2005. The first price cycle saw housing prices rise by around 16 percent above trend, and was followed by a 12 percent drop between 1980 and 1985 (see Table 5). The 1976-1985 cycle in housing prices was accompanied by wild fluctuations in residential investment, with basically no changes between 1976 and 1980, and a large rise (26 percent) between 1980 and 1985. Housing preference shocks aside, it appears that in the first house price cycle monetary policy shocks did not play an important role. If anything, monetary surprises in the 1976-1980 boom worked to cool off the housing price increase: the net contribution of the monetary component to house price changes was -3 percent, thus suggesting that exogenous monetary factors did not play a major role here. Instead, the improvement in non-housing technology relative to housing technology (or, simply put, technology shocks in general) account for an increase in house prices of around 5 percent.

The recent house price cycle tells a slightly different story. The housing boom of the turn of the century saw housing prices and housing investment rise together, thus suggesting that demand factors might have played a more prominent role. Indeed, as shown by Table 5, housing preference shocks played a major role in the 2000-2005 expansion. In addition, however, monetary conditions explain a non-negligible part of the increase in house prices (more than a quarter), and about one half of the increase in residential investment. Perhaps even more suggestive is the role of monetary policy shocks in ending the boom in 2005 and 2006: the combined effect of monetary shocks reduced housing investment by 11 percent, and house prices by 3 percent.

We conclude this subsection relating our results to those in Brunnermeier and Juilliard (2006) and Piazzesi and Schneider (2006 and 2007): these authors have emphasized the role that inflation can play in driving fluctuations in house prices. Brunnermeier and Juilliard (2006) use a model where buyers and renters suffer from money illusion to show how lower inflation can tilt preferences from renting towards owning, thus raising house prices when inflation is low, and vice versa. Piazzesi and Schneider (2006) build an OLG model to show that the Great Inflation of the 1970s led to a portfolio shift by making housing more attractive than equity. This mechanism is well suited to explain the housing boom of the 1970s, but cannot explain the rise in house prices at the turn of the century. The same authors (Piazzesi and Schneider, 2007) construct an alternative model in which agents who suffer from inflation illusion interact with "smart" agents in markets for nominal assets: they show that, under this assumption, nominal interest rates move with smart agents' inflation expectations, and housing booms occur whenever these expectations are either especially high or low. There are some key differences between our analysis and theirs. First, we take a different position on what are the driving shocks in the housing market, and let the data decide how much each shock contributes: our variance decomposition exercise shows that inflation movements do not account for more than 15 percent of house price fluctuations, thus playing down the role of inflation disturbances as a source of house prices movements. Second, we consider a different set of nominal and real frictions.

5.2 Subsample Estimates: Financial Liberalization and the Contribution of Collateral Effects to Consumption Fluctuations Revisited

In this subsection, we measure the spillover effects from the housing market to the broader economy. As we explained above, a large component of the spillovers in our model go through the effects that fluctuations in housing prices have on consumption expenditure; these effects, as we documented in Section 4.3, mostly rely on the degree of financial frictions, as measured by the wage share of credit constrained agents and by the loan-to-value ratio.

In our benchmark estimates, we have maintained the assumption that the model structural parameters were constant throughout the sample. Such assumption was supported by the findings of Smets and Wouters (2007), who argue that most of structural changes in the U.S. economy can be assigned to changes in the volatility of the shocks. However, several market innovations following the financial reforms of the early 1980s drastically affected the housing market. Campbell and Hercowitz (2005), for instance, argue that mortgage market liberalization drastically reduced the equity requirements associated with collateralized borrowing. More in general, several developments in the loan market might have enhanced the ability to households to borrow, thus reducing the fraction of credit constrained households, as pointed out by Dynan, Elmendorf and Sichel (2006). Motivated by this evidence, we estimate our model across two subperiods, and use our estimates to measure the feedback from housing market fluctuations to consumer spending. Following Campbell and Hercowitz (2005), we set a "low" loan-to-value ratio in the first subperiod, and a "high" loan-to-value ratio in the second subperiod in order to model financial liberalization in our setup. We do so setting $m = 0.775$ in the period 1965:I-1982:IV, and $m = 0.925$ in the period 1989:I-2006:IV.[50]

[50]The first subperiod ends in 1982:IV, in line with evidence from Campbell and Hercowitz (2005) that dates the beginning of financial liberalization with the Garn-St.Germain Act of 1982 that deregulated the Savings and Loan

As we mentioned earlier, high loan-to-value ratios potentially amplify the response of consumption to given "demand" side disturbances; however, we remain agnostic about the overall importance of collateral effects, by estimating two different values of α (as well as all other parameters) for the two subsamples.

Table 6 compares the model estimates for the two subperiods. The late period captures the high financial liberalization period. The broader message is that most structural parameters do not differ significantly across subperiods, whereas, as in Smets and Wouters (2007), the volatility of the most underlying shocks seems to have fallen in the second period. Interestingly, we find a significantly lower value for α in the first subperiod (0.68) compared to the second (0.80). However, the smaller share of credit constrained agents is more than offset by the larger loan-to-value ratio: as shown by Figure 9, consumption responds more to a given size preference shock in the second period (a similar result holds when comparing monetary shocks). Hence the estimates suggest that financial innovation might have reduced the fraction of credit constrained people, but at the same time might have increased their sensitivity to given changes in economic conditions.

Using the subsamples estimates, we calculate the counterfactual consumption path in absence of collateral constraints ($\alpha = 1$), and subtract it from actual consumption to measure the contribution of collateral constraints to consumption growth. Figure 10 presents our results: in the early period (left panel), the contribution of collateral effects to consumption fluctuations is small, accounting for slightly less than 2 percent of the total variance of year-on-year consumption growth.[51] The late period (right panel) tells instead a different story: collateral effects account for a much greater role, explaining 14 percent of the total variance in consumption growth.[52] This result is also in line with the findings of Case, Quigley and Shiller (2005), who show that the reaction of consumption to home prices increased after 1986, when tax law changes began to favor borrowing against home equity and when home equity loans became more widely available. Over the period 2002-2004, the contribution of collateral effects to year-on-year consumption growth was around 0.4 per cent.

industry. The second subsample in 1989:I: this way, we have two subsamples of equal length and we allow for a transition phase between the two regimes.

[51]The variance ratio is calculated by dividing the variance of consumption growth in absence of collateral effects by the total variance of consumption growth in each subsample.

[52]Using the full sample estimates, instead, the variance of consumption growth explained by collateral effects is around 5 percent in both periods.

6 Concluding Remarks

The role of the housing market in business fluctuations has recently gained considerable attention among academics and policymakers. On the one hand, this reflects the observation that, while central bankers have won the battle for price stability, large fluctuations in asset values are common in many developed economies. On the other, this reflects the consideration that developments in the housing market might broader macroeconomic consequences: for instance, the rise in housing valuations in the United States at the turn of the century not only seems to have stimulated residential investment, but, through home equity extraction, has been cited as one of the driving forces behind high consumption growth. However, while academic and policy debates often focus on the importance of the housing market, with a particular attention to the wealth effects of changes in house prices, the new generation of business cycle models that has become popular in monetary policy analysis largely abstracts from housing altogether. Our paper has aimed at filling this gap, formulating and estimating a dynamic stochastic general equilibrium model of the housing market and the business cycle.

Our estimated model accounts well for several features of the data. At cyclical frequencies, it matches the observation that both housing prices and housing investment are strongly procyclical, volatile, and very sensitive to monetary shocks. Over longer horizons, the model can account extremely well for the prolonged rise in real house prices over the last four decades, and views this increase as the consequence of slower technological progress in the housing sector, and the presence of land (a fixed factor) in the production function for new homes. We have used our model to address two important questions. First, what shocks drive the housing market at business cycle frequency? Our answer is that housing demand shocks and housing technology shocks account for roughly one quarter each of the cyclical volatility of housing investment and housing prices. Monetary shocks account for between 15 and 20 percent, but they have played a major role in the housing market cycle at the turn of the century. Second, do fluctuations in the housing market propagate to other forms of expenditure? Our answer is that the spillovers from the housing market to the broader economy are non-negligible, concentrated on consumption rather than business investment, and they might have become more important over time, to the extent that financial innovation has increased the marginal availability of funds for credit-constrained agents.

Tables and figures

Table 1A

Calibrated Parameters

Parameter	Value
β	0.9925
β'	0.97
j	0.12
μ_c	0.35
μ_h	0.10
μ_l	0.10
μ_b	0.10
δ_h	0.01
δ_{kc}	0.025
δ_{kh}	0.03
X, X_{wc}, X_{wh}	1.15
m	0.85
ρ_s	0.975

Table 1B

Steady State Targets

Variable	Interpretation	Value
$4 \times R - 1$	Annual Real Interest Rate	3%
C/GDP	Consumption share	67%
IK/GDP	Business Investment share	27%
$q \times IH/GDP$	Housing Investment share	6%
$qH/(4 \times GDP)$	Housing Wealth	1.36
$k_c/(4 \times GDP)$	Business Capital in Non-Housing Sector	2.05
$k_h/(4 \times GDP)$	Business Capital in Housing Sector	0.04
$p_l/(4 \times GDP)$	Value of land	0.50

Note: The definition of GDP and consumption exclude the imputed value of rents.

Table 2A

Prior and Posterior Distribution of the Structural Parameters

	Prior Distribution			Posterior Distribution			
Parameter	Distr.	Mean	St.Dev	Mean	2.5 percent	Median	97.5 percent
ε	Beta	0.5	0.075	0.33	0.25	0.33	0.41
ε'	Beta	0.5	0.075	0.58	0.46	0.58	0.69
η	Gamma	0.5	0.1	0.52	0.33	0.52	0.73
η'	Gamma	0.5	0.1	0.51	0.34	0.51	0.70
ξ	Normal	1	0.1	0.66	0.91	0.67	0.38
ξ'	Normal	1	0.1	0.98	1.17	0.99	0.78
$\phi_{k,c}$	Gamma	10	2.5	15.32	12.12	15.27	18.81
$\phi_{k,h}$	Gamma	10	2.5	11.08	6.86	10.88	16.50
α	Beta	0.65	0.05	0.79	0.72	0.79	0.85
r_R	Beta	0.75	0.1	0.61	0.52	0.61	0.67
r_π	Normal	1.5	0.1	1.36	1.23	1.36	1.52
r_Y	Normal	0	0.1	0.51	0.40	0.51	0.63
θ_π	Beta	0.667	0.05	0.83	0.79	0.83	0.87
ι_π	Beta	0.5	0.2	0.72	0.56	0.71	0.89
$\theta_{w,c}$	Beta	0.667	0.05	0.81	0.76	0.81	0.85
$\iota_{w,c}$	Beta	0.5	0.2	0.08	0.02	0.08	0.17
$\theta_{w,h}$	Beta	0.667	0.05	0.91	0.88	0.91	0.93
$\iota_{w,h}$	Beta	0.5	0.2	0.43	0.21	0.42	0.68
ζ	Beta	0.5	0.2	0.72	0.53	0.72	0.88
$100 \times \gamma_{AC}$	Normal	0.5	1	0.32	0.30	0.32	0.35
$100 \times \gamma_{AH}$	Normal	0.5	1	0.10	-0.05	0.10	0.28
$100 \times \gamma_{AK}$	Normal	0.5	1	0.27	0.23	0.27	0.30

$Note$: Results based on 200,000 draws from the Metropolis algorithm.

Table 2B

Prior and Posterior Distribution of the Shock Processes

	Prior Distribution			Posterior Distribution			
Parameter	Distr.	Mean	St. Dev.	Mean	2.5 percent	median	97.5 percent
ρ_{AC}	Beta	0.8	0.1	0.95	0.92	0.95	0.97
ρ_{AH}	Beta	0.8	0.1	0.997	0.99	0.997	0.999
ρ_{AK}	Beta	0.8	0.1	0.93	0.89	0.93	0.96
ρ_j	Beta	0.8	0.1	0.95	0.91	0.95	0.98
ρ_z	Beta	0.8	0.1	0.98	0.94	0.99	1.00
ρ_τ	Beta	0.8	0.1	0.91	0.86	0.91	0.95
σ_{AC}	Uniform[0,0.2]			0.0101	0.0089	0.0101	0.0115
σ_{AH}	Uniform[0,0.2]			0.0196	0.0175	0.0195	0.0218
σ_{AK}	Uniform[0,0.2]			0.0111	0.0088	0.0110	0.0138
σ_j	Uniform[0,0.2]			0.0462	0.0274	0.0444	0.0771
σ_R	Uniform[0,0.2]			0.0034	0.0028	0.0033	0.0041
σ_z	Uniform[0,0.2]			0.0437	0.0132	0.0447	0.0768
σ_τ	Uniform[0,0.2]			0.0287	0.0200	0.0281	0.0397
σ_p	Uniform[0,0.2]			0.0047	0.0040	0.0047	0.0054
σ_s	Uniform[0,0.2]			0.0003	0.0002	0.0003	0.0004
$\sigma_{n,h}$	Gamma	0.001	0.01	0.1203	0.1078	0.1199	0.1360
$\sigma_{w,h}$	Gamma	0.001	0.01	0.0071	0.0063	0.0071	0.0081

$Note$: Results based on 200,000 draws from the Metropolis algorithm.

Business Cycle Properties of the Model

	Model			Data
	Median	2.5 percent	97.5 percent	
Standard deviation (percent)				
C	1.59	1.21	2.07	1.22
IH	8.50	6.79	10.63	9.97
IK	4.04	3.16	5.18	4.87
q	2.19	1.75	2.73	1.87
π	0.49	0.41	0.60	0.40
R	0.32	0.25	0.41	0.32
GDP	2.22	1.72	2.88	2.17
Correlations				
C, GDP	0.87	0.75	0.93	0.88
IH, GDP	0.64	0.43	0.79	0.78
IK, GDP	0.89	0.80	0.94	0.75
q, GDP	0.67	0.45	0.81	0.58
q, C	0.58	0.31	0.76	0.48
q, IH	0.48	0.20	0.69	0.41

Note: The statistics are computed using a random selection of 1,000 draws from the posterior distribution and, for each of them, 100 artificial time series of the main variables of length equal to that of the data, giving a sample of 100,000 series. The business cycle component of each simulated series is extracted using the HP-filter (with smoothing parameter set to 1,600). Summary statistics of the posterior distribution of the moments are computed by pooling together all the simulations. GDP denotes domestic demand excluding government purchases and investment, chained 2000 dollars.

Table 4

Decomposition of the Asymptotic Variance of the Forecast Error

	u_C	u_H	u_K	u_j	u_R	u_z	u_τ	u_p	u_s
C	18.8	1.0	0.9	0.3	18.7	8.9	18.9	22.1	9.3
IH	3.2	29.3	0.6	27.7	15.0	8.9	6.8	3.9	3.9
IK	9.3	0.1	34.4	0.1	14.5	7.5	9.0	17.6	6.7
q	8.6	19.0	0.6	26.3	11.4	10.9	6.0	12.5	3.8
π	4.7	0.1	0.5	0.4	5.2	2.6	2.9	59.4	23.9
R	3.9	0.6	9.3	3.9	19.6	5.3	5.4	17.1	33.4
GDP	15.8	0.9	8.2	2.1	21.5	1.5	19.1	21.9	9.0

$Note$: The table reports the posterior median value of the variance of the forecast errors at business cycle frequencies (extracted using the HP filter with smoothing parameter equal to 1600).

Table 5

Contribution to Housing Booms of the Estimated Shocks

Period		Percent change, q	Technology	Monetary Pol.	Housing Pref.
1976:I	1980:I	16.6	5.3	-3.0	12.4
1980:II	1985:IV	-12.3	-3.1	0.1	-5.7
2000:I	2005:I	10.1	3.1	2.6	7.9
2005:II	2006:IV	-0.3	-0.2	-2.7	0.5
		Percent change, IH			
1976:I	1980:I	0.7	-27.9	-13.1	34.2
1980:II	1985:IV	26.4	48.3	-2.4	-15.3
2000:I	2005:I	19.2	-5.6	11.7	22.2
2005:II	2006:IV	-15.5	-4.3	-11.4	-3.9

Note: Contribution of Technology Shocks (Non-Housing, Housing and Investment Specific), Monetary Shocks (Interest Rate and Inflation Objective) and Housing Preference Shocks to the housing market cycles reported in the text.

Table 6

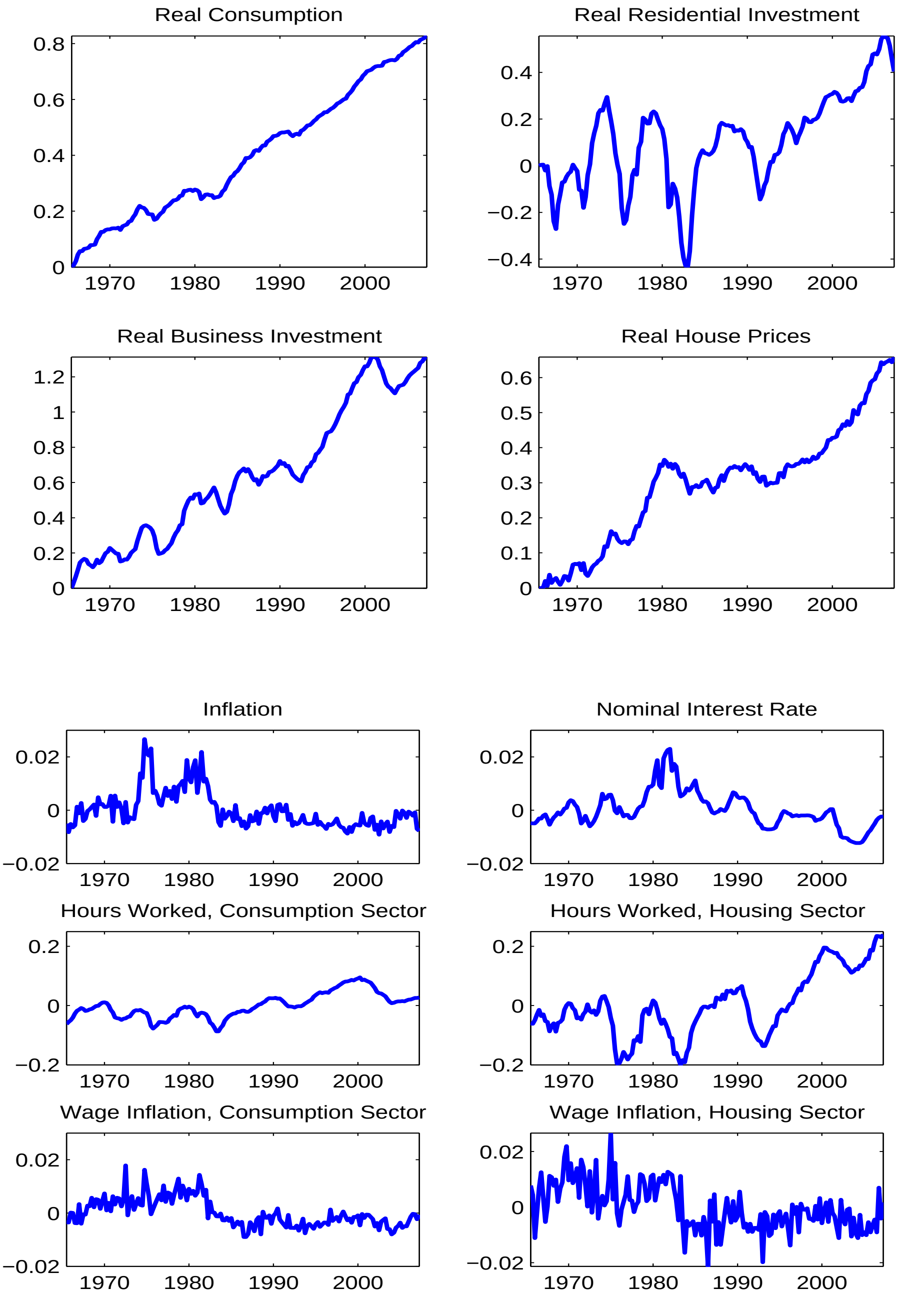
Subsample Estimates

	Structural Parameters					Shock Processes and Meas. Error			
	1965:I-1982:IV		1989:I-2006:IV			1965:I-1982:IV		1989:I-2006:IV	
	Median	St.Dev	Median	St.Dev		Median	St.Dev	Median	St.Dev
ε	0.39	0.05	0.42	0.05	ρ_{AC}	0.93	0.03	0.90	0.03
ε'	0.50	0.07	0.65	0.06	ρ_{AH}	0.99	0.01	0.995	0.004
η	0.51	0.10	0.49	0.09	ρ_{AK}	0.92	0.04	0.92	0.02
η'	0.49	0.10	0.49	0.10	ρ_j	0.88	0.04	0.94	0.02
ξ	0.86	0.11	0.78	0.12	ρ_z	0.96	0.03	0.89	0.04
ξ'	0.97	0.10	0.97	0.10	ρ_τ	0.83	0.06	0.86	0.06
$\phi_{k,c}$	13.30	1.77	12.30	1.74	σ_{AC}	0.0113	0.0012	0.0083	0.0008
$\phi_{k,h}$	10.24	2.48	9.74	2.45	σ_{AH}	0.0250	0.0024	0.0140	0.0013
α	0.68	0.05	0.80	0.03	σ_{AK}	0.0090	0.0018	0.0109	0.0015
r_R	0.59	0.05	0.74	0.03	σ_j	0.1028	0.0340	0.0561	0.014
r_π	1.49	0.08	1.50	0.09	σ_R	0.0047	0.0006	0.0015	0.0002
r_Y	0.38	0.07	0.34	0.07	σ_z	0.0263	0.0071	0.0112	0.002
θ_π	0.78	0.03	0.81	0.03	σ_τ	0.0327	0.0087	0.0184	0.007
ι_π	0.76	0.10	0.86	0.08	σ_p	0.0065	0.0009	0.0038	0.0005
$\theta_{w,c}$	0.77	0.03	0.85	0.02	σ_s	0.0006	0.0001	4E-5	1E-5
$\iota_{w,c}$	0.12	0.07	0.12	0.05	$\sigma_{n,h}$	0.1485	0.0127	0.0955	0.0084
$\theta_{w,h}$	0.90	0.02	0.91	0.02	$\sigma_{w,h}$	0.0085	0.0009	0.0041	0.0005
$\iota_{w,h}$	0.56	0.15	0.17	0.11					
ζ	0.54	0.13	0.87	0.07					
$100 \times \gamma_{AC}$	0.27	0.04	0.26	0.03					
$100 \times \gamma_{AH}$	-0.12	0.12	0.09	0.10					
$100 \times \gamma_{AK}$	0.28	0.06	0.41	0.04					

$Note$: Results based on 200,000 draws from the Metropolis algorithm. As explained in the text, the loan-to-value ratio m is set at 0.775 in the first subperiod, at 0.925 in the second subperiod.

Figure 1

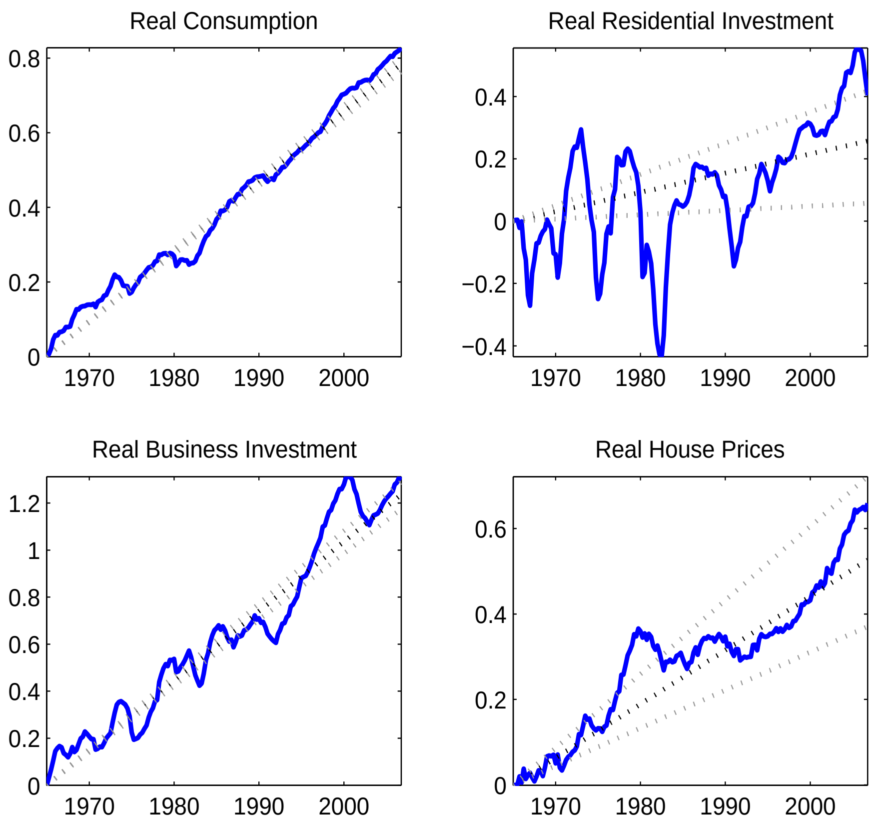
Data



Note: Consumption and investment are divided by population and log-transformed. The first observation (1965:I) is normalized to zero. Variables in the bottom panel are demeaned. Hours worked are divided by population.

Figure 2

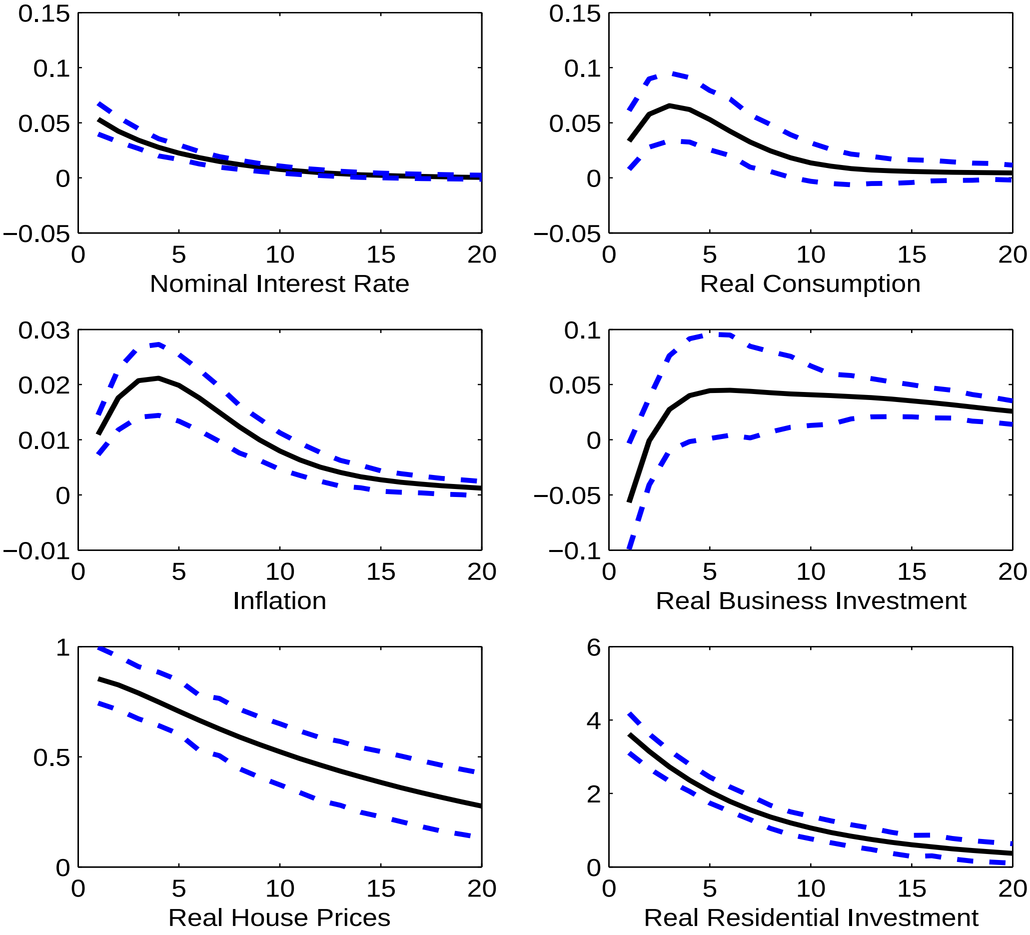
Estimated trends



Note: Dashed lines correspond to the median, 2.5 percentile and 97.5 percentile of the posterior distribution of the trends. Solid line: data.

Figure 3

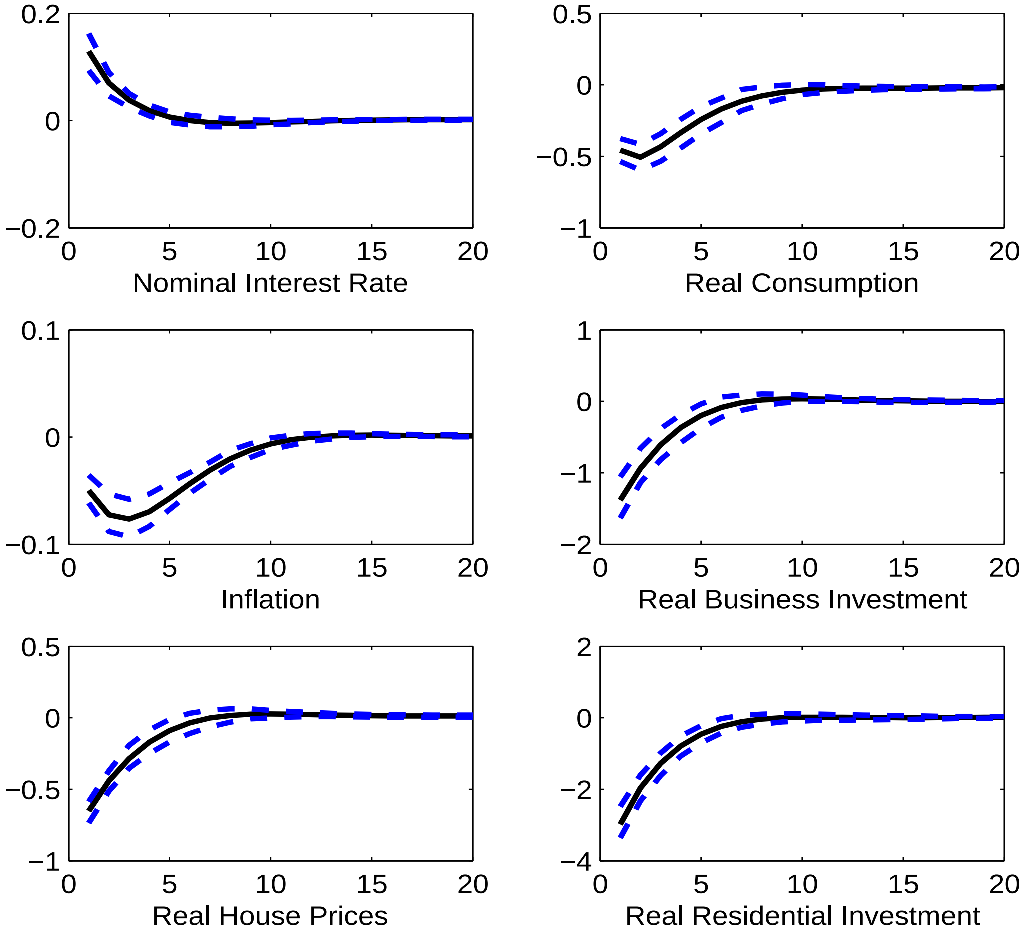
Impulse responses to a housing preference shock



Note: The solid line is the mean impulse response. The dashed lines are the 10 percent and 90 percent posterior intervals. The y-axis measures percent deviation from the steady state.

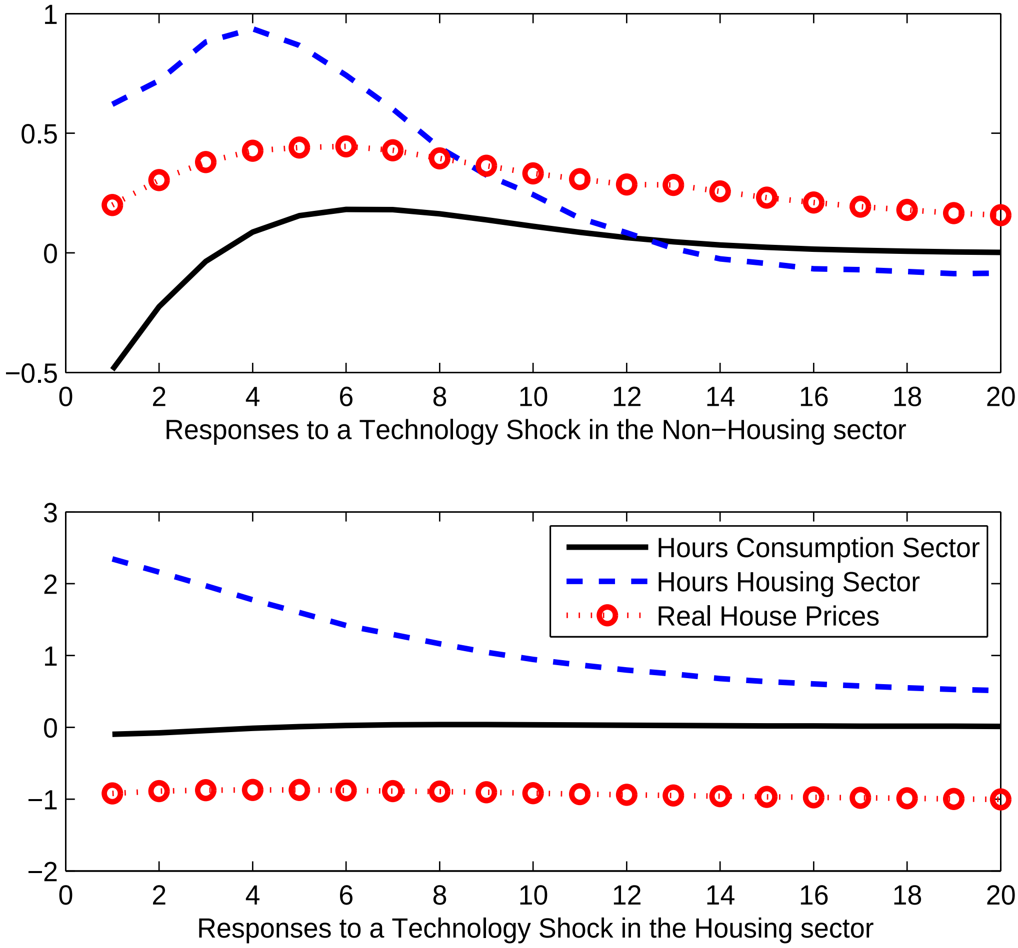
Figure 4

Impulse responses to a monetary policy shock



Note: The solid line is the mean impulse response. The dashed lines are the 10 percent and 90 percent posterior intervals. The y-axis measures percent deviation from the steady state.

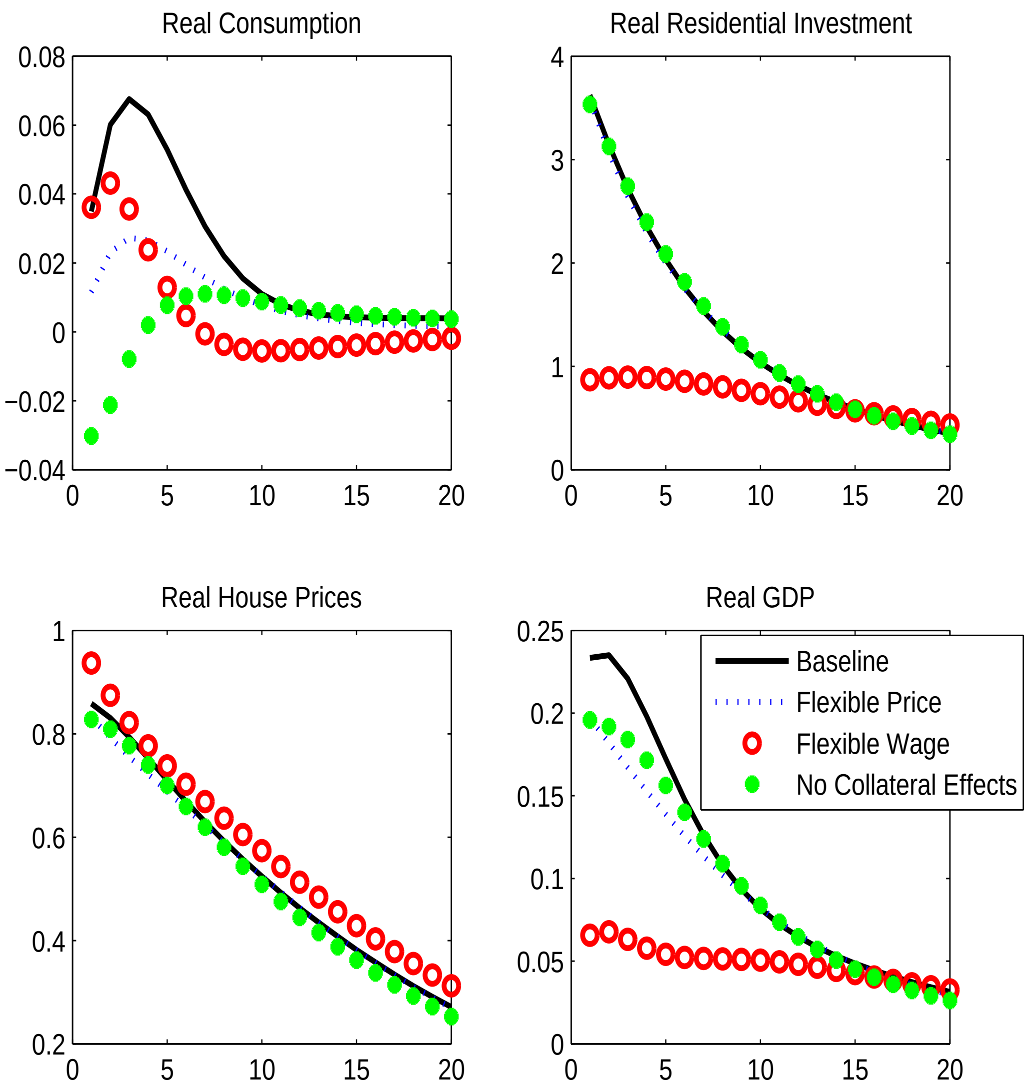
Impulse responses of sectoral hours and real house prices to technology shocks



Note: The y-axis measures percent deviation from the steady state.

Figure 6

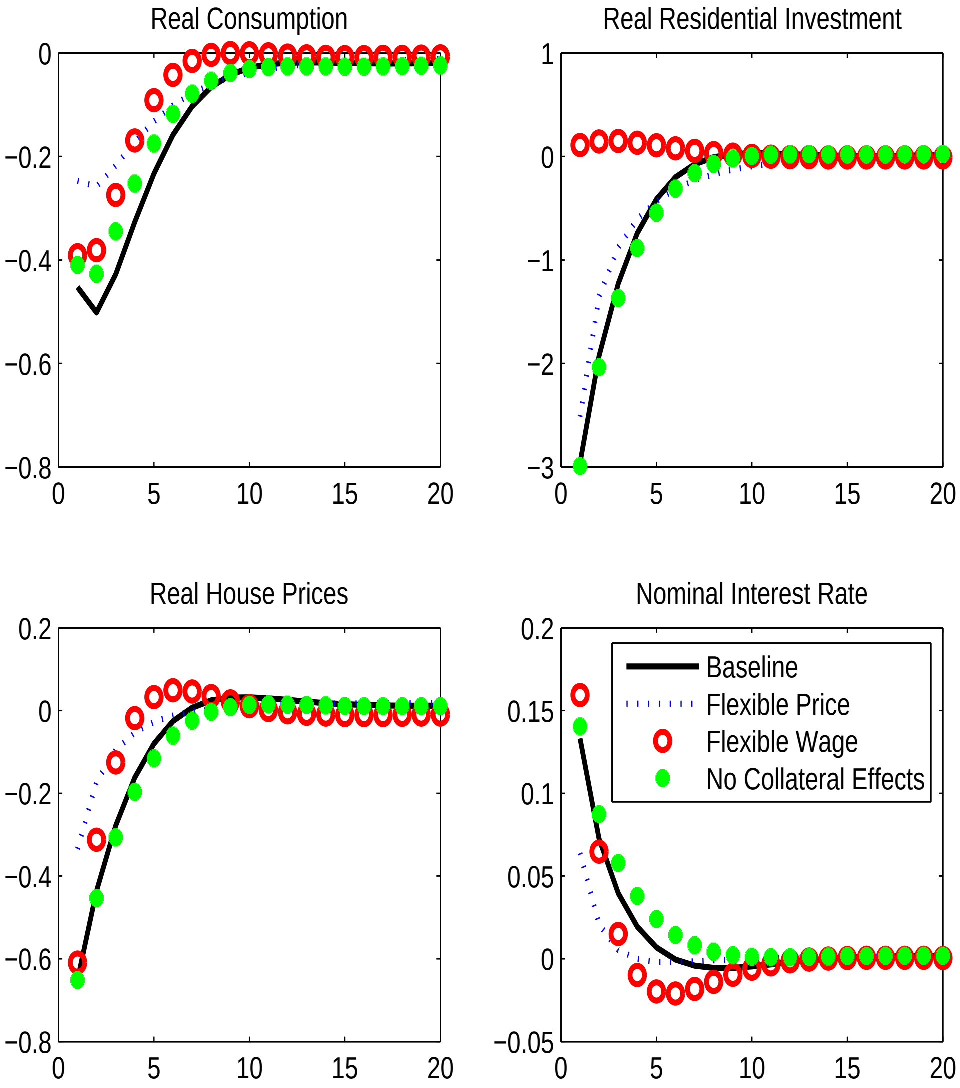
Impulse responses to a housing preference shock: sensitivity analysis



Note: The y-axis measures percent deviation from the steady state.

Figure 7

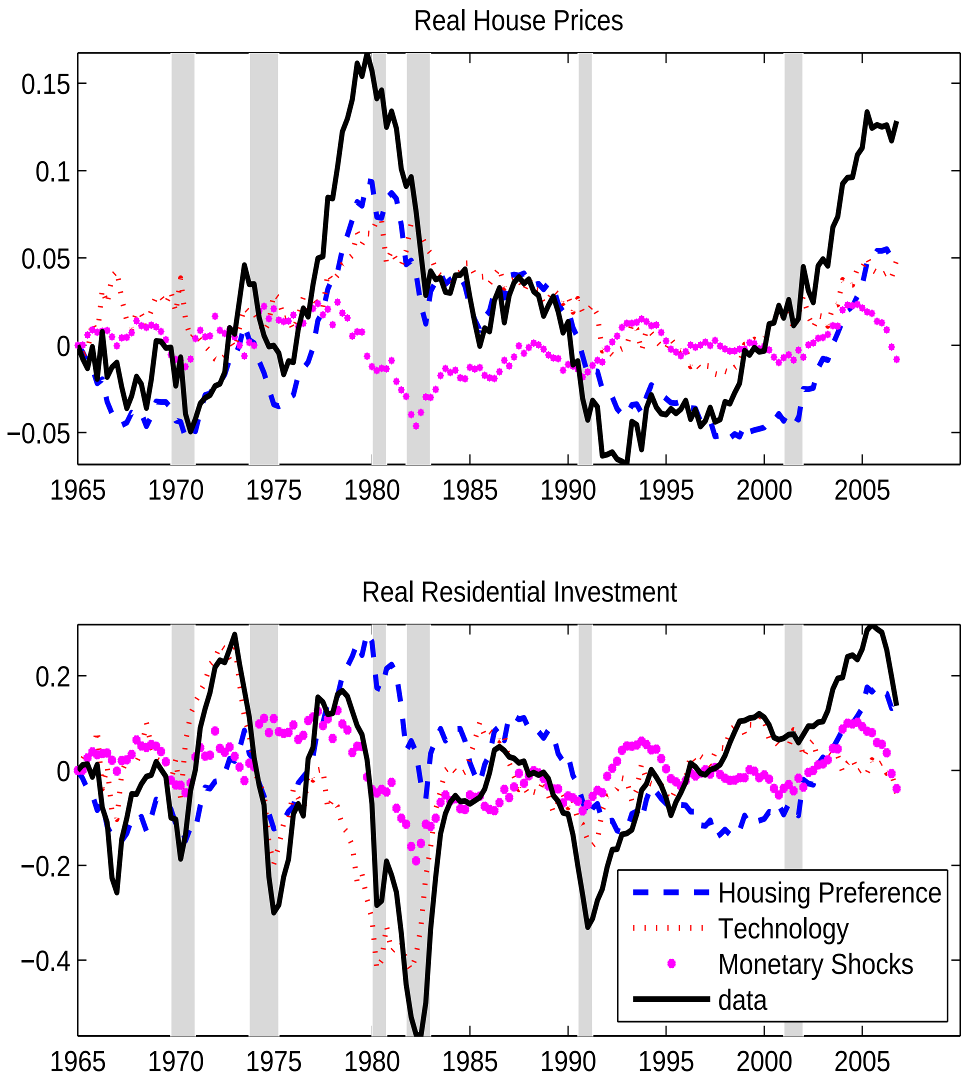
Impulse responses to a monetary policy shock: sensitivity analysis



Note: The y-axis measures percent deviation from the steady state.

Figure 8

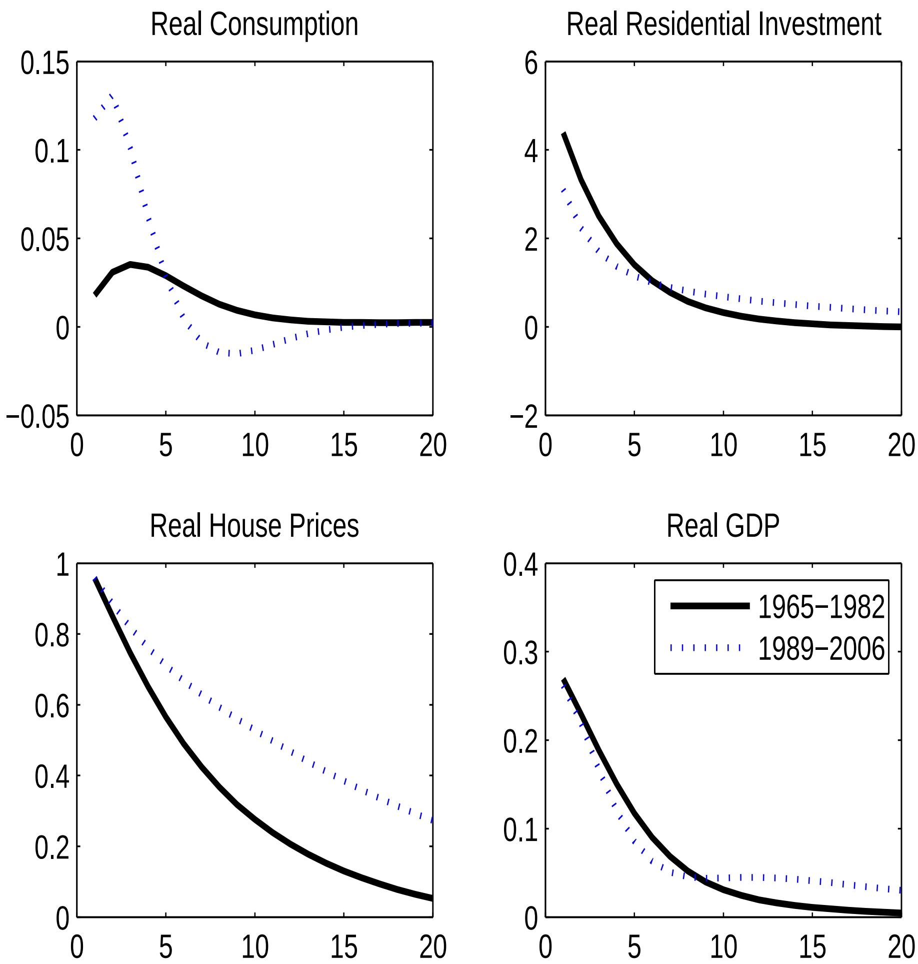
Historical decomposition of real house prices and real residential investment to housing preference shocks, technology shocks and monetary shocks.



Note: Monetary shocks include iid monetary policy shocks and changes in the inflation objective. Technology shocks include housing, non-housing and investment specific technology shocks. All series are in deviation from the estimated trend. Shaded areas indicate recessions as determined by NBER.

Figure 9

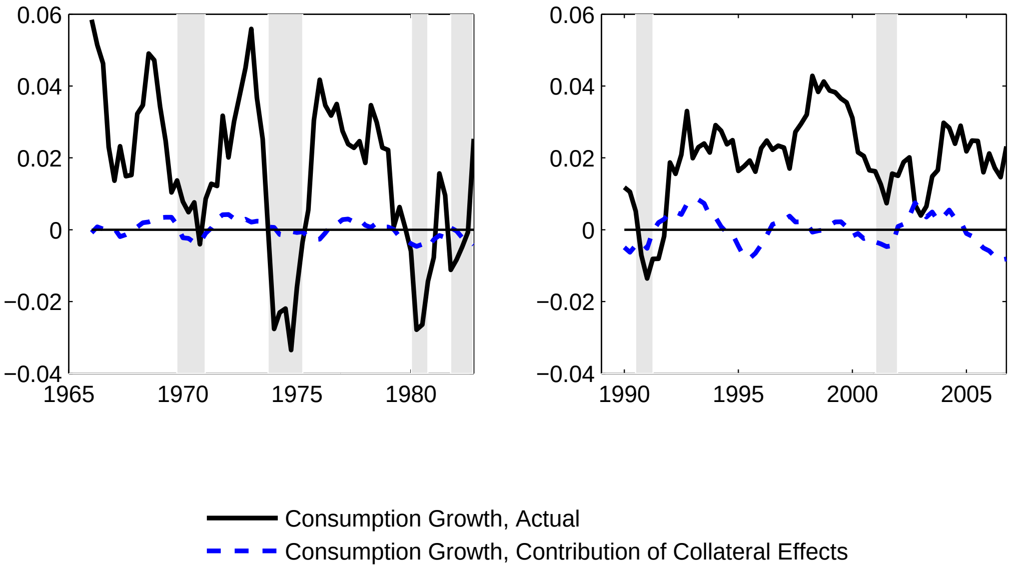
Impulse response functions to a housing preference shock in the two subsamples.



Note: The y-axis measures percent deviation from the steady state. The standard error of the preference shock in the second period is normalized so that both shocks affect house prices by the same amount in the first period.

Figure 10

The contribution of collateral effects to fluctuations in year-on-year consumption growth: results based on subsample estimates



Note: The contribution of collateral effects is calculated subtracting from actual consumption growth the path of simulated consumption growth obtained shutting off collateral effects (setting $\alpha = 1$ and $m = 0$). Shaded areas indicate recessions as determined by NBER.

Appendix A: Data and Sources

Aggregate Consumption: Real Personal Consumption Expenditure (seasonally adjusted, billions of chained 2000 dollars, Table 1.1.6), divided the civilian noninstitutional population (CNP16OV). Source: Bureau of Economic Analysis (BEA).

Business Fixed Investment: Real Private Nonresidential Fixed Investment (seasonally adjusted, billions of chained 2000 dollars, Table 1.1.6), divided by CNP16OV. Source: BEA.

Residential Investment: Real Private Residential Fixed Investment (seasonally adjusted, Billions of chained 2000 dollars, Table 1.1.6.), divided by CNP16OV, logged. Source: BEA.

Inflation: Quarter on quarter log differences in the implicit price deflator for the nonfarm business sector, demeaned. Source: Bureau of Labor Statistics (BLS).

Nominal Short-term Interest Rate: Nominal 3-month treasury bill rate (secondary market rate), expressed in quarterly units, demeaned. (Series ID: H15/H15/RIFSGFSM03_NM). Source: Board of Governors of the Federal Reserve System.

Real House Prices: Census bureau house price index (new one-family houses sold including value of lot) deflated with the implicit price deflator for the nonfarm business sector. Source: Census Bureau, `http://www.census.gov/const/price_sold_cust.xls`. A description of this price index is at `http://www.census.gov/const/www/descpi_sold.pdf`.

Hours in Consumption-good Sector: Total nonfarm payrolls (Series ID: PAYEMS in Saint Louis Fed Fred2) less all employees (Series ID: USCONS) in the construction sector, times average weekly hours of production workers (Series ID: CES0500000005), divided by CNP16OV . Demeaned. Source: BLS.

Hours in Housing Sector: All employees in the construction sector (Series ID: USCONS in Saint Louis Fed Fred2), times Average weekly hours of construction workers (series ID: CES2000000005, source: BLS), divided by CNP16OV. Demeaned.

Wage Inflation in Consumption-good Sector: quarterly changes in average hourly earnings of production or nonsupervisory workers on private nonfarm payrolls, total private, (Series ID: CES0500000008). Demeaned. Source: BLS.

Wage Inflation in Housing Sector: quarterly changes in average hourly earnings of production or nonsupervisory workers in the construction industry, (Series ID: CES2000000008). Demeaned. Source: BLS.

Appendix B: The Complete Model

We summarize here the complete set of non-linear equations describing the equilibrium conditions of the model. Let u_c denote the marginal utility of consumption, u_{nc} (u_{nh}) the marginal disutility of working in the goods (housing) sector, u_h the marginal utility of housing (with analogous definitions holding for impatient households). We drop the t subscript to denote the steady state value of a particular variable.

The budget constraint for patient households is:

$$\begin{aligned} c_t + \frac{k_{c,t}}{\mathsf{A}_{k,t}} + k_{h,t} + k_{b,t} + q_t h_t + p_{l,t} l_t - b_t = \frac{w_{c,t}}{X_{wc,t}} n_{c,t} + \frac{w_{h,t}}{X_{wh,t}} n_{h,t} \\ + \left(R_{c,t} z_{c,t} + \frac{1-\delta_{kc}}{\mathsf{A}_{k,t}} \right) k_{c,t-1} + \left(R_{h,t} z_{h,t} + 1 - \delta_{kh} \right) k_{h,t-1} + p_{b,t} k_{b,t} - \frac{R_{t-1} b_{t-1}}{\pi_t} \\ + \left(p_{l,t} + R_{l,t} \right) l_{t-1} + q_t \left(1 - \delta \right) h_{t-1} + Div_t - \phi_t - \frac{a\left(z_{c,t}\right)}{\mathsf{A}_{k,t}} k_{c,t-1} - a\left(z_{h,t}\right) k_{h,t-1}. \end{aligned} \quad \text{(A.1)}$$

The corresponding first order conditions for patient households are:

$$u_{c,t} q_t = u_{h,t} + \beta G_C E_t \left(u_{c,t+1} q_{t+1} \left(1 - \delta_h\right)\right) \quad \text{(A.2)}$$

$$u_{c,t} = \beta G_C E_t \left(u_{c,t+1} R_t / \pi_{t+1} \right) \quad \text{(A.3)}$$

$$u_{c,t} \left(\frac{1}{\mathsf{A}_{k,t}} + \frac{\partial \phi_{c,t}}{\partial k_{c,t}} \right) = \beta G_C E_t \left(u_{c,t+1} \left(R_{c,t+1} z_{c,t+1} - \frac{a\left(z_{c,t}\right)}{\mathsf{A}_{k,t}} + \frac{1-\delta_{kc}}{\mathsf{A}_{k,t+1}} - \frac{\partial \phi_{c,t+1}}{\partial k_{c,t}} \right)\right) \quad \text{(A.4)}$$

$$u_{c,t} \left(1 + \frac{\partial \phi_{h,t}}{\partial k_{h,t}} \right) = \beta G_C E_t \left(u_{c,t+1} \left(R_{h,t+1} z_{h,t+1} - a\left(z_{h,t}\right) + 1 - \delta_{kh} - \frac{\partial \phi_{h,t+1}}{\partial k_{h,t}} \right)\right) \quad \text{(A.5)}$$

$$u_{c,t} w_{c,t} = u_{nc,t} X_{wc,t} \quad \text{(A.6)}$$

$$u_{c,t} w_{h,t} = u_{nh,t} X_{wh,t} \quad \text{(A.7)}$$

$$u_{ct} \left(p_{bt} - 1 \right) = 0 \quad \text{(A.8)}$$

$$R_{ct} \mathsf{A}_{kt} = a'\left(z_{ct}\right) \quad \text{(A.9)}$$

$$R_{ht} = a'\left(z_{ht}\right) \quad \text{(A.10)}$$

$$u_{c,t} p_{l,t} = \beta G_C E_t u_{c,t+1} \left(p_{l,t+1} + R_{l,t+1} \right) \quad \text{(A.11)}$$

The budget and borrowing constraint for impatients are:

$$c'_t + q_t \left(h'_t - \left(1 - \delta_h\right) h'_{t-1} \right) = \frac{w'_{c,t}}{X'_{wc,t}} n'_{c,t} + \frac{w'_{h,t}}{X'_{wh,t}} n'_{h,t} + b'_t - \frac{R_{t-1}}{\pi_t} b'_{t-1} + Div'_t \quad \text{(A.12)}$$

$$b'_t = mE_t\left(q_{t+1}h'_t\pi_{t+1}/R_t\right) \tag{A.13}$$

and the first-order conditions are:

$$u_{c',t}q_t = u_{h',t} + \beta' G_C E_t\left(u_{c',t+1}\left(q_{t+1}\left(1-\delta_h\right)\right)\right) + E_t\left(\lambda_t \frac{m_t q_{t+1}\pi_{t+1}}{R_t}\right) \tag{A.14}$$

$$u_{c',t} = \beta' G_C E_t\left(u_{c',t+1}\frac{R_t}{\pi_{t+1}}\right) + \lambda_t \tag{A.15}$$

$$u_{c',t}w'_{c,t} = u_{nc',t}X'_{wc,t} \tag{A.16}$$

$$u_{c',t}w'_{h,t} = u_{nh',t}X'_{wh,t} \tag{A.17}$$

where λ_t denotes the multiplier on the borrowing constraint, which is greater than zero in a neighborhood of the equilibrium.

The production technologies are (normalizing land to unity):

$$Y_t = \left(\mathsf{A}_{c,t}\left(n^{\alpha}_{c,t}n'^{1-\alpha}_{c,t}\right)\right)^{1-\mu_c}\left(z_{c,t}k_{c,t-1}\right)^{\mu_c} \tag{A.18}$$

$$IH_t = \left(\mathsf{A}_{h,t}\left(n^{\alpha}_{h,t}n'^{1-\alpha}_{h,t}\right)\right)^{1-\mu_h-\mu_l-\mu_b} k^{\mu_b}_{b,t}\left(z_{h,t}k_{h,t-1}\right)^{\mu_h}. \tag{A.19}$$

The first-order conditions for the wholesale goods firms will be

$$(1-\mu_c)\,\alpha Y_t = X_t w_{c,t} n_{c,t} \tag{A.20}$$

$$(1-\mu_c)(1-\alpha)\,Y_t = X_t w'_{c,t} n'_{c,t} \tag{A.21}$$

$$(1-\mu_h-\mu_l-\mu_b)\,\alpha q_t IH_t = w_{h,t} n_{h,t} \tag{A.22}$$

$$(1-\mu_h-\mu_l-\mu_b)(1-\alpha)\,q_t IH_t = w'_{h,t} n'_{h,t} \tag{A.23}$$

$$\mu_c Y_t = X_t R_{c,t} z_{c,t} k_{c,t-1} \tag{A.24}$$

$$\mu_h q_t IH_t = R_{h,t} z_{h,t} k_{h,t-1} \tag{A.25}$$

$$\mu_l q_t IH_t = R_{l,t} l_{t-1} \tag{A.26}$$

$$\mu_b q_t IH_t = p_{b,t} k_{b,t}. \tag{A.27}$$

The Phillips curve is:

$$\log \pi_t - \iota_\pi \log \pi_{t-1} = \beta G_C \left(E_t \log \pi_{t+1} - \iota_\pi \log \pi_t\right) - \varepsilon_\pi \log \left(X_t/X\right) + \log u_{p,t}. \tag{A.28}$$

Denote with $\omega_{i,t}$ nominal wage inflation, that is $\omega_{i,t} = w_{i,t} - w_{i,t-1} + \pi_t$ for each sector-household pair. The four wage equations are:

$$\omega_{c,t} - \iota_{wc} \log \pi_{t-1} = \beta G_C \left(E_t \omega_{c,t+1} - \iota_{wc} \log \pi_t\right) - \varepsilon_{wc} \log \left(X_{wc,t}/X_{wc}\right) \tag{A.29}$$

$$\omega'_{c,t} - \iota_{wc} \log \pi_{t-1} = \beta' G_C \left(E_t \omega'_{c,t+1} - \iota_{wc} \log \pi_t\right) - \varepsilon'_{wc} \log \left(X_{wc,t}/X_{wc}\right) \tag{A.30}$$

$$\omega_{h,t} - \iota_{wh} \log \pi_{t-1} = \beta G_C \left(E_t \omega_{h,t+1} - \iota_{wh} \log \pi_t\right) - \varepsilon_{wh} \log \left(X_{wh,t}/X_{wh}\right) \tag{A.31}$$

$$\omega'_{h,t} - \iota_{wh} \log \pi_{t-1} = \beta' G_C \left(E_t \omega'_{h,t+1} - \iota_{wh} \log \pi_t\right) - \varepsilon'_{wh} \log \left(X_{wh,t}/X_{wh}\right) \tag{A.32}$$

where $\varepsilon_{wc} = \left(1 - \theta_{wc}\right)\left(1 - \beta G_C \theta_{wc}\right)/\theta_{wc}$ $\varepsilon'_{wc} = \left(1 - \theta_{wc}\right)\left(1 - \beta' G_C \theta_{wc}\right)/\theta_{wc}$ $\varepsilon_{wh} = \left(1 - \theta_{wc}\right)\left(1 - \beta G_C \theta_{wc}\right)/\theta_{wc}$ and $\varepsilon'_{wh} = \left(1 - \theta_{wh}\right)\left(1 - \beta' G_C \theta_{wh}\right)/\theta_{wh}$.

The Taylor rule is:

$$R_t = \left(R_{t-1}\right)^{r_R} \pi_t^{r_\pi(1-r_R)} \left(\frac{GDP_t}{G_C GDP_{t-1}}\right)^{r_Y(1-r_R)} \overline{rr}^{1-r_R} \frac{u_{R,t}}{\mathsf{s}_t} \tag{A.33}$$

where GDP_t is the sum of the value added of the two sectors, that is $GDP_t = Y_t - k_{b,t} + qIH_t$.

Two market clearing conditions are

$$C_t + IK_{c,t}/\mathsf{A}_{k,t} + IK_{h,t} + k_{b,t} = Y_t - \phi_t \tag{A.34}$$

$$h_t + h'_t - \left(1 - \delta_h\right)\left(h_{t-1} + h'_{t-1}\right) = IH_t. \tag{A.35}$$

By Walras' law, $b_t + b'_t = 0$. Finally, total land is normalized to unity:

$$l_t = 1 \tag{A.36}$$

In equilibrium, dividends paid to households equal respectively:

$$Div_t = \frac{X_t - 1}{X_t} Y_t + \frac{X_{wc,t} - 1}{X_{wc,t}} w_{c,t} n_{c,t} + \frac{X_{wh,t} - 1}{X_{wh,t}} w_{h,t} n_{h,t}$$

$$Div'_t = \frac{X'_{wc,t} - 1}{X'_{wc,t}} w'_{c,t} n'_{c,t} + \frac{X'_{wh,t} - 1}{X'_{wh,t}} w'_{h,t} n'_{h,t}.$$

In addition, we specify the functional forms for the capital adjustment cost and the utilization rate as:

$$
\begin{aligned}
\phi_t &= \frac{\phi_{kc}}{2G_{IK_c}}\left(\frac{k_{c,t}}{k_{c,t-1}} - G_{IK_c}\right)^2 \frac{k_{c,t-1}}{(1+\gamma_{AK})^t} + \frac{\phi_{kh}}{2G_{IK_h}}\left(\frac{k_{h,t}}{k_{h,t-1}} - G_{IK_h}\right)^2 k_{h,t-1} \\
a(z_{c,t}) &= R_c\left(\varpi z_{c,t}^2/2 + (1-\varpi) z_{c,t} + (\varpi/2 - 1)\right) \\
a(z_{h,t}) &= R_h\left(\varpi z_{h,t}^2/2 + (1-\varpi) z_{h,t} + (\varpi/2 - 1)\right)
\end{aligned}
$$

where R_c and R_h are the steady state values of the rental rates of the two types of capital. In the estimation of the model, we specify our prior for the curvature of the capacity utilization function in terms of $\zeta = \varpi/(1+\varpi)$. With this change of variables, ζ is bounded between 0 and 1, since ϖ is positive: values of ζ close to unity imply that the cost of adjusting capacity becomes arbitrarily large.

Equations A.1 to A.36 together with the values for IK_c, IK_h, GDP_t, ϕ_t, $a(z)$, Div_t and Div'_t and the laws of motion for the exogenous shocks (reported in the main text), define a system of 36 equations in the following variables:

Patient households: $c \quad h \quad k_c \quad k_h \quad k_b \quad n_c \quad n_h \quad b \quad l \quad z_c \quad z_h$

Impatient households: $c' \quad h' \quad n'_c \quad n'_h \quad b'$

Firms: $IH \quad Y$

Markets and prices: $q \quad R \quad \pi \quad \lambda \quad X \quad w_c \quad w_h \quad w'_c \quad w'_h \quad X_{wc} \quad X_{wh} \quad X'_{wh} \quad X'_{wh} \quad R_c \quad R_h \quad R_l \quad p_b \quad p_l$.

After detrending the variables by their balanced growth trends, we linearize the resulting system around the non-stochastic steady state and compute the decision rules using standard methods. A computational appendix (available at *http://www2.bc.edu/~iacoviel/research_files.htm*) describes these steps in more detail (the website also includes our data and replication files).

References

[1] Adolfson, Malin; Laseén, Stefan; Lindé, Jesper, and Villani, Mattias. "Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through." *Journal of International Economics*, 2007, 72, pp. 481-511.

[2] Aoki, Kosuke; Proudman James, and Vlieghe Jan. "House prices, Consumption, and Monetary Policy: a Financial Accelerator Approach." *Journal of Financial Intermediation*, 2004, 13, pp. 414-35.

[3] Barsky, Robert; House, Christopher, and Kimball, Miles. "Sticky Price Models and Durable Goods." *American Economic Review*, 2007, 97, pp. 984-998.

[4] Benhabib, Jess, Richard Rogerson, and Randall Wright, "Homework in Macroeconomics: Household Production and Aggregate Fluctuations." *Journal of Political Economy*, 99 (1991), pp. 1166-1187.

[5] Bernanke, Ben S., and Gertler, Mark. "Inside the Black Box: The Credit Channel of Monetary Policy Transmission." *Journal of Economic Perspectives*, Fall 1995, *9*(4), pp. 27-48.

[6] Bernanke Ben S.; Gertler Mark, and Gilchrist, Simon**.** "The Financial Accelerator in a Quantitative Business Cycle Framework", in John B. Taylor and Michael Woodford, eds., Handbook of Macroeconomics, Vol. 1C. Amsterdam: North-Holland, 1999, pp. 1341-1393.

[7] Bouakez, Hafedh; Cardia, Emanuela, and Ruge-Murcia, Francisco. "The Transmission of Monetary Policy in a Multi-Sector Economy." University of Montreal, mimeo, 2005.

[8] Brunnermeier, Markus K., and Julliard, Christian. "Money Illusion and Housing Frenzies." NBER Working Paper No. 12810, December 2006.

[9] Carlstrom, Charles T., and Fuerst, Timothy S. "Co-Movement in Sticky Price Models with Durable Goods." Federal Reserve Bank of Cleveland Working Paper 0614, November 2006.

[10] Campbell, Jeffrey, and Zvi Hercowitz, "The Role of Collateralized Household Debt in Macroeconomic Stabilization," NBER Working Paper 11330, 2005.

[11] Campbell, John Y., and Cocco, Joao F., "How do House Prices Affect Consumption? Evidence from Micro Data." *Journal of Monetary Economics*, 2007, 54, 591-621.

[12] Campbell, John Y., and Mankiw, Gregory N. "Consumption, Income and Interest Rates: Reinterpreting the Time Series Evidence." in Olivier J. Blanchard and Stanley Fisher, eds., *NBER Macroeconomics Annual*, Cambridge: MIT Press, 1989, pp. 185-216.

[13] Carrasco, Raquel; Labeaga, Jose M., and Lopez-Salido, J. David. "Consumption and Habits: Evidence from Panel Data." *Economic Journal*, January 2005, *115*(500), pp. 144-165.

[14] Case, Karl E.; Quigley, John M., and Shiller, Robert J. "Comparing Wealth Effects: The Stock Market versus the Housing Market."*Advances in Macroeconomics*, 2005, *5*(1), pp. 1-32.

[15] Christiano, Lawrence, Eichenbaum, Martin, and Charles Evans, "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy*, 2005, 113(1), pp. 1-46.

[16] Corrado, Carol; Lengermann, Paul; Bartelsman, Eric, and Beaulieu, J. Joseph. "Modeling Aggregate Productivity at a Disaggregate Level: New Results for U.S. Sectors and Industries." Board of Governors of the Federal Reserve System, mimeo, 2006.

[17] Davis, Morris A., and Heathcote, Jonathan. "Housing and the Business Cycle." *International Economic Review,* August 2005, *46*(3), pp. 751-784.

[18] Del Negro, Marco, and Christopher Otrok, "99 Luftballons: Monetary Policy and the House Price Boom Across U.S. States." *Journal of Monetary Economics*, forthcoming.

[19] Diaz, Antonia, and Luengo-Prado, Maria. "Precautionary Saving and Wealth Distribution with Durable Goods." Northeastern University, mimeo, 2005.

[20] DiCecio, Riccardo. "Comovement: It's Not A Puzzle." Federal Reserve Bank of St. Louis Working Paper No. 2005-035, June 2005.

[21] Dynan, Karen E.; Elmendorf, Douglas W. and and Sichel, Daniel. "Can Financial Innovation Help to Explain the Reduced Volatility of Economic Activity?." *Journal of Monetary Economics, 53*(1), pp. 123-150, January 2006.

[22] Edge, Rochelle; Kiley, Michael T. and Laforte, Jean-Philippe. "An Estimated DSGE Model of the US Economy with an Application to Natural Rate Measures." Board of Governors of the Federal Reserve System, mimeo, December 2005.

[23] Eichenbaum, Martin and Jonas D.M. Fisher, "Evaluating the Calvo Model of Sticky Prices." NBER Working Paper No. 10617, July 2004.

[24] Erceg, Christopher, and Levin, Andrew. “Optimal Monetary Policy with Durable Consumption Goods.” *Journal of Monetary Economics*, October 2006, *53*(7), pp. 1341-59.

[25] Fisher, Jonas D. M. “Why Does Household Investment Lead Business Investment over the Business Cycle?.”Federal Reserve Bank of Chicago Working Paper Series, No. 14, Revised 2006.

[26] Galí, Jordi, and Gertler Mark, “Inflation Dynamics: A Structural Econometric Analysis.” *Journal of Monetary Economics*, 1999, 44, pp. 195-222.

[27] Gallin, Joshua. “The Long-Run Relationship between House Prices and Rents.” Federal Reserve Board of Governors Finance and Economics Discussion Series Paper, September 2004.

[28] Gervais, Martin. “Housing Taxation and Capital Accumulation.” *Journal of Monetary Economics*, October 2002, *49*(7), pp. 1461-1489.

[29] Gort, Michael, Greenwood, Jeremy, and Rupert, Peter. “Measuring the Rate of Technological Progress in Structures.” *Review of Economic Dynamics*, 2, January 1999, pp. 207–30.

[30] Greenwood, Jeremy, and Hercowitz, Zvi. “The Allocation of Capital and Time over the Business Cycle.” *Journal of Political Economy*, December 1991, *99*(6), pp. 1188-214.

[31] Hornstein, Andreas, and Praschnik, Jack. “Intermediate Inputs and Sectoral Comovement in the Business Cycle.” *Journal of Monetary Economics*, December 1997, *40*(3), pp. 573-595.

[32] Horvath, Michael. “Sectoral Shocks and Aggregate Fluctuations.” *Journal of Monetary Economics*, February 2000, *45*(1), pp. 69-106.

[33] Iacoviello, Matteo. “House Prices, Borrowing Constraints and Monetary Policy in the Business Cycle.” *American Economic Review*, June 2005, *95*(3), pp. 739-764.

[34] Ireland, Peter N. “Technology Shocks and the Business Cycle: An Empirical Investigation.” *Journal of Economic Dynamics and Control*, May 2001, 25, pp. 703-719.

[35] Jappelli, Tullio. “Who Is Credit Constrained in the U.S. Economy?” *Quarterly Journal of Economics*, February 1990, *105*(1), pp. 219-234.

[36] Jorgenson, Dale W.; Gollop, Frank M., and Fraumeni, Barbara M. *Productivity and U.S. Economic Growth*. Harvard Economic Studies, vol. 159. Cambridge, MA: Harvard University Press, 1987.

[37] Lustig, Hanno N., and van Nieuwerburgh, Stijn G. "Housing Collateral, Consumption Insurance and Risk Premia: an Empirical Perspective." *Journal of Finance*, June 2005, *60*(3), pp. 1167-1219.

[38] Peterson, Brian. "Aggregate Uncertainty, Individual Uncertainty and Illiquidity: Housing and the Business Cycle." Indiana University, mimeo, 2004.

[39] Piazzesi, Monika, and Schneider, Martin. "Inflation and the Price of Real Assets." University of Chicago, mimeo, 2006.

[40] Piazzesi, Monika, and Schneider, Martin. "Inflation Illusion, Credit, and Asset Prices." 2007, forthcoming in John Y. Campbell (ed.), *Asset Prices and Monetary Policy*.

[41] Shiller, Robert. "Long-Term Perspectives on the Current Boom in House Prices."*Economist's Voice,* March 30, 2006.

[42] Smets, Frank, and Wouters, Raf. "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area." *Journal of the European Economic Association,* September 2003, *1*(5), pp. 1123-1175.

[43] Smets, Frank, and Wouters, Raf. "Shocks and Frictions in U.S. Business Cycles." *American Economic Review,* June 2007, *97*(3), pp. 586-606.

[44] Stiroh, Kevin. "Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?" *American Economic Review,* December 2002, *92*(5), pp. 1559-76.

[45] Sullivan, Daniel. "Trends in Real Wage Growth" *Chicago Fed Letter,* Number 115, March 1997.

[46] Thomas, Julia K. "Is Lumpy Investment Relevant for the Business Cycle?" *Journal of Political Economy,* June 2002, *110*(3) pp. 508-34.

[47] Topel, Robert H. and Rosen, Sherwin, "Housing Investment in the United States." *Journal of Political Economy*, August 1988, 96(4), pp. 718-40.

[48] Whelan, Karl."A Two-Sector Approach to Modeling U.S. NIPA Data." *Journal of Money, Credit, and Banking,* August 2003, *35*(4), pp. 627-656.

[49] Woodford, Michael. *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton, N.J.: Princeton University Press, 2003.

RECENTLY PUBLISHED "TEMI" (*)

N. 633 – *The reliability of EMU fiscal indicators: Risks and safeguards*, by Fabrizio Balassone, Daniele Franco and Stefania Zotteri (June 2007).

N. 634 – *Prezzi delle esportazioni, qualità dei prodotti e caratteristiche di impresa: un'analisi su un campione di imprese italiane*, by Matteo Bugamelli (June 2007).

N. 635 – *Openness to trade and industry cost dispersion: Evidence from a panel of Italian firms*, by Massimo Del Gatto, Gianmarco I.P. Ottaviano and Marcello Pagnini (June 2007).

N. 636 – *The weighting process in the SHIW*, by Ivan Faiella and Romina Gambacorta (June 2007).

N. 637 – *Emerging markets spreads and global financial conditions*, by Alessio Ciarlone, Paolo Piselli and Giorgio Trebeschi (June 2007).

N. 638 – *Comparative advantage patterns and domestic determinants in emerging countries: An analysis with a focus on technology*, by Daniela Marconi and Valeria Rolli (September 2007).

N. 639 – *The generation gap: Relative earnings of young and old workers in Italy*, by Alfonso Rosolia and Roberto Torrini (September 2007).

N. 640 – *The financing of small innovative firms: The Italian case*, by Silvia Magri (September 2007).

N. 641 – *Assessing financial contagion in the interbank market: Maximum entropy versus observed interbank lending patterns*, by Paolo Emilio Mistrulli (September 2007).

N. 642 – *Detecting long memory co-movements in macroeconomic time series, by* Gianluca Moretti (September 2007).

N. 643 – *The producer service sector in Italy: Long-term growth and its local determinants*, by Valter Di Giacinto and Giacinto Micucci (September 2007).

N. 644 – *Aggregazioni bancarie e specializzazione nel credito alle PMI: peculiarità per area geografica*, by Enrico Beretta and Silvia Del Prete (November 2007).

N. 645 – *Costs and benefits of creditor concentration: An empirical approach*, by Amanda Carmignani and Massimo Omiccioli (November 2007).

N. 646 – *Does the underground economy hold back financial deepening? Evidence from the Italian credit market*, by Giorgio Gobbi and Roberta Zizza (November 2007).

N. 647 – *Optimal monetary policy under low trend inflation*, by Guido Ascari and Tiziano Ropele (November 2007).

N. 648 – *Indici di bilancio e rendimenti di borsa: un'analisi per le banche italiane*, by Angela Romagnoli (November 2007).

N. 649 – *Bank profitability and taxation,* by Ugo Albertazzi and Leonardo Gambacorta (November 2007).

N. 650 – *Modelling bank lending in the euro area: A non-linear approach,* by Leonardo Gambacorta and Carlotta Rossi (November 2007).

N. 651 – *Revisiting poverty and welfare dominance,* by Gian Maria Tomat (November 2007).

N. 652 – *The general equilibrium effects of fiscal policy: Estimates for the euro area,* by Lorenzo Forni, Libero Monteforte and Luca Sessa (November 2007).

N. 653 – *Securitisation and the bank lending channel,* by Yener Altunbas, Leonardo Gambacorta and David Marqués (November 2007).

N. 654 – *The cyclical response of fiscal policies in the euro area. Why do results of empirical research differ so strongly?*, by Roberto Golinelli and Sandro Momigliano (January 2008).

N. 655 – *What's behind "inflation perceptions"? A survey-based analysis of Italian consumers*, by Paolo Del Giovane, Silvia Fabiani and Roberto Sabbatini (January 2008).

N. 656 – *The effects of fiscal policy in Italy: Evidence from a VAR model*, by Raffaela Giordano, Sandro Momigliano, Stefano Neri and Roberto Perotti (January 2008).

N. 657 – *Excess money growth and inflation dynamics*, by Barbara Roffia and Andrea Zaghini (January 2008).

N. 658 – *R&D and market structure in a horizontal differentiation framework*, by Davide Fantino (January 2008).

(*) Requests for copies should be sent to:
Banca d'Italia – Servizio Studi di struttura economica e finanziaria – Divisione Biblioteca e Archivio storico – Via Nazionale, 91 – 00184 Rome – (fax 0039 06 47922059). They are available on the Internet www.bancaditalia.it.

2004

P. ANGELINI and N. CETORELLI, *Gli effetti delle modifiche normative sulla concorrenza nel mercato creditizio*, in F. Panetta (eds.), Il sistema bancario negli anni novanta: gli effetti di una trasformazione, Bologna, il Mulino, **TD No. 380 (October 2000)**.

P. CHIADES and L. GAMBACORTA, *The Bernanke and Blinder model in an open economy: The Italian case*, German Economic Review, Vol. 5, 1, pp. 1-34, **TD No. 388 (December 2000)**.

M. BUGAMELLI and P. PAGANO, *Barriers to investment in ICT*, Applied Economics, Vol. 36 , 20, pp. 2275-2286, **TD No. 420 (October 2001)**.

F. BUSETTI, *Preliminary data and econometric forecasting: An application with the Bank of Italy quarterly model*, CEPR Discussion Paper, 4382, **TD No. 437 (December 2001)**.

A. BAFFIGI, R. GOLINELLI and G. PARIGI, *Bridge models to forecast the euro area GDP*, International Journal of Forecasting, Vol. 20, 3, pp. 447-460, **TD No. 456 (December 2002)**.

D. AMEL, C. BARNES, F. PANETTA and C. SALLEO, *Consolidation and efficiency in the financial sector: A review of the international evidence*, Journal of Banking and Finance, Vol. 28, 10, pp. 2493-2519, **TD No. 464 (December 2002)**.

M. PAIELLA, *Heterogeneity in financial market participation: Appraising its implications for the C-CAPM*, Review of Finance, Vol. 8, 3, pp. 445-480, **TD No. 473 (June 2003)**.

F. CINGANO and F. SCHIVARDI, *Identifying the sources of local productivity growth*, Journal of the European Economic Association, Vol. 2, 4, pp. 720-742, **TD No. 474 (June 2003)**.

E. BARUCCI, C. IMPENNA and R. RENÒ, *Monetary integration, markets and regulation*, Research in Banking and Finance, 4, pp. 319-360, **TD No. 475 (June 2003)**.

G. ARDIZZI, *Cost efficiency in the retail payment networks: first evidence from the Italian credit card system*, Rivista di Politica Economica, Vol. 94, 3, pp. 51-82, **TD No. 480 (June 2003)**.

E. BONACCORSI DI PATTI and G. DELL'ARICCIA, *Bank competition and firm creation*, Journal of Money Credit and Banking, Vol. 36, 2, pp. 225-251, **TD No. 481 (June 2003)**.

R. GOLINELLI and G. PARIGI, *Consumer sentiment and economic activity: a cross country comparison*, Journal of Business Cycle Measurement and Analysis, Vol. 1, 2, pp. 147-170, **TD No. 484 (September 2003)**.

L. GAMBACORTA and P. E. MISTRULLI, *Does bank capital affect lending behavior?*, Journal of Financial Intermediation, Vol. 13, 4, pp. 436-457, **TD No. 486 (September 2003)**.

F. SPADAFORA, *Il pilastro privato del sistema previdenziale: il caso del Regno Unito*, Economia Pubblica, 34, 5, pp. 75-114, **TD No. 503** (**June 2004**).

C. BENTIVOGLI and F. QUINTILIANI, *Tecnologia e dinamica dei vantaggi comparati: un confronto fra quattro regioni italiane*, in C. Conigliani (eds.), *Tra sviluppo e stagnazione: l'economia dell'Emilia-Romagna*, Bologna, Il Mulino, **TD No. 522 (October 2004)**.

R. BRONZINI, FDI Inflows, *Agglomeration and host country firms' size: Evidence from Italy*, Regional Studies, Vol. 41, 7, pp. 963-978, **TD No. 526 (December 2004).**

G. GOBBI and F. LOTTI, *Entry decisions and adverse selection: An empirical analysis of local credit markets,* Journal of Financial Services Research, Vol. 26, 3, pp. 225-244, **TD No. 535 (December 2004)**.

E. GAIOTTI and F. LIPPI, *Pricing behavior and the introduction of the euro: Evidence from a panel of restaurants*, Giornale degli Economisti e Annali di Economia, 2004, Vol. 63, 3-4, pp. 491-526, **TD No. 541 (February 2005)**.

L. GAMBACORTA, *How do banks set interest rates?,* NBER Working Paper, 10295, **TD No. 542 (February 2005).**

A. CICCONE, F. CINGANO and P. CIPOLLONE, *The private and social return to schooling in Italy*, Giornale degli Economisti e Annali di Economia, Vol. 63, 3-4, pp. 413-444, **TD No. 569 (January 2006)**.

2005

L. DEDOLA and F. LIPPI, *The monetary transmission mechanism: Evidence from the industries of 5 OECD countries,* European Economic Review, 2005, Vol. 49, 6, pp. 1543-1569, **TD No. 389 (December 2000)**.

D. Jr. MARCHETTI and F. NUCCI, *Price stickiness and the contractionary effects of technology shocks.* European Economic Review, Vol. 49, 5, pp. 1137-1164, **TD No. 392 (February 2001)**.

G. CORSETTI, M. PERICOLI and M. SBRACIA, *Some contagion, some interdependence: More pitfalls in tests of financial contagion,* Journal of International Money and Finance, Vol. 24, 8, pp. 1177-1199, **TD No. 408 (June 2001)**.

GUISO L., L. PISTAFERRI and F. SCHIVARDI, *Insurance within the firm*. Journal of Political Economy, Vol. 113, 5, pp. 1054-1087, **TD No. 414** (**August 2001**)

R. CRISTADORO, M. FORNI, L. REICHLIN and G. VERONESE, *A core inflation indicator for the euro area,* Journal of Money, Credit, and Banking, Vol. 37, 3, pp. 539-560, **TD No. 435 (December 2001)**.

F. ALTISSIMO, E. GAIOTTI and A. LOCARNO, *Is money informative? Evidence from a large model used for policy analysis,* Economic & Financial Modelling, Vol. 22, 2, pp. 285-304, **TD No. 445 (July 2002)**.

G. DE BLASIO and S. DI ADDARIO, *Do workers benefit from industrial agglomeration?* Journal of regional Science, Vol. 45, (4), pp. 797-827, **TD No. 453 (October 2002).**

G. DE BLASIO and S. DI ADDARIO, *Salari, imprenditorialità e mobilità nei distretti industriali italiani,* in L. F. Signorini, M. Omiccioli (eds.), *Economie locali e competizione globale: il localismo industriale italiano di fronte a nuove sfide*, Bologna, il Mulino, **TD No. 453 (October 2002).**

R. TORRINI, *Cross-country differences in self-employment rates: The role of institutions,* Labour Economics, Vol. 12, 5, pp. 661-683, **TD No. 459 (December 2002)**.

A. CUKIERMAN and F. LIPPI, *Endogenous monetary policy with unobserved potential output,* Journal of Economic Dynamics and Control, Vol. 29, 11, pp. 1951-1983, **TD No. 493 (June 2004)**.

M. OMICCIOLI, *Il credito commerciale: problemi e teorie,* in L. Cannari, S. Chiri e M. Omiccioli (eds.), *Imprese o intermediari? Aspetti finanziari e commerciali del credito tra imprese in Italia,* Bologna, Il Mulino, **TD No. 494 (June 2004)**.

L. CANNARI, S. CHIRI and M. OMICCIOLI, *Condizioni di pagamento e differenziazione della clientela,* in L. Cannari, S. Chiri e M. Omiccioli (eds.), *Imprese o intermediari? Aspetti finanziari e commerciali del credito tra imprese in Italia*, Bologna, Il Mulino, **TD No. 495 (June 2004)**.

P. FINALDI RUSSO and L. LEVA, *Il debito commerciale in Italia: quanto contano le motivazioni finanziarie?,* in L. Cannari, S. Chiri e M. Omiccioli (eds.), *Imprese o intermediari? Aspetti finanziari e commerciali del credito tra imprese in Italia*, Bologna, Il Mulino, **TD No. 496 (June 2004)**.

A. CARMIGNANI, *Funzionamento della giustizia civile e struttura finanziaria delle imprese: il ruolo del credito commerciale,* in L. Cannari, S. Chiri e M. Omiccioli (eds.), *Imprese o intermediari? Aspetti finanziari e commerciali del credito tra imprese in Italia*, Bologna, Il Mulino, **TD No. 497 (June 2004)**.

G. DE BLASIO, *Credito commerciale e politica monetaria: una verifica basata sull'investimento in scorte,* in L. Cannari, S. Chiri e M. Omiccioli (eds.), *Imprese o intermediari? Aspetti finanziari e commerciali del credito tra imprese in Italia,* Bologna, Il Mulino, **TD No. 498 (June 2004)**.

G. DE BLASIO, *Does trade credit substitute bank credit? Evidence from firm-level data.* Economic notes, Vol. 34, 1, pp. 85-112, **TD No. 498 (June 2004).**

A. DI CESARE, *Estimating expectations of shocks using option prices,* The ICFAI Journal of Derivatives Markets, Vol. 2, 1, pp. 42-53, **TD No. 506 (July 2004).**

M. BENVENUTI and M. GALLO, *Il ricorso al "factoring" da parte delle imprese italiane,* in L. Cannari, S. Chiri e M. Omiccioli (eds.), *Imprese o intermediari? Aspetti finanziari e commerciali del credito tra imprese in Italia*, Bologna, Il Mulino, **TD No. 518 (October 2004)**.

L. CASOLARO and L. GAMBACORTA, *Redditività bancaria e ciclo economico,* Bancaria, Vol. 61, 3, pp. 19-27, **TD No. 519 (October 2004)**.

F. PANETTA, F. SCHIVARDI and M. SHUM, *Do mergers improve information? Evidence from the loan market,* CEPR Discussion Paper, 4961, **TD No. 521 (October 2004)**.

P. DEL GIOVANE and R. SABBATINI, *La divergenza tra inflazione rilevata e percepita in Italia,* in P. Del Giovane, F. Lippi e R. Sabbatini (eds.), *L'euro e l'inflazione: percezioni, fatti e analisi*, Bologna, Il Mulino, **TD No. 532 (December 2004).**

R. TORRINI, *Quota dei profitti e redditività del capitale in Italia: un tentativo di interpretazione*, Politica economica, Vol. 21, 1, pp. 7-41, **TD No. 551 (June 2005)**.

M. OMICCIOLI, *Il credito commerciale come "collateral"*, in L. Cannari, S. Chiri, M. Omiccioli (eds.), Imprese o intermediari? Aspetti finanziari e commerciali del credito tra imprese in Italia, Bologna, il Mulino, **TD No. 553 (June 2005)**.

L. CASOLARO, L. GAMBACORTA and L. GUISO, *Regulation, formal and informal enforcement and the development of the household loan market. Lessons from Italy*, in Bertola G., Grant C. and Disney R. (eds.) The Economics of Consumer Credit: European Experience and Lessons from the US, Boston, MIT Press, **TD No. 560 (September 2005)**.

S. DI ADDARIO and E. PATACCHINI, *Lavorare in una grande città paga, ma poco*, in Brucchi Luchino (ed.), *Per un'analisi critica del mercato del lavoro*, Bologna , Il Mulino, **TD No. 570 (January 2006)**.

P. ANGELINI and F. LIPPI, *Did inflation really soar after the euro changeover? Indirect evidence from ATM withdrawals*, CEPR Discussion Paper, 4950, **TD No. 581 (March 2006)**.

S. FEDERICO, *Internazionalizzazione produttiva, distretti industriali e investimenti diretti all'estero,* in L. F. Signorini, M. Omiccioli (eds.), *Economie locali e competizione globale: il localismo industriale italiano di fronte a nuove sfide*, Bologna, il Mulino, **TD No. 592 (October 2002).**

S. DI ADDARIO, *Job search in thick markets: Evidence from Italy*, Oxford Discussion Paper 235, Department of Economics Series, **TD No. 605 (December 2006)**.

2006

F. BUSETTI, *Tests of seasonal integration and cointegration in multivariate unobserved component models,* Journal of Applied Econometrics, Vol. 21, 4, pp. 419-438, **TD No. 476 (June 2003).**

C. BIANCOTTI, *A polarization of inequality? The distribution of national Gini coefficients 1970-1996*, Journal of Economic Inequality, Vol. 4, 1, pp. 1-32, **TD No. 487 (March 2004)**.

L. CANNARI and S. CHIRI, *La bilancia dei pagamenti di parte corrente Nord-Sud (1998-2000)*, in L. Cannari, F. Panetta (a cura di), Il sistema finanziario e il Mezzogiorno: squilibri strutturali e divari finanziari, Bari, Cacucci, **TD No. 490 (March 2004).**

M. BOFONDI and G. GOBBI, *Information barriers to entry into credit markets,* Review of Finance, Vol. 10, 1, pp. 39-67, **TD No. 509 (July 2004).**

FUCHS W. and LIPPI F., *Monetary union with voluntary participation*, Review of Economic Studies, Vol. 73, pp. 437-457 **TD No. 512 (July 2004).**

GAIOTTI E. and A. SECCHI, *Is there a cost channel of monetary transmission? An investigation into the pricing behaviour of 2000 firms*, Journal of Money, Credit and Banking, Vol. 38, 8, pp. 2013-2038 **TD No. 525 (December 2004)**.

A. BRANDOLINI, P. CIPOLLONE and E. VIVIANO, *Does the ILO definition capture all unemployment?*, Journal of the European Economic Association, Vol. 4, 1, pp. 153-179, **TD No. 529 (December 2004)**.

A. BRANDOLINI, L. CANNARI, G. D'ALESSIO and I. FAIELLA, *Household wealth distribution in Italy in the 1990s*, in E. N. Wolff (ed.) International Perspectives on Household Wealth, Cheltenham, Edward Elgar, **TD No. 530 (December 2004)**.

P. DEL GIOVANE and R. SABBATINI, *Perceived and measured inflation after the launch of the Euro: Explaining the gap in Italy*, Giornale degli economisti e annali di economia, Vol. 65, 2 , pp. 155-192, **TD No. 532 (December 2004).**

M. CARUSO, *Monetary policy impulses, local output and the transmission mechanism*, Giornale degli economisti e annali di economia, Vol. 65, 1, pp. 1-30, **TD No. 537 (December 2004).**

L. GUISO and M. PAIELLA, *The role of risk aversion in predicting individual behavior, In P. A. Chiappori e C. Gollier (eds.) Competitive Failures in Insurance Markets: Theory and Policy Implications, Monaco, CESifo*, **TD No. 546 (February 2005).**

G. M. TOMAT, *Prices product differentiation and quality measurement: A comparison between hedonic and matched model methods*, Research in Economics, Vol. 60, 1, pp. 54-68, **TD No. 547 (February 2005)**.

F. LOTTI, E. SANTARELLI and M. VIVARELLI, *Gibrat's law in a medium-technology industry: Empirical evidence for Italy*, in E. Santarelli (ed.), Entrepreneurship, Growth, and Innovation: the Dynamics of Firms and Industries, New York, Springer, **TD No. 555 (June 2005).**

F. BUSETTI, S. FABIANI and A. HARVEY, *Convergence of prices and rates of inflation*, Oxford Bulletin of Economics and Statistics, Vol. 68, 1, pp. 863-878, **TD No. 575 (February 2006).**

M. CARUSO, *Stock market fluctuations and money demand in Italy, 1913 - 2003*, Economic Notes, Vol. 35, 1, pp. 1-47, **TD No. 576 (February 2006)**.

S. IRANZO, F. SCHIVARDI and E. TOSETTI, *Skill dispersion and productivity: An analysis with matched data,* CEPR Discussion Paper, 5539, **TD No. 577 (February 2006).**

R. BRONZINI and G. DE BLASIO, *Evaluating the impact of investment incentives: The case of Italy's Law 488/92.* Journal of Urban Economics, Vol. 60, 2, pp. 327-349, **TD No. 582 (March 2006).**

R. BRONZINI and G. DE BLASIO, *Una valutazione degli incentivi pubblici agli investimenti,* Rivista Italiana degli Economisti , Vol. 11, 3, pp. 331-362, **TD No. 582 (March 2006).**

A. DI CESARE, *Do market-based indicators anticipate rating agencies? Evidence for international banks,* Economic Notes, Vol. 35, pp. 121-150, **TD No. 593 (May 2006).**

L. DEDOLA and S. NERI, *What does a technology shock do? A VAR analysis with model-based sign restrictions*, Journal of Monetary Economics, Vol. 54, 2, pp. 512-549, **TD No. 607 (December 2006)**.

R. GOLINELLI and S. MOMIGLIANO, *Real-time determinants of fiscal policies in the euro area*, Journal of Policy Modeling, Vol. 28, 9, pp. 943-964, **TD No. 609 (December 2006).**

P. ANGELINI, S. GERLACH, G. GRANDE, A. LEVY, F. PANETTA, R. PERLI,S. RAMASWAMY, M. SCATIGNA and P. YESIN, *The recent behaviour of financial market volatility*, BIS Papers, 29, **QEF No. 2 (August 2006)**.

2007

L. CASOLARO. and G. GOBBI, *Information technology and productivity changes in the banking industry*, Economic Notes, Vol. 36, 1, pp. 43-76, **TD No. 489 (March 2004)**.

M. PAIELLA, *Does wealth affect consumption? Evidence for Italy*, Journal of Macroeconomics, Vol. 29, 1, pp. 189-205, **TD No. 510 (July 2004).**

F. LIPPI. and S. NERI, *Information variables for monetary policy in a small structural model of the euro area*, Journal of Monetary Economics, Vol. 54, 4, pp. 1256-1270, **TD No. 511 (July 2004)**.

A. ANZUINI and A. LEVY, *Monetary policy shocks in the new EU members: A VAR approach,* Applied Economics, Vol. 39, 9, pp. 1147-1161, **TD No. 514 (July 2004)**.

R. BRONZINI, *FDI Inflows, agglomeration and host country firms' size: Evidence from Italy*, Regional Studies, Vol. 41, 7, pp. 963-978, **TD No. 526 (December 2004).**

L. MONTEFORTE, *Aggregation bias in macro models: Does it matter for the euro area?*, Economic Modelling, 24, pp. 236-261, **TD No. 534 (December 2004)**.

A. DALMAZZO and G. DE BLASIO, *Production and consumption externalities of human capital: An empirical study for Italy*, Journal of Population Economics, Vol. 20, 2, pp. 359-382, **TD No. 554 (June 2005).**

M. BUGAMELLI and R. TEDESCHI, *Le strategie di prezzo delle imprese esportatrici italiane,* Politica Economica, v. 3, pp. 321-350, **TD No. 563 (November 2005)**.

L. GAMBACORTA and S. IANNOTTI, *Are there asymmetries in the response of bank interest rates to monetary shocks?,* Applied Economics, v. 39, 19, pp. 2503-2517, **TD No. 566 (November 2005).**

S. DI ADDARIO and E. PATACCHINI, *Wages and the city. Evidence from Italy*, Development Studies Working Papers 231, Centro Studi Luca d'Agliano, **TD No. 570 (January 2006)**.

P. ANGELINI and F. LIPPI, *Did prices really soar after the euro cash changeover? Evidence from ATM withdrawals*, International Journal of Central Banking, Vol. 3, 4, pp. 1-22, **TD No. 581 (March 2006)**.

A. LOCARNO, *Imperfect knowledge, adaptive learning and the bias against activist monetary policies*, International Journal of Central Banking, v. 3, 3, pp. 47-85, **TD No. 590 (May 2006)**.

F. LOTTI and J. MARCUCCI, *Revisiting the empirical evidence on firms' money demand*, Journal of Economics and Business, Vol. 59, 1, pp. 51-73, **TD No. 595 (May 2006)**.

P. CIPOLLONE and A. ROSOLIA, *Social interactions in high school: Lessons from an earthquake*, American Economic Review, Vol. 97, 3, pp. 948-965, **TD No. 596 (September 2006).**

A. BRANDOLINI, *Measurement of income distribution in supranational entities: The case of the European Union,* in S. P. Jenkins e J. Micklewright (eds.), Inequality and Poverty Re-examined, Oxford, Oxford University Press, **TD No. 623 (April 2007).**

M. PAIELLA, *The foregone gains of incomplete portfolios*, Review of Financial Studies, Vol. 20, 5, pp. 1623-1646, **TD No. 625 (April 2007).**

K. BEHRENS, A. R. LAMORGESE, G.I.P. OTTAVIANO and T. TABUCHI, *Changes in transport and non transport costs: local vs. global impacts in a spatial network*, Regional Science and Urban Economics, Vol. 37, 6, pp. 625-648, **TD No. 628 (April 2007).**

R. GIORDANO, S. MOMIGLIANO, S. NERI and R. PEROTTI, *The Effects of Fiscal Policy in Italy: Evidence from a VAR Model*, European Journal of Political Economy, Vol. 23, 3, pp. 707-733, **TD No. 656 (December 2007).**

FORTHCOMING

P. ANGELINI, *Liquidity and announcement effects in the euro area*, Giornale degli economisti e annali di economia, **TD No. 451 (October 2002).**

S. MAGRI, *Italian households' debt: The participation to the debt market and the size of the loan*, Empirical Economics, **TD No. 454 (October 2002)**.

L. MONTEFORTE and S. SIVIERO, *The Economic Consequences of Euro Area Modelling Shortcuts*, Applied Economics, **TD No. 458 (December 2002).**

L. GUISO and M. PAIELLA,, *Risk aversion, wealth and background risk*, Journal of the European Economic Association, **TD No. 483 (September 2003).**

G. FERRERO, *Monetary policy, learning and the speed of convergence*, Journal of Economic Dynamics and Control, **TD No. 499 (June 2004).**

F. SCHIVARDI e R. TORRINI, *Identifying the effects of firing restrictions through size-contingent Differences in regulation*, Labour Economics, **TD No. 504 (giugno 2004)**.

S. MOMIGLIANO, J. Henry and P. Hernández de Cos, *The impact of government budget on prices: Evidence from macroeconometric models*, Journal of Policy Modelling, **TD No. 523 (October 2004).**

D. Jr. MARCHETTI and F. Nucci, *Pricing behavior and the response of hours to productivity shocks*, Journal of Money Credit and Banking, **TD No. 524 (December 2004).**

L. GAMBACORTA, *How do banks set interest rates?*, European Economic Review, **TD No. 542 (February 2005).**

A. NOBILI, *Assessing the predictive power of financial spreads in the euro area: does parameters instability matter?*, Empirical Economics, Vol. 31, 4, pp. , **TD No. 544 (February 2005)**.

P. ANGELINI and A. Generale, *On the evolution of firm size distributions*, American Economic Review, **TD No. 549 (June 2005).**

R. FELICI and M. PAGNINI,, *Distance, bank heterogeneity and entry in local banking markets*, The Journal of Industrial Economics, **TD No. 557 (June 2005).**

M. BUGAMELLI and R. TEDESCHI, *Le strategie di prezzo delle imprese esportatrici italiane*, Politica Economica, **TD No. 563 (November 2005).**

S. DI ADDARIO and E. PATACCHINI, *Wages and the city. Evidence from Italy*, Labour Economics, **TD No. 570 (January 2006)**.

M. BUGAMELLI and A. ROSOLIA, *Produttività e concorrenza estera*, Rivista di politica economica, **TD No. 578 (February 2006).**

E. VIVIANO, *Entry regulations and labour market outcomes. Evidence from the Italian retail trade sector*, Labour Economics, **TD No. 594 (MAY 2006)**.

S. FEDERICO and G. A. MINERVA, *Outward FDI and local employment growth in Italy*, Review of World Economics, **TD No. 613 (February 2007).**

F. BUSETTI and A. HARVEY, *Testing for trend*, Econometric Theory **TD No. 614 (February 2007).**

V. CESTARI, P. DEL GIOVANE and C. ROSSI-ARNAUD, *Memory for Prices and the Euro Cash Changeover: An Analysis for Cinema Prices in Italy*, In P. Del Giovane e R. Sabbatini (eds.), The Euro Inflation and Consumers' Perceptions. Lessons from Italy, Berlin-Heidelberg, Springer, **TD No. 619 (February 2007).**

B. ROFFIA and A. ZAGHINI, *Excess money growth and inflation dynamics*, International Finance, **TD No. 629 (June 2007)**.

M. DEL GATTO, GIANMARCO I. P. OTTAVIANO and M. PAGNINI, *Openness to trade and industry cost dispersion: Evidence from a panel of Italian firms*, Journal of Regional Science, **TD No. 635 (June 2007)**.

A. CIARLONE, P. PISELLI and G. TREBESCHI, *Emerging Markets' Spreads and Global Financial Conditions*, Journal of International Financial Markets, Institutions & Money, **TD No. 637 (June 2007).**

S. MAGRI, *The financing of small innovative firms: The Italian case*, Economics of Innovation and New Technology, **TD No. 640 (September 2007)**.