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TECHNICAL UNIVERSITY OF LISBON

Department of Economics

Sandra Gomes & Catarina Mendicino

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Housing Market Dynamics: Any News?*

Sandra Gomes† Bank of Portugal and ISEG/TULisbon

Caterina Mendicino‡ Bank of Portugal

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Abstract

This paper quantifies the importance of news shocks for housing market fluctuations. To this purpose, we extend Iacoviello and Neri (2010)'s model of the housing market to include news shocks and estimate it using Bayesian methods and U.S. data. We find that news shocks: (1) account for a sizable fraction of the variability in house prices and other macroeconomic variables over the business cycle and (2) significantly contributed to booms and busts episodes in house prices over the last three decades. By linking news shocks to agents' expectations, we find that house price growth was positively related to inflation expectations during the boom of the late 1970's while it was negatively related to interest rate expectations during the housing boom that peaked in the mid-2000's.

Keywords: bayesian estimation, news shocks, local identification, housing market, financial frictions, inflation and interest rate expectations.

JEL codes: C50, E32, E44.

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†Address: Bank of Portugal, Economic Research Department, Av. Almirante Reis 71, 1150-012 Lisbon, Portugal; e-mail: sandra.cristina.gomes@bportugal.pt

‡Address: Bank of Portugal, Economic Research Department, Av. Almirante Reis 71, 1150-012 Lisbon, Portugal; e-mail: cmendicino@bportugal.pt

1 Introduction

How important are expectation-driven cycles for housing market dynamics? Survey evidence shows that house price dynamics are significantly related to macroeconomic expectations and particularly to optimism about future house prices appreciation.[1] However, macroeconomic models of the housing market mainly rely on fundamental developments in the economy to explain fluctuations in house prices and residential investment. Among others, Davis and Heathcote (2005) develop a multi-sector model of the housing market that matches the co-movement of residential investment with GDP and other components of GDP by assuming technology shocks as the only source of fluctuations; Iacoviello and Neri (2010) add real, nominal, and credit frictions, along with a larger set of shocks, to the multi-sector framework and highlight the role of housing preference shock, technology and monetary factors.[2]

This paper evaluates the empirical importance of expectations-driven cycles for housing market fluctuations. In particular, following most of the literature on expectations-driven cycles, we explore the importance of news shocks as relevant sources of uncertainty.[3] To this purpose we estimate Iacoviello and Neri (2010)'s model extended to incorporate news over different time horizons about the structural shocks of the model. The framework we use is particularly relevant to the purpose of this paper since its rich modelling structure allows for the quantifying of news shocks originated in different sectors of the economy, e.g., the housing market, the production sector, inflationary factors and the conduct of monetary policy. As in Schmitt-Grohe and Uribe (2012), we assume that the structural shocks of the model feature a standard unanticipated component and an anticipated component driven by innovations announced 4 and 8 quarters in advance. Thus, the innovation announced 4 quarters in advance can be views as a revision of the innovation announced 8 quarters in advance and the current innovation can be interpreted as a revision to the sum of the anticipated innovations. To quantify the empirical relevance of news shocks, we fit the model to U.S. data using likelihood-based Bayesian methods. As highlighted by Schmitt-Grohe and Uribe (2012), it is feasible to identify and estimate news shocks by using DSGE models with forward looking agents and likelihood-based methods.

This paper provides several insightful results. First, the model that allows for news shocks is

[1] In particular, Case and Shiller (2003) document that expectations of future house price increases had a role in past housing booms in the U.S.; Piazzesi and Schneider (2009) use the University of Michigan Survey of Consumers to show that during the boom that peaked in the mid-2000's, expectations of rising house prices significantly increased; Nofsinger (2011) argues that the emotions and psychological biases of households play an important role in economic booms.

[2] For other papers of the housing market, see, among others, Aoki, Proudman, and Vlieghe (2004), Iacoviello (2005), Finocchiaro and Queijo von Heideken (2009), Kiyotaki, Michaelides, and Nikolov (2010), Liu, Zha and Wang (2011).

[3] See, among others, Beaudry and Portier (2004, 2007), Floden (2007), Christiano, Ilut, Motto, and Rostagno (2008), Schmitt-Grohe and Uribe (2012).

strongly preferred in terms of overall goodness of fit. In particular, the data favor the inclusion of news shocks over a longer time-horizon, i.e. 8 quarters in advance. Further, on the bases of local identification analysis as in Iskrev (2010a, 2010b), we argue that news shocks are neither "nearly irrelevant", i.e. do not affect the solution of the model or the model implied moments, or "nearly redundant", i.e. their effect can be replicated by other shocks. News shocks are distinguishable from unanticipated shocks in terms of the solution of the model and are also important in determining the statistical properties of the model. Indeed, news shocks affect economic choices and, in particular, the housing and credit decisions of households differently than unanticipated shocks.

Second, news shocks explain around 40 percent of business cycle fluctuations in house prices and a sizable fraction of variations in consumption, residential and non-residential investment. In particular, expectations about future cost-push shocks are the largest contributors to business cycle fluctuations. Among other news shocks, news related to productivity explains almost one-quarter of the variability in business investment. News shocks related to monetary factors account for a larger fraction of variations in house prices and consumption than expectations about future productivity shocks. A plausible reason for the importance of news shocks is related to the fact that these shocks generate the co-movement among business investment, consumption and house prices observed in the data, especially during periods of housing booms.

Third, news shocks contribute to the boom-phases in house prices, whereas the busts are almost entirely the result of unanticipated monetary policy and productivity shocks. In particular, expectations of cost-push shocks are found to be important for the run up in house prices and residential investment during the housing booms that occurred concurrently with the energy crises of the 1970's. Investment specific news shocks are the main contributor to residential investment growth during the "new economy" cycle of the late 1990's. Expectations of housing productivity shocks and investment specific shocks somewhat contribute to changes in house prices during the latest boom, whereas expected downward cost pressures on inflation muted its increase over the same period.

Last, exploring the linkage between news shocks and expectations, we find that the model is successful in matching the dynamics of the survey-based inflation and interest rate expectations and the co-movement of these expectations with house prices. Under the assumption of debt contracts in nominal terms, changes in the expected real rates affect households borrowing and investment decisions. Thus, the model suggests an important role of inflation or interest rates expectations for movements in house prices. We show that news shocks account for a large fraction of variation in the model-generated expectations: inflation expectations are mainly related to news on the cost-push shock, while a large part of variations in interest rate expectations is explained by news on the shock to the target of the central bank and on the investment-specific shock. The importance of the latter shock is plausibly related to the GDP growth component of the interest-rate rule followed by the monetary authority.

Further, using survey-based expectations on inflation and interest rates, we also test the plausibility of the expectation channel featured by the model. On the base of Granger causality tests we find that news shocks also contain statistically significant information for survey-based inflation and interest rate expectations. As a result, the model mimics particularly well the evidence that higher inflation expectations are strongly related to house prices during the boom of the 1970's whereas lower interest rate expectations are significantly related to the run up in house prices during the latest boom. The link between interest rate expectations and house prices over the last decade seems to be mainly driven by the systematic component of the policy rule, and, in particular, by expectations about GDP growth as opposed to news on monetary policy shocks.

This paper is related to the growing empirical literature that explores the role of news shocks over the business cycle. Beaudry and Portier (2006) using a VAR approach showed that business cycle fluctuations in the data are primarily driven by changes in agents' expectations about future technological growth. Since their seminal paper, several authors have investigated the importance of expectations-driven cycles as a source of business cycle fluctuations.[4] This paper is particularly related to Schmitt-Grohe and Uribe (2012) that estimating a real business cycle model, document that news on future neutral productivity shocks, investment-specific shocks, and government spending shocks account for more than two thirds of predicted aggregate fluctuations in postwar U.S. data. We contribute to their findings by documenting that news shocks are also important for housing market fluctuations. Moreover, differently from previous papers, we assess the relative importance of the unanticipated and anticipated component of the shocks in affecting both the structural and statistical properties of the model. Further, we also explore the linkage between news shocks and the endogenous expectations of the model and document how expectations on inflation and interest rates are related to house price booms and busts.[5] To the best of our knowledge, there are no other attempts to quantify the role of news shocks for housing market fluctuations in this strand of the business cycle literature.

Few other authors have also studied the transmission mechanism of expectations on future

[4] Among others, see, Barsky and Sims (2009), Kurmann and Otrok (2009), Fujiwara, Hirose and Shintani (2011), Khan and Tsoukalas (2009), Milani and Treadwell (2009), Badarinza and Margaritov (2011).

[5] Very few papers analyze the ability of DSGE models to match the dynamics of expectations. These other studies mainly focus on how alternative assumptions regarding agents' information about the central bank's inflation target help to match inflation expectations. In particular, Schorfheide (2005) estimates on U.S. data two versions of a DSGE, featuring either full information or learning regarding the target inflation rate, and shows that, during the period 1982-1985, inflation expectations calculated from the learning model track the survey forecasts more accurately than the full-information forecasts; Del Negro and Eusepi (2010) using inflation expectations as an observable show that when agents have perfect information about the value of the policymaker's inflation target model helps to better fit the dynamics of inflation expectations.

fundamentals to house prices in macro models. Lambertini, Mendicino and Punzi (2010) show that changes in expectations of future macroeconomic developments can generate empirically plausible boom-bust cycles in the housing market; Tomura (2010) documents that uncertainty about the duration of a period of temporary high income growth can generate housing booms in an open economy model; Adam, Kuang and Marcet (2011) explain the joint dynamics of house prices and the current account over the years 2001-2008 by relying on a model of "internally rational" agents that form beliefs about how house prices relate to economic fundamentals; Burnside, Eichenbaum and Rebelo (2011) document that heterogeneous beliefs about long-run fundamentals can lead to booms and busts in the housing market. We complement previous findings by providing a quantitative assessment of the importance of expectation-driven cycles for housing prices and by documenting the type of news shocks that are more relevant in driving housing market fluctuations.

The rest of the paper is organized as follows. Section 2 describes the model and Section 3 describes the estimation methodology. Section 4 tests for local identification of the shocks. Section 5 comments on the results of news shocks as a source of fluctuations in the housing market and Section 6 investigates the role of news shocks for booms and busts in house prices and residential investment. Section 7 relates agents' expectations to house prices. Section 8 concludes.

2 The Model

We rely on the model of the housing market developed by Iacoviello and Neri (2010). The model features real, nominal, and financial frictions, as well as a large set of shocks. Three sectors of production are assumed: a non-durable goods sector, a non-residential investment sector, and a residential sector. Households differ in terms of their discount factor and gain utility from non-durable consumption, leisure, and housing services. In addition, housing can be used as collateral for loans. For completeness, we describe the main features of the model in the next subsections.

2.1 Households

The economy is populated by a continuum of households of two types: patient and impatient. Impatient households discount the future at a higher rate than patient households. Thus, in equilibrium, impatient households are net borrowers while patient households are net lenders. We, henceforth, interchangeably refer to patient and impatient households as Lenders and Borrowers, respectively. Discount factor heterogeneity generates credit flows between agents. This feature was originally introduced in macro models by Kiyotaki and Moore (1997) and extended to a model of the housing market by Iacoviello (2005). Both types of households consume, work in two sectors, namely in the non-durable goods sector and the housing sector, and accumulate housing.

Lenders Lenders, maximize the following lifetime utility:

$$U_t = E_t \sum_{t=0}^{\infty} (\beta^t G_C)^t z_t \left\{ \Gamma_c \ln\left(c_t - \varepsilon c_{t-1}\right) + j_t \, ln \; h_t - \frac{\tau_t}{1+\eta} \left[(n_{c,t})^{1+\xi} + (n_{h,t})^{1+\xi} \right]^{\frac{1+\eta}{1+\xi}} \right\},$$

where β is the discount factor ($0 < \beta' < \beta < 1$), ε is the external habits parameter ($0 < \varepsilon < 1$), η is the inverse of the elasticity of work effort with respect to the real wage ($\eta > 0$), and ξ defines the degree of substitution between hours worked in the two sectors ($\xi \geq 0$). G_C is the trend growth rate of real consumption and Γ_c is a scaling factor of the marginal utility of consumption. z_t, j_t and τ_t are shocks to the intertemporal preferences, housing demand and labor supply, respectively, that follow $AR(1)$ processes. Lenders decide how much to consume, c_t, the amount of hours devoted to work in each sector, $n_{c,t}$ and $n_{h,t}$, the accumulation of housing h_t (priced at q_t), the supply of intermediate inputs $k_{b,t}$ (priced at $p_{b,t}$), the stock of land l_t (that is priced at $p_{l,t}$), and the stock of capital used in the two sectors of production, $k_{c,t}$ and $k_{h,t}$. Lenders also choose the capital utilization rate in each sector, $z_{c,t}$ and $z_{h,t}$ (subject to a convex cost $a\left(\bullet\right)$). Finally, they decide on the amount of lending, b_t. Loans yield a riskless (gross) nominal interest rate denoted by R_t. On the other hand, Lenders receive wage income ($w_{c,t}$ and $w_{h,t}$ are the real wages in each sector, relative to the consumption good price), income from renting capital (at the real rental rates $R_{c,t}$ and $R_{h,t}$) and land (at the real rental rate $R_{l,t}$), and from supplying intermediate goods to firms. Capital in the non-durable goods sector and in the housing sector as well as land depreciate at (quarterly) rates δ_{kc}, δ_{kh} and δ_h. Finally, Lenders receive (lump-sum) dividends from owning firms and from labor unions (D_t). Thus, their period budget constraint is:

$$c_t + \frac{k_{c,t}}{A_{k,t}} + k_{h,t} + k_{b,t} + q_t h_t + p_{l,t} l_t - b_t = \frac{w_{c,t} n_{c,t}}{X_{wc,t}} + \frac{w_{h,t} n_{h,t}}{X_{wh,t}} +$$

$$+ \left(R_{c,t} z_{c,t} + \frac{1-\delta_{kc}}{A_{k,t}} \right) k_{ct-1} + (R_{h,t} z_{h,t} + 1 - \delta_{kh}) k_{ht-1} + p_{b,t} k_{b,t} + (p_{l,t} + R_{l,t}) l_{t-1} + q_t (1-\delta_h) h_{t-1}$$
$$+ D_t - \frac{R_{t-1} b_{t-1}}{\pi_t} - \phi_{c,t} - \phi_{h,t} - \frac{a\left(z_{c,t}\right) k_{c,t-1}}{A_{k,t}} - a\left(z_{h,t}\right) k_{h,t-1},$$

where π_t is the (quarter-on-quarter) inflation rate in the consumption goods sector. $A_{k,t}$ is an investment-specific technology shock that represents the marginal cost of producing consumption good sector specific capital.[6] G_{IK_c} and G_{IK_h} are the trend growth rates of capital used in the two

[6] This follows the same process as productivity in the non-durable goods and housing sectors, see Section 2.2.

sectors of production and $\phi_{c,t}$ and $\phi_{h,t}$ are convex adjustment costs for capital.[7]

Both types of households supply labor to unions in the two sectors of production. The unions differentiate labor services and sell it in a monopolistic competitive labor market. Thus, there is a wedge between the wage paid by firms to labor unions and those received by households ($X_{wc,t}$ and $X_{wh,t}$ denote the markups in the non-durable and housing sectors, respectively). Wages are set according to a Calvo (1983) scheme (with a $1-\theta_{w,c}$ exogenous probability of re-optimization when labor is supplied to the non-durable goods sector union and a $1-\theta_{w,h}$ is the probability in the housing sector) with partial indexation to past inflation (with parameters $\iota_{w,c}$ and $\iota_{w,h}$ in the corresponding sectors).

Borrowers Borrowers' and Lenders' utility function are similarly defined.[8] Borrowers do not own capital, land or firms. They only receive dividends from labor unions. Hence, the borrowers period budget constraint is:

$$c_t^{'} + q_t\left(h_t^{'} - (1-\delta_h)h_{t-1}^{'}\right) - b_t^{'} \leq \frac{w_{c,t}^{'}n_{c,t}^{'}}{X_{wc,t}^{'}} + \frac{w_{h,t}^{'}n_{h,t}^{'}}{X_{wh,t}^{'}} + D_t^{'} - \frac{R_{t-1}b_{t-1}^{'}}{\pi_t}.$$

Borrowers are constrained in that they may only borrow up to a fraction of the expected present value of next-period value of their housing stock:

$$b_t^{'} \leq mE_t\left(\frac{q_{t+1}h_t^{'}\pi_{t+1}}{R_t}\right),$$

where $m \leq 1$ represents the loan-to-value ratio.[9]

2.2 Firms

Non-durable goods, business capital and housing are produced by a continuum of wholesale firms that act under perfect competition. Price rigidities are introduced in the non-durable sector, while

[7] $\phi_{c,t} = \frac{\phi_{kc}}{2G_{IK_c}}\left(\frac{k_{c,t}}{k_{c,t-1}} - G_{IK_c}\right)^2 \frac{k_{c,t-1}}{(1+\gamma_{AK})^t}$ is the good-sector capital adjustment cost, and $\phi_{h,t} = \frac{\phi_{kh}}{2G_{IKh}}\left(\frac{k_{h,t}}{k_{h,t-1}} - G_{IK_h}\right)^2 k_{h,t-1}$ is the housing-sector capital adjustment cost; γ_{AK} represents the long-run net growth rate of technology in business capital, ϕ_{kc} and ϕ_{kh} are the coefficients for adjustment cost (i.e., the relative prices of installing the existing capital) for capital used in the consumption sector and housing sector, respectively.

[8] Variables and parameters with a prime ($'$) refer to Borrowers while those without a prime refer to Lenders.

[9] Given the assumed difference in the discount factor, the borrowing restriction holds with equality in the steady state. As common in the literature, we solve the model assuming that the constraint is also binding in a neighbourhood of the steady state. See, among others, Campbell and Hercowitz (2004), Iacoviello (2005), Iacoviello and Minetti (2006), Iacoviello and Neri (2010) and Sterk (2010).

retail sale prices of housing are assumed to be flexible.

Wholesale firms Wholesale firms operate in a perfect competition flexible price market and produce both non-durable goods, Y_t, and new houses, IH_t. To produce non-durable goods the wholesale firms use labor (supplied by both types of households) and capital as inputs of production while the producers of new houses also use intermediate goods and land. Production technologies are assumed to be Cobb-Douglas:

$$Y_t = \left(A_{c,t} \left(n_{c,t}\right)^{\alpha} \left(n^{'}_{c,t}\right)^{1-\alpha} \right)^{1-\mu_c} \left(z_{c,t} k_{c,t-1}\right)^{\mu_c}$$

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

where α is a parameter that measures the labor income share of Lenders and $A_{h,t}$ and $A_{c,t}$ are the productivity shocks to the non-durable goods sector and housing sector, respectively. The productivity shocks are defined as:[10]

$$\ln(A_{x,t}) = t \ln(1 + \gamma_{A_x}) + \ln(Z_{x,t}), \quad x = c, h$$

where $\ln(Z_{c,t})$ and $\ln(Z_{h,t})$ follow $AR(1)$ processes (with serially uncorrelated, zero mean innovations with standard-deviations σ_{A_c} and σ_{Ah}) and γ_{A_c} and γ_{A_h} are the long-run net growth rates of technology in each sector, such that:

$$\ln(Z_{x,t}) = \rho_{Ax} \ln(Z_{x,t-1}) + u_{x,t}.$$

Retailers Wholesale firms in the non-durable goods sector sell their output under perfect competition to retailers that act under monopolistic competition when selling the goods to households. Retailers differentiate the non-durable goods and then sell them to households, charging a markup, X_t, over the wholesale price. Retailers set their prices under a Calvo-type mechanism (the exogenous probability of re-optimization is equal to $1 - \theta_\pi$) with partial indexation to past inflation (driven by parameter ι_π). This setup leads to the following forward-looking Phillips curve:

$$ln\pi_t - \iota_\pi ln\pi_{t-1} = \beta G_C \left(E_t ln\pi_{t+1} - \iota_\pi ln\pi_t\right) - \epsilon_\pi ln(\frac{X_t}{X}) + u_{p,t}$$

where $\epsilon_\pi = \frac{(1-\theta_\pi)(1-\beta\theta_\pi)}{\theta_\pi}$ and $u_{p,t}$ is an i.i.d. cost-push shock.

[10] The investment-specific technology shock, $A_{k,t}$, is similarly defined.

2.3 Monetary Policy Authority

The monetary authority sets the (gross) nominal interest rate according to the following Taylor-type rule:

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

where rr is the steady-state real interest rate, GDP is the economy's gross domestic product, $u_{R,t}$ is an i.i.d. shock and $A_{s,t}$ is a persistent shock to the central bank's inflation target. Following Iacoviello and Neri (2009), GDP is defined as the sum of consumption and investment at constant prices $GDP_t = C_t + IK_t + qIH_t$, where q is real housing prices along the balanced growth path in terms of the price of the consumption good.

2.4 News Shocks

In the model there are seven $AR(1)$ shocks – z_t, j_t, τ_t, $A_{h,t}$, $A_{c,t}$, $A_{k,t}$ and $A_{s,t}$ – and two i.i.d. shocks: $u_{p,t}$ and $u_{R,t}$. Expectations of future macroeconomic developments are introduced as in the existing news shock literature. We assume that the error term of the shocks, with the exception of preferences ,$u_{x,t}$, consists of an unanticipated component, $\varepsilon_{x,t}^0$, and anticipated changes n quarters in advance, $\varepsilon_{x,t-n}^n$, with $n = \{4, 8\}$,

$$u_{x,t} = \varepsilon_{x,t}^0 + \varepsilon_{x,t-4}^4 + \varepsilon_{x,t-8}^8,$$

where $\varepsilon_{x,t}$ is i.i.d and $x = \{c, h, k, p, R, s\}$. Thus, at time $t - n$ agents receive a signal about future macroeconomic conditions at time t. As in Schmitt-Grohe and Uribe (2012) we assume anticipated changes four and eight quarters ahead. This assumption allows for revisions in expectations, e.g., $\varepsilon_{x,t-8}^8$can be revised at time $t - 4$ (up or down, partially or completely, in the latter case $\varepsilon_{x,t-4}^4 = -\varepsilon_{x,t-8}^8$) and $\varepsilon_{x,t-4}^4 + \varepsilon_{x,t-8}^8$ can be revised at time 0 (again, partially or completely, in the latter case $\varepsilon_{x,t}^0 = -(\varepsilon_{x,t-4}^4 + \varepsilon_{x,t-8}^8)$ and $u_{x,t} = 0$).

3 Estimation

In this section, we describe both the estimation methodology and the data used. We also briefly comment on the estimation results. Last, we evaluate the model both in terms of overall goodness of fit.

3.1 Methodology

The set of structural parameters of the model describing technology, adjustment costs, price and wage rigidities, the monetary policy rule, and the shocks is estimated using Bayesian techniques. We proceed in two steps. First, we obtain the mode of the posterior distribution which summarizes information about the likelihood of the data and the priors on the parameters' distributions by numerically maximizing the log of the posterior. We then approximate the inverse of the Hessian matrix evaluated at the mode. We subsequently use the random walk Metropolis-Hastings algorithm to simulate the posterior, where the covariance matrix of the proposal distribution is proportional to the inverse Hessian at the posterior mode computed in the first step. After checking for convergence, we perform statistical inference on the model's parameters or functions of the parameters, such as second moments.[11] For recent surveys of Bayesian methods, see An and Schorfheide (2007) and Fernandéz-Villaverde (2010).

In setting the parameters' prior distributions, we follow Iacoviello and Neri (2010). In particular, we use a beta distribution for the serial correlations of the shocks, ρ_{Ax}, and an inverse gamma distribution for the standard deviations of the shocks, σ_x. In order to avoid over-weighting *a priori* any of the two components of the shocks, we assume that the variance of the unanticipated innovation is equal to the sum of the variances of the anticipated components.[12]

$$\left(\sigma_x^0\right)^2 = \left(\sigma_x^4\right)^2 + \left(\sigma_x^8\right)^2 .$$

Introducing news shocks to the model adds 12 additional parameters. In order to make the estimation less cumbersome, we reduce the set of parameters by calibrating those that affect the steady state of the model. Most of these parameters are calibrated as in Iacoviello and Neri (2010) while others are set to the mean estimated values reported in their estimates. Thus, as in most estimated DSGE models, the steady-state ratios are unchanged during the estimation. As common in the literature, we also fix the autoregressive parameters of the inflation targeting shock.[13] See Table 1.

3.2 Data

As in Iacoviello and Neri (2010), we consider ten observables: real consumption per capita, real private business and residential fixed investment per capita, quarterly inflation, nominal short-term interest rate, real house prices, hours worked per capita in the consumption-good and the housing

[11] To perform inference we discard the first 10 per cent of observations.

[12] The same approach has been followed, among others, by Fujiwara, Hirose and Shintani (2011).

[13] See, among others, Adolfson et al. (2007) and Iacoviello and Neri (2010).

sectors, and the nominal wage quarterly change in the consumption and housing sector.[14] Real variables are deflated by the output implicit price deflator in the non-farm business sector. We also allow for measurement error in hours and wage growth in the housing sector. As in Iacoviello and Neri (2010) we use quarterly data from 1965Q1. The desire to have a sample over which monetary policy was conducted using conventional tools restrict us to consider data up to 2007Q4.[15]

3.3 Parameter Estimates

Tables 2 and 3 display the priors chosen for the model's parameters and the standard deviations of the shocks, as well as the posterior mean, standard deviations and the 95 percent probability intervals. The posterior estimates of the model's parameters feature a substantial degree of wage and price stickiness, and a low degree of indexation in prices and wages in the consumption sector. The estimated monetary policy rule features a moderate response to inflation, a modest degree of interest-rate smoothing, and a positive reaction to GDP growth. Finally, all shocks are quite persistent and moderately volatile. News shocks display a much lower volatility than unanticipated shocks.

We do not find sizable differences with respect to the estimates reported by Iacoviello and Neri (2010). We find a slightly higher response to inflation and GDP growth and a lower response to the lagged interest rate in the Taylor Rule as well as higher stickiness and lower indexation in the Phillips Curve. These differences are mainly related to revisions in the series for inflation.[16]

3.4 Overall Goodness of Fit

In order to evaluate the importance of news shocks for the overall goodness of fit of the model, we compare the estimated model presented above against two other specifications: without news shocks ($u_{x,t} = \varepsilon^0_{x,t}$) and with news only at a 4 quarter horizon ($u_{x,t} = \varepsilon^0_{x,t} + \varepsilon^4_{x,t-4}$). The latter specification helps us to assess the potential importance of signal revisions.

Table 4 reports the log marginal data density of each model, the difference with respect to the log marginal data density of the model without news shocks, and the implied Bayes factor.[17] Both versions of the model that allow for news shocks display a significantly higher log data density

[14] For details on the series used and the data transformations see the Appendix.

[15] The exclusion of the most recent years allows to understand housing market dynamics over the average business cycle, i.e. not affected by the period of extreme macroeconomic fluctuations that characterized the recent financial crisis. A version of the model with the addition of a collateral shocks has been separately estimated. However, due to the lack of data on debt and house holding of credit constraint households, we find it difficult to identify such a shock and, thus, to capture the dynamics of the recent credit crunch.

[16] Iacoviello and Neri (2010) used data from 1965Q1 to 2006Q4. Therefore, we use a different vintage of the data set.

[17] Given that *a priori* we assign equal probability to each model, the Bayes factor equals the posterior odds ratio.

compared to the no-news model. Accordingly, the Bayes factor indicates decisive evidence in favor of the models with news shocks, see Jeffreys (1961) and Kass and Raftery (1995). In order for the model without news to be preferred, we would need a priori probability over this model 1.7×10^{25} larger than the prior belief about the model with 4 and 8-quarter ahead news.[18] Thus, we conclude that the data strongly favor the inclusion of news shocks. Moreover, the model that also includes longer horizon signals outperforms all other specifications in terms of overall goodness of fit.

All versions of the model are estimated using our updated data set. See Section 3.2. As a last check, in the last three rows of Table 4 we report the Bayes factor using Iacoviello and Neri (2010) data set. The same results hold.

4 Are News Shocks Different than Other Shocks?

In order to avoid concerns related to the identifiability of news shocks, we test for local identification in the model and in the moments. To circumvent the difficulty of explicitly deriving the relationships between the deep parameters of the model and the structural characteristics of the model used to estimate them, we use the local identification approach. As in Schmitt-Grohe and Uribe (2012) we rely on the methodology proposed by Iskrev (2010a). The analysis consists of evaluating the ranks of Jacobian and can be performed for any given system of equations describing the linearized model and the corresponding parameter space. The analysis strictly follows Iskrev (2010a and 2010b).

Let $J_T(\boldsymbol{\theta})$ be the Jacobian matrix of the mapping from the deep parameters of the model, θ, to the vector m_T collecting the parameters that determine the unconditional theoretical moments of the observables (of sample size T) in the model. The Jacobian matrix can be factorized as $J_T(\theta) = \frac{\partial m}{\partial \tau} \frac{\partial \tau}{\partial \theta}$, where τ represents a vector collecting the (non-constant elements of the) reduced-form parameters of the first-order solution to the model, $\frac{\partial m}{\partial \tau}$ measures the sensitivity of the moments to the reduced-form parameters τ, and $\frac{\partial \tau}{\partial \theta}$ measures the sensitivity of τ to the deep parameters θ. A parameter θ_i is locally identifiable if the Jacobian matrix $\frac{\partial J(\boldsymbol{\theta})}{\partial \theta_i}$ has full column rank at θ_i.[19] Evaluating the Jacobian matrix $\frac{\partial J(\boldsymbol{\theta})}{\partial \theta}$ analytically, we find that, in a neighborood of the posterior mean of the estimated parameters, all parameters reported in Tables 2 and 3 are locally identified.[20] A parameter is weakly identified if it is "nearly irrelevant", i.e. does not affect the solution of the model or the model implied moments, or it is"nearly redundant", i.e. if its effect can be replicated by other parameters. For completeness, in the following, we summarize the conditions for identification both in the model and in the moments.

Identification in the model. Since τ fully characterizes the steady state and the model

[18] 6.4×10^{12} larger than the prior belief about the model with 4-quarter ahead news shocks.

[19] We compute derivatives of the first and second order covariances.

[20] For the analitical derivation of the Jacobian matrix, see the on line appendix to Iskrev (2010a).

dynamics, low sensitivity to a particular parameter means that this parameter is unidentifiable in the model for purely model-related reasons, thus unrelated to the series used as observables in the estimation. If the Jacobian matrix $\frac{\partial\tau}{\partial\theta}$ does not have full column rank, then some of the parameters are unidentifiable in the model. Strictly speaking, a parameter θ_i is (locally) weakly identified in the model if either (1) τ is insensitive to changes in θ_i, i.e. $\frac{\partial\tau}{\partial\boldsymbol{\theta}_i} \simeq 0$, or (2) if the effects on τ of changing θ_i can be offset by changing other parameters, i.e. $\cos\left(\frac{\partial\tau}{\partial\boldsymbol{\theta}_i}, \frac{\partial\tau}{\partial\boldsymbol{\theta}_{-i}}\right) \simeq 1$.

Regarding the identification of the shocks, we measure collinearity between the column of the Jacobian $\frac{\partial\tau}{\partial\theta}$ with respect to the standard deviations of the news shocks, the standard deviation of the unanticipated shocks and the autocorrelation parameters. Panel A of Figure 1 reports the pairs of parameters with the highest value of the cosine among all possible combinations of shocks' parameters. First, the maximum value of the cosine across possible sets of shocks' parameters suggests weak collinearity relationships among these parameters with respect to the solution of the model. Second, the highest collinearity is generally not found among the standard deviation of the unanticipated component of the error term of a shock, $\sigma_{\varepsilon^0_{x,t}}$, and the standard deviation of the anticipated components of the same shocks, $\sigma_{\varepsilon^4_{x,t-4}}$ and $\sigma_{\varepsilon^8_{x,t-8}}$. Thus, arguably, the unanticipated and anticipated components of any shock do not play a similar role in the solution of the model. In other words, examining how the identification of parameters is influenced by the structural characteristics of the model, we find that both unanticipated and news shocks are identified in the model.

Identification in the moments. Parameters that are identifiable in the model could be poorly identified if some of the variables are unobserved. On the other hand, it is important to notice that if a parameter does not affect the solution of the model ($\frac{\partial\tau}{\partial\boldsymbol{\theta}_i} \simeq 0$) then its value is also irrelevant for the statistical properties of the data generated by the model ($\frac{\partial J(\boldsymbol{\theta})}{\partial\theta_i} \simeq 0$). Indeed, the statistical and the economic modelling aspects of identification are complementary. In the following we test for local identification in the moments related to the ten observables used in the estimation.

Panel B of Figure 1 reports pairs of shocks' parameters with the highest value of the cosine among the columns of the Jacobian matrix, $\frac{\partial J(\boldsymbol{\theta})}{\partial\theta}$. Once we evaluate the role of shocks in the selected moments, we find that collinearity is higher with respect to te model implied moments than with respect to the model solution. It is important to highlight that while the identification in the model only depends on the structural features of the model, the strength of idenfication in the moments depends on the number of observables and on the specific set of selected variables. Overall, the effect of unanticipated shocks in the moments is generally more similar to the 4-quarter anticipated component of the same shock. The collinearity between the investment specific shock and the 8 quarters ahead news shock offers an exepction. The highest cosine is displayed between the standard deviation of the housing preference shock and the persistence of the same shock.

However, it is important to stress that no multicollinearity is found across parameters.

The relative importance of each shock in determining the model's statistical properties for the ten observables used to estimate the model, can be used as a measure of the strength of identification. Figure 2 reports the sensitivity in the moments to the shocks' parameters at the posterior mean, i.e. the norm of columns of the Jacobian matrix, $\frac{\partial J(\boldsymbol{\theta})}{\partial \theta}$, corresponding to each of the shocks parameters.[21] News shocks display high sensitivity in the moments and are, thus, important in determining the statistical properties of the model. This is particularly true for expectations of investment specific shocks and changes in the inflation target, both 4 and 8 quarters ahead, and for 8-quarters ahead expectations of cost push shocks. Unanticipated shocks generally display lower sensitivity in the moments. Housing productivity shocks offer an exception.

Summarizing, all shocks are identified, though with varying strength of idenfication. News shocks appear to be distinguishable from unanticipated shocks both in terms of the solution of the model and for the determination of the model implied moments of the ten observables used in the estimation.

5 News Shocks and Housing Market Dynamics

In this section, we highlight key findings regarding the transmission mechanism of news shocks and quantify the role of news shocks for housing market dynamics. First, we analyze the contribution of news shocks for fluctuations of selected variables over the business cycle. Then, we assess their role for the observed house prices booms and busts over the sample period.

5.1 Transmission Mechanism

The transmission of news shocks relies on two distinguishable features. First, news shocks can induce optimism about future house price appreciation and generate hump-shaped dynamics in house prices that resemble the patterns observed in the data during periods of housing booms. Expectations about the occurrence of shocks that lead to an increase in house prices, such as a future monetary policy loosening, an increase in the productivity of consumption goods or a decline in the supply of houses, immediately generate beliefs of future appreciations in housing prices and fuel current housing demand. Consequently, house prices gradually rise, peak at the time in which expectations are fulfilled and, then, slowly decline towards the initial level. Thus, in contrast to standard unanticipated shocks, the peak effect on prices and quantities is not immediate. Figure 3 reports the effect of unanticipated and news shocks on house prices.

[21] The norm is normalized by the value of each moment.

Second, news shocks generate the co-movement among house prices, consumption, residential- and non-residential investment, and hours worked in both sectors of production observed in the data, especially during periods of housing booms.[22] Figures 4 and 5 report, respectively, the effect of selected unanticipated and the corresponding 8-quarters ahead news shocks on key macroeconomic variables. News shocks affect economic choices and, in particular, the housing and credit decisions of households differently than unanticipated shocks. As news spread, the value of housing collateral increases and the rise in house prices is, thus, coupled with an expansion in household credit and consumption. Moreover, due to limits to credit, Borrowers increase their labor supply in order to raise internal funds for housing investments. Given the presence of adjustment costs for capital, firms start adjusting the stock of capital already at the time in which news about the occurrence of future shocks that come along with demand pressures in one of the two sectors spread. The increase in business and housing investment makes also GDP rise. For the increase in investment to be coupled with an increase in hours, wages rise. Thus, news shocks in this model generate pro-cyclicality among all relevant variables.[23]

5.2 Business Cycle Fluctuations

Are news shocks a relevant source of business cycle fluctuations? Table 5 shows the contribution of the anticipated and unanticipated components of the shocks to the unconditional variance of the observable variables at business cycle frequencies. News shocks account for slightly less than 40 percent of the variance in house prices, about 13 percent of the variance in residential investment, and more than half of the variance of consumption, business investment, and inflation. Expectations 8-quarters ahead account for most of the variations reported above. Regarding the different types of news shocks, news related to cost-push shocks are by far the most important source of fluctuations among the anticipated shocks. See Table 6. In particular, expectations about future cost push shocks explain slightly less than 30 percent of the variability in house prices, more than 40 percent of variations in consumption, business investment and inflation, and have about the same importance as news on productivity shocks for explaining residential investment. News shocks related to monetary factors are mainly driven by the persistent shock to the target of the central bank and explain a bit more of variations in house prices and consumption than news of productivity shocks. News shocks about productivity in the three sectors explain almost one-quarter of the variability in business investment. A plausible reason for the importance of news shocks is related to

[22] Lambertini, Mendicino and Punzi (2010) document that, over the last three decades, housing prices boom-bust cycles in the U. S. have been characterized on average by co-movement in GDP, consumption, business investment, hours worked, real wages and housing investment.

[23] For a detailed analysis of the transmission mechanism of these shocks in the framework presented above, see Lambertini, Mendicino and Punzi (2010).

the fact that these shocks are able to generate co-movement among a broad set of macroeconomic variables.[24] See section 5.1. Since news shocks are an important source of fluctuations in business investment, along with consumption and house prices they contribute to the co-movement across these variables.

Regarding the unanticipated component of the shocks, preference shocks have a considerable role in explaining house prices and residential investment. This result is mainly driven by the housing preference shock, which in the model resembles a housing demand shock. Housing preference shocks have been previously documented in the literature as an important source of co-movement between house prices and consumption in models of collateral constraints at the household level.[25] However, as highlighted by Liu, Wang ans Zha (2011), in the absence of credit frictions at the firm level, preference shocks turn out to be not very important for business investment, and thus, contribute little to the co-movement among house prices, consumption and business investment.

Monetary shocks explain a bit less than 10 percent of the variability in house prices and investment, and about 14 percent of the volatility of the other variables whereas, productivity shocks explain around 30 and 10 percent of the variability in residential investment and house prices, respectively. This latter result is mainly related to housing productivity shocks. Contrary to news shocks, the unanticipated component of the cost-push shock is not among the main drivers of fluctuations.

Which unanticipated shocks loose importance once we introduce news shocks? To address this question, we compare the role of the unanticipated shocks in the estimated model with news shocks ($u_{x,t} = \varepsilon^0_{x,t} + \varepsilon^4_{x,t-4} + \varepsilon^8_{x,t-8}$) against the estimated model without news shocks ($u_{x,t} = \varepsilon^0_{x,t}$). See Table 7. In the model without news shocks, cost-push shocks are as important as productivity and monetary policy shocks in accounting for the observed variability in house prices and business investment. Cost-push shocks are also a main source of fluctuations in consumption. The introduction of news shocks as a source of fluctuations significantly reduces the importance of unanticipated cost-push shocks and gives a predominant role to the anticipated component of this shock. As for residential investment, consumption and business investment we also find a less sizable role for productivity and monetary factors. The importance of the unanticipated component of all shocks is significantly reduced for house prices.

[24] Lambertini, Mendicino and Punzi (2010) document that, over the last three decades, housing prices boom-bust cycles in the U. S. have been characterized on average by co-movement in GDP, consumption, business investment, hours worked, real wages and housing investment.

[25] See, among others, Iacoviello (2005), Iacoviello and Neri (2010), Christensen, Corrigan, Mendicino and Nishiyama (2009).

6 Boom-Bust Cycles in House Prices

In this section, we quantify the contribution of different shocks to house price growth over boom-bust episodes. To identify the main cycles in real house prices, we use the Bry-Boschan algorithm with a one-year minimum criterion to define a cycle phase. The peaks and troughs of the four cycles identified with this method coincide with local maxima and minima of the real house price series. See Figure 6. We report the results for the two main booms that peak in 1979Q4 and 2005Q4, respectively. Real residential investment displays co-movement with house prices during the first two decades of the sample. The peaks in residential investment anticipate the peaks in house prices only by one quarter. In contrast, during the last two decades, the cycles of residential investment and house prices are unsynchronized. House prices generally increase since the mid-1990's to 2005Q3. In contrast, residential investment displays a different pattern and more closely follow the U.S. economic cycle. Leading the NBER business activity peak by a few quarters, the series displays a peak in 2000Q3, whereas the decline in housing investment ends in 2003Q1, a few quarters after the through of activity. Thus, we also consider an alternative cycle for residential investment peaking in 2000Q3, as identified by the Bry-Boschan algorithm.

Table 8 reports the contribution of the estimated shocks to house prices and residential investment growth during each boom- and bust-phase. Adding up the contribution of news and unanticipated shocks we find that: (i) cost-push shocks display a sizable contribution to the run up in house prices and residential investment of the late 1970's; (ii) monetary and productivity factors are found to be important for the subsequent bust; (iii) productivity accounts for more than half of the increase in house prices and residential investment during the most recent period; (iv) monetary factors significantly contribute to the early bust-phase of the more recent cycle in house prices; (v) housing preference shocks significantly contribute to changes in house prices, whereas the contribution of these shocks to changes in residential investment is not sizable.

Is there any role for news shocks during housing market booms and busts? Regarding the relative importance of the anticipated and unanticipated component of shocks for changes in house prices, news shocks contribute to the boom-phases, whereas the busts are almost entirely the result of unanticipated monetary policy and productivity shocks. News shocks also sizably contributed to changes in residential investment. See Tables 9 and 10.

News on cost-push shocks is found to be important for the run up in house prices and residential investment during the boom of the late 1970's. In particular, expectations of cost-push shocks contribute to around 30 percent of the run up in housing prices and 80 percent of residential investment growth. Unanticipated productivity and monetary shocks mainly account for the subsequent bust. It is worth highlighting that expectations of cost-push shocks significantly contributed to housing market dynamics during the entire 1970's.[26] News on cost push shocks is arguably related to expectations of oil price shocks. In fact, in 1973 and 1979 most of the industrialized nations, including the U.S. experienced two major oil crises mainly on account of disruptions to energy supply. It is common in DSGE models to explain the inflationary pressures generated by the dramatic increase in oil prices through cost push shocks.[27] Once we allow for news on the cost push shock, we find that expectations about future inflationary pressures were more important than current shocks in determining agents' housing investment decisions during the high inflation period of the 1970's. In the next section we investigate the relationships between inflation expectations, news shocks and housing market dynamics.[28]

Supporting the idea of a productivity-driven economic expansion mainly related to expectations of a "New Economy", investment specific news shocks were the main contributors to residential investment growth during the second-half of the 1990's.[29] Further, investment specific news shocks together with expectations of downward cost pressures on inflation account entirely for the subsequent decline. Despite a more sizable role for the unanticipated component of productivity and monetary policy shocks, news about productivity shocks in the housing sector and investment specific news shocks account together for about 20 percent of the increase in house prices over the latest boom. The contribution of news about cost-push shocks also considerably muted the run up in house prices over its entire boom phase.

Summarizing, expectation-driven cycles are mainly related to news regarding cost-push shocks, shocks to productivity in the housing sector and investment-specific technology shocks. In contrast, the contribution of the unanticipated component of the shocks is mainly related to monetary factors and productivity in the two sectors of production.

7 Interpreting News Shocks: the Role of Expectations

Results presented above show that news about future cost-push, housing productivity, and investment specific shocks are important sources of housing market fluctuations. Given that the effect of news shocks mainly works through expectations, we now investigate the importance of expectations

[26] As for the first cycle of the early 1970's, news on inflation and housing productivity together account for about 17 percent of the boom and 65 percent of the bust in house prices.

[27] De Graeve et al. (2009) relying on an estimated macro-finance model argue that the 1973 inflation hike is attributable to wage and price-markup shocks. Several papers have documented the role of oil shocks for macroeconomic developments in the 1970s. See, among others, the seminal work by Bruno and Sachs (1985). The impact of a change in the price of oil has also been found to have decreased over time. See Blanchard and Gali (2009) and the references therein.

[28] Regarding inflation expectations and credit and real estate dynamics see also Piazzesi and Schneider (2010).

[29] See, among others, Jerman and Quadrini (2003) and Shiller (2000) for detailed account on productivity growth driven by computer technology and the use of new equipment since the mid-1990's.

for the transmission of news shocks to house prices. The assumption of nominal debt contracts suggests a role for both inflation and interest rates expectations in the housing and credit decisions of households. The housing pricing equation derived from the model can be expressed as

$$q_t = E_t \sum_{j=0}^{\infty j} (\tilde{\beta})^j \frac{u_{c,t+j}}{u_{c,t}} \frac{u_{h,t+j}}{u_{c,t+j}}, \tag{1}$$

where $\Lambda_{t,t+j} = \tilde{\beta}^j \frac{u_{c,t+j}}{u_{c,t}}$ is the stochastic discount factor or *pricing kernel* and $\frac{u_{h,t+j}}{u_{c,t+j}}$ is the marginal rate of substitution between housing and consumption.[30] Agents choose housing and consumption goods such that the sum of the current and expected marginal rate of substitution between the two goods, discounted by $\tilde{\beta}^j \frac{u_{c,t+j}}{u_{c,t}}$, is equal to the relative price of houses.[31] Movements in the real interest rate, i.e. the inverse of the *pricing kernel*, determine house price dynamics. Since debt contracts are in nominal terms, expected inflation affects the debt decisions of the households and also enters the optimality condition for housing investment. Lower expected real rates, through either higher expected inflation rates or lower interest rates, induce households to borrow more and to increase their housing investment, therefore contributing to an increase in house prices and credit flows.

We proceed in two steps. First, we quantify the contribution of news shocks to model-based expectations and test the model's ability to match survey-based expectations. Second, we explore the linkages between agents' expectations and house prices.

7.1 Survey- versus Model-based Expectations

Are news shocks related to agents' expectations? Table 11 reports the variance decomposition of the model-based expectations about inflation and interest rates generated over the sample period.[32] Inflation expectations are mostly explained by the anticipated component of the cost-push shock and the shock to the target of the central bank. In particular, news of future inflationary shocks explain around 50 percent of the variability in both 1- and 4-quarter ahead inflation expectations, with a predominant role for news shocks over longer horizon. Interest rate expectations are also driven by news of inflation targeting shocks and investment specific shocks. The importance of the anticipated components of the investment specific shock is plausibly related to the GDP component

[30] Solving forward the lender's f.o.c. for housing it is possible to derive the equilibrium housing price equation (1), where the discount factor is defined as $\tilde{\beta} \equiv \beta G_C (1 - \delta_h)$.

[31] The house prices equation could alternatively be derived from the Borrowers' housing demand. In this latter case it would involve the lagrange multiplier of the borrowing constraint. In equilibrium both specification hold.

[32] The type of heterogeneity featured by the model does not imply heterogeneity in agents' expectations. Both types of agents have the same expectations about future inflation and interest rates.

of the interest-rate rule. In fact, investment specific news shocks are among the driving forces of investment which itself represents a significant share of GDP.[33]

As an alternative validation of the model, we assess the plausibility of the model implied expectations by relating them to survey estimates of expected inflation and interest rates, which are not part of the information set of the model.[34] We measure observed inflation expectations using the 1- and 4-quarter ahead expected GDP deflator quarterly change estimated by the Federal Reserve Bank of Philadelphia Survey of Professional Forecasters (SPF). Alternatively, we also use the expected change in prices from the University of Michigan Survey of Consumers.[35] Interest rate expectations are measured by the 1- and 4-quarter ahead expectations for the three-month Treasury bill rate provided by the SPF. We find that both inflation and interest rates expectations generated by the model are in line with the survey-based expectations. See Figure 7.

Next, we evaluate the information content of news shocks for the observed expectations on the base of Granger causality tests. We focus on the news shocks that are more relevant to each type of expectations generated by the model. The results of the test show that news shocks contain statistically significant information for all measures of observed inflation and interest rate expectations. See Tables 12 and 13.[36] Thus, news shocks are found to be important in explaining model-generated expectations about inflation and interest rates. Further, they also contain significant information for survey-based expectations.

7.2 Expectations and House Prices

Next, we explore the relationship between expectations and house prices. The link documented above between news shocks and agents' expectations suggests an important role for both inflation and interest rate expectations in house prices fluctuations. Table 14 reports the correlations between house prices and expectations over the observed boom and bust episodes. Survey based inflation expectations are strongly positively correlated with house prices during the boom-bust cycle of the late 1970's. In contrast, the correlation becomes weaker during the more recent cycle. Observed interest rate expectations are negatively correlated with house prices during the recent boom and positively correlated during the bust-phase. See also Figure 8. One plausible reason for the weaker co-movement of inflation expectations and house prices during the more recent boom,

[33] Expectations on inflation and interest rates are not among the observables used in the estimation.

[34] Previous papers that explore the ability of DSGE models to fit the dynamics of inflation expectations focus on alternative assumptions regarding agents' information on the target of the central bank. See, i.e., Schorfheide (2005) and Del Negro and Eusepi (2010).

[35] In the Michigan survey, the question asked is "By what percent do you expect prices to go up, on the average, during the next 12 months?". We use the mean of the responses to this question.

[36] The number of lags included in the tests was chosen based on the Akaike information criteria. The results are however robust to the introduction of alternative numbers of lags.

could be related to the ability of the monetary authority to stabilize both inflation and inflation expectations since the mid-1980's. This could also explain the countercyclical behavior of interest rate expectations during the latest house price boom. In fact, under more stable inflation expectations, expected lower future real rates would be mainly related to expectations of a lower nominal interest rate.[37]

As for the model-based expectations, inflation expectations are positively correlated with house prices during the boom-bust episodes, whereas the relationship between interest rate expectations and house prices varies through time and became negative during the most recent period of run up in house prices. See Table 14. By visual inspection, we can see that the expected interest rate declined during the early phase of the more recent boom (2000Q3-2004Q1) and the trough in interest rate expectations anticipate the peak in house prices.

Interest rate expectations in the model are mainly driven by the systematic component of the policy rule. In fact, interest rate expectations seem to be strongly linked to expectations regarding both inflation and GDP growth as opposed to news about monetary policy shocks. The negative correlation between house prices and interest rate expectations during the more recent booms is explained by a decline in model-based expectations regarding GDP growth. In fact, during the early phase of the more recent house prices boom that coincided with the 2001 recession period, interest rate expectations decline given a deterioration of GDP growth expectations. See Figure 9.

Summarizing, the model performs reasonably well in capturing the relationship between expectations and house prices. In particular, it is able to match the co-movement between house prices and inflation expectations during the earlier cycles in housing prices and the counter-cyclical behavior of interest rate expectations during the more recent boom.

8 Conclusions

This paper quantifies the role of expectations-driven cycles for housing market fluctuations in the United States. Due to their ability to generate pro-cyclical and hump-shaped dynamics, news shocks emerge as relevant sources of macroeconomic fluctuations and explain a sizable fraction of

[37] Piazzesi and Schneider (2010) input survey-based expectations into an endowment model economy with nominal credit and housing collateral and show that heterogeneous inflation expectations induce disagreement about the real rate and thus, turn out to account for the increase in credit volumes and the portfolio shift towards real estate during the Great Inflation of the 1970's. Our general equilibrium analysis abstracts from heterogeneity in expectations. However, since the dynamics of the model are mainly driven by the borrowers, we can conjecture that allowing for heterogenous expectations would not change our results. In fact, if, as in Piazzesi and Schneider (2010), the borrowers are the ones who have higher inflation expectations, then they will also perceive a lower real interest rate than the lenders, and, thus, prefer to increase their demand for external funds as well as housing investment. In contrast, the lenders, expecting higher real interest rates, would be willing to lend more. Thus, disagreement about the real interest rate could potentially stimulate credit flows and exacerbate housing dynamics even further.

variation in house prices and housing investment and more than half of the variation in consumption and business investment. Housing productivity, investment-specific and cost-push news shocks, are among the main sources of business cycle fluctuations.

News shocks also significantly contribute to booms and busts in housing prices. In particular, expectations about cost-push shocks turn out to be an important factor during the booms of the 1970's while investment-specific shocks are more relevant after the 1980's. News shocks also turn out to be important for inflation and interest rate expectations that in the context of debt contracts in nominal terms play a decisive role in agents decisions and thus house prices movement. Exploring the link between news shocks and expectations, we find that the estimated model effectively captures the relationship of house prices with higher inflation expectations during the booms of the 1970's, and with lower interest rate expectations during the more recent boom.

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Appendix A

A Data

A.1 Observables

In the following we describe in detail the data used in the estimation:

- Real consumption: Real Personal Consumption Expenditure (seasonally adjusted, billions of chained 2005 dollars), divided by the Civilian Noninstitutional Population. Log-transformed and normalized to zero in 1965:1.
- Business Fixed Investment: Real Private Nonresidential Fixed Investment (seasonally adjusted, billions of chained 2005 dollars), divided by the Civilian Noninstitutional Population. Log-transformed and normalized to zero in 1965:1.
- Residential Investment: Real Private Residential Fixed Investment (seasonally adjusted, billions of chained 2005 dollars), divided by the Civilian Noninstitutional Population. Log-transformed and normalized to zero in 1965:1.
- Hours Worked in Consumption Sector: Total Nonfarm Payrolls less all employees in the construction sector times Average Weekly Hours of Production Workers divided the Civilian Noninstitutional Population. Log-transformed and normalized to zero in 1965:1.
- Hours Worked in Housing Sector: All Employees in the Construction Sector, times Average Weekly Hours of Construction Workers divided by the Civilian Noninstitutional Population. Log-transformed and normalized to zero in 1965:1.
- Growth in Nominal Wage in Consumption-good Sector: Average Hourly Earnings of Production/ Nonsupervisory Workers on Private Nonfarm Payrolls, Total Private. Demeaned.
- Growth in Nominal Wage in Housing Sector: Average Hourly Earnings of Production/ Nonsupervisory Workers in the Construction Industry. Demeaned.
- 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. Demeaned.
- Inflation: quarter-on-quarter log differences in the implicit price deflator for output in the nonfarm business sector. Demeaned.
- Nominal Short-term Interest Rate: 3-month Treasury Bill Rate (Secondary Market Rate), expressed in quarterly units. Demeaned.

The data series as described above are shown in Figure A.1.

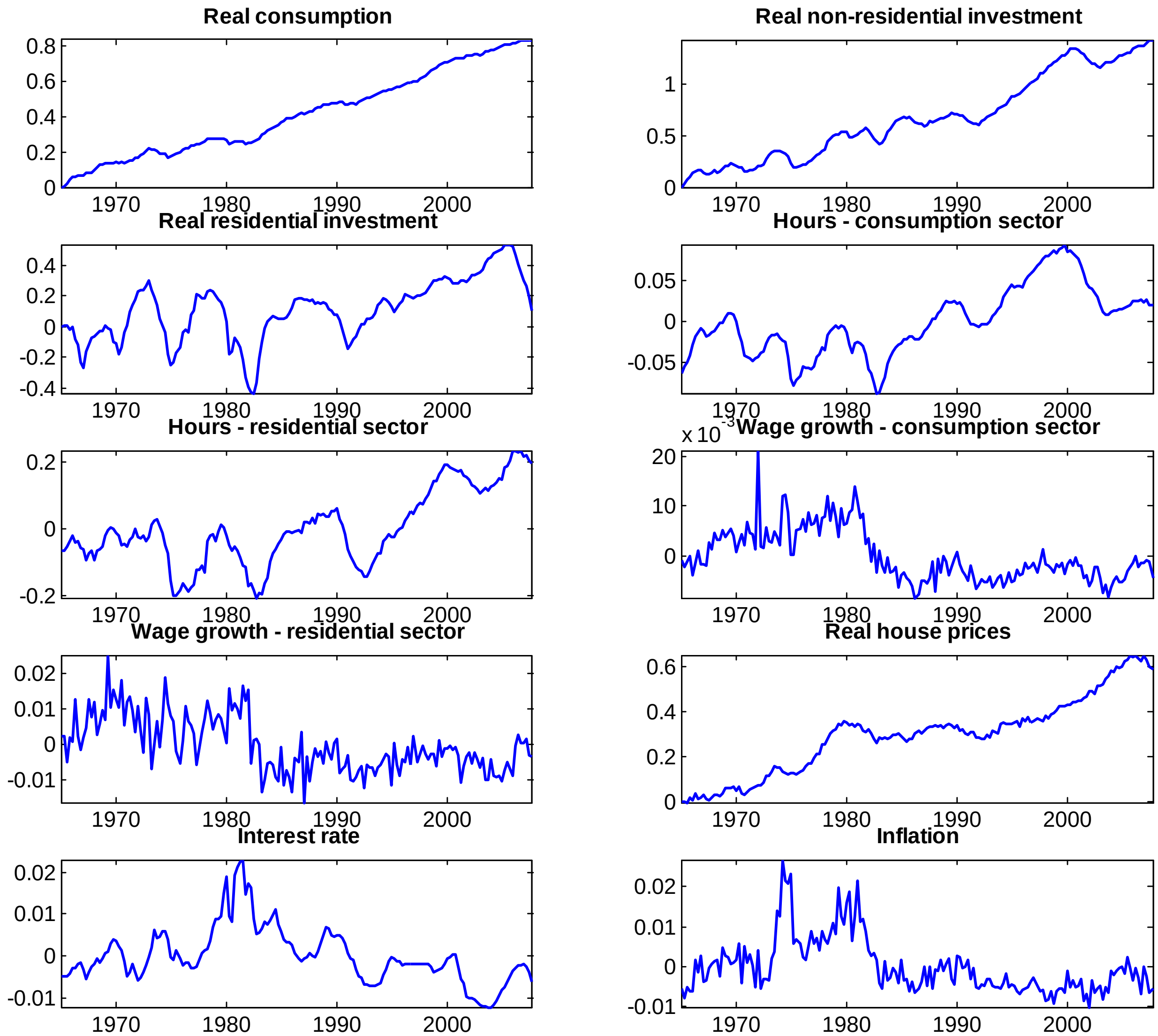


Figure A.1: Data

A.2 Expectations

The survey-based expectations data analysed in the paper are:

- Inflation expectations: 1- and 4-quarter ahead expected GDP deflator quarterly change estimated by the Federal Reserve Bank of Philadelphia Survey of Professional Forecasters or, alternatively, the expected change in prices from the University of Michigan Survey of Consumers.[38] Demeaned.
- Interest rate expectations: 1- and 4-quarter ahead expectations for the three-month Treasury bill rate provided by the Federal Reserve Bank of Philadelphia Survey of Professional Forecasters. Demeaned.

These data are ploted in Figure A.2.

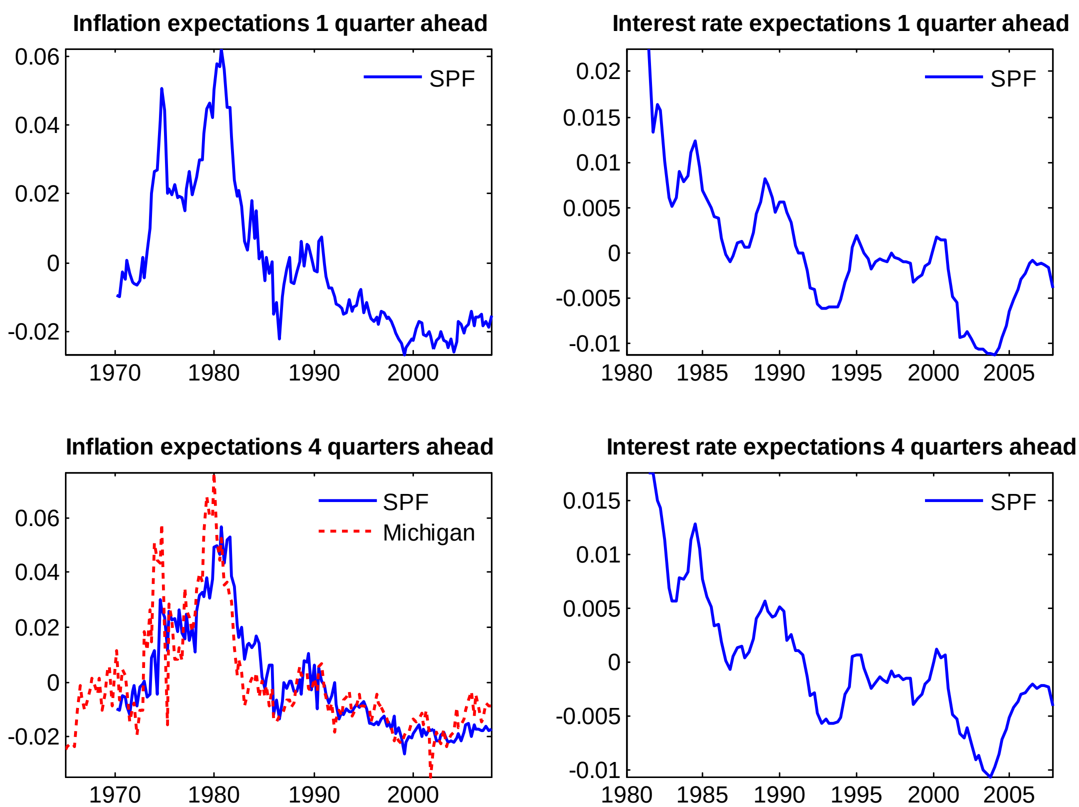


Figure A.2: Survey based expectations

[38]In the Michigan survey, the question asked is "By what percent do you expect prices to go up, on the average, during the next 12 months?".

Table 1: Calibrated parameters

Technology		*Preferences*	
μ_c	0.35	β	0.9925
μ_h	0.10	$\beta^{'}$	0.97
μ_l	0.10	ξ	0.66
μ_b	0.10	$\xi^{'}$	0.97
α	0.79	j	0.12
δ_h	0.01	η	0.52
δ_{kc}	0.025	$\eta^{'}$	0.51
δ_{kh}	0.03		
X	1.15	*Other*	
X_{wc}	1.15	m	0.85
X_{wh}	1.15	ρ_s	0.975
γ_{AC}	0.0032		
γ_{AH}	0.0008		
γ_{AK}	0.0027		

Table 2: Estimation results

Parameter		Prior			Posterior		
		Type	Mean	Stdev	Mean	5%	95%
Habits	ε	$\mathcal{B}$	0.50	0.075	0.3263	0.2469	0.4003
	$\varepsilon\prime$	$\mathcal{B}$	0.50	0.075	0.6018	0.5009	0.6991
Investment adjustment costs	$\phi_{k,c}$	$\mathcal{G}$	10	10.01	14.9672	11.4618	18.3434
	$\phi_{k,h}$	$\mathcal{G}$	10	10.46	10.7674	6.6969	14.9466
Calvo prob. - prices	θ_{π}	$\mathcal{B}$	0.667	0.05	0.8997	0.8817	0.9181
Calvo prob. - wages cons. sector	$\theta_{w,c}$	$\mathcal{B}$	0.667	0.05	0.8580	0.8170	0.8979
Calvo prob. - wages hous. sector	$\theta_{w,h}$	$\mathcal{B}$	0.667	0.05	0.9020	0.8829	0.9215
Indexation - prices	ι_{π}	$\mathcal{B}$	0.50	0.20	0.0446	0.0058	0.0824
Indexation - wages cons. sector	$\iota_{w,c}$	$\mathcal{B}$	0.50	0.20	0.0535	0.0056	0.0982
Indexation - wages hous. sector	$\iota_{w,h}$	$\mathcal{B}$	0.50	0.20	0.4844	0.2442	0.7238
Cap. utilization adjustment costs	ζ	$\mathcal{B}$	0.50	0.20	0.6840	0.5111	0.8622
Taylor rule - Smoothing	r_R	$\mathcal{B}$	0.75	0.10	0.6552	0.5946	0.7150
Taylor rule - Inflation response	r_{π}	$\mathcal{N}$	1.50	0.10	1.5654	1.4664	1.6624
Taylor rule - Output growth response	r_Y	$\mathcal{N}$	0.00	0.10	0.8025	0.7066	0.9018
Autoregressive parameters							
Prod. consumption sector	ρ_{AC}	$\mathcal{B}$	0.80	0.10	0.9531	0.9289	0.9772
Prod. housing sector	ρ_{AH}	$\mathcal{B}$	0.80	0.10	0.9970	0.9943	0.9997
Prod. capital sector	ρ_{AK}	$\mathcal{B}$	0.80	0.10	0.9756	0.9593	0.9925
Preferences - housing	ρ_j	$\mathcal{B}$	0.80	0.10	0.9454	0.9230	0.9672
Preferences - labor	ρ_{τ}	$\mathcal{B}$	0.80	0.10	0.9458	0.9213	0.9707
Preferences - intertemporal	ρ_z	$\mathcal{B}$	0.80	0.10	0.8061	0.6121	0.9600

$\mathcal{B}$=Beta, $\mathcal{N}$=Normal, $\mathcal{G}$=Gamma.

Table 3: Estimation results (cont.)

Parameter		Prior			Posterior		
		Type	Mean	Stdev	Mean	5%	95%
Stand. deviation - unant.shocks							
Prod. consumption sector	σ_{AC}	$\mathcal{IG}$	0.001	0.01	0.0096	0.0086	0.0106
Prod. housing sector	σ_{AH}	$\mathcal{IG}$	0.001	0.01	0.0187	0.0162	0.0211
Prod. capital sector	σ_{AK}	$\mathcal{IG}$	0.001	0.01	0.0015	0.0002	0.0036
Preferences - housing	σ_j	$\mathcal{IG}$	0.001	0.01	0.0606	0.0431	0.0793
Preferences - labor	σ_τ	$\mathcal{IG}$	0.001	0.01	0.0589	0.0339	0.0826
Preferences - intertemporal	σ_z	$\mathcal{IG}$	0.001	0.01	0.0107	0.0074	0.0138
Cost push	σ_p	$\mathcal{IG}$	0.001	0.01	0.0016	0.0010	0.0022
Monetary policy	σ_R	$\mathcal{IG}$	0.001	0.01	0.0031	0.0024	0.0036
Inflation objective	σ_s	$\mathcal{IG}$	0.001	0.01	0.0239×10^{-2}	0.0178×10^{-2}	0.0299×10^{-2}
Stand. deviation - ant. shocks 4-q							
Prod. consumption sector	σ_{AC4}	$\mathcal{IG}$	0.0035	0.02	0.0005	0.0002	0.0010
Prod. housing sector	σ_{AH4}	$\mathcal{IG}$	0.0035	0.02	0.0007	0.0002	0.0016
Prod. capital sector	σ_{AK4}	$\mathcal{IG}$	0.0035	0.02	0.0006	0.0002	0.0010
Cost push	σ_{p4}	$\mathcal{IG}$	0.0035	0.02	0.0004	0.0002	0.0008
Monetary policy	σ_{R4}	$\mathcal{IG}$	0.0035	0.02	0.0004	0.0002	0.0006
Inflation objective*100	σ_{s4}	$\mathcal{IG}$	0.0035	0.02	0.0250×10^{-2}	0.0156×10^{-2}	0.0344×10^{-2}
Stand. deviation - ant. shocks: 8-q							
Prod. consumption sector	σ_{AC8}	$\mathcal{IG}$	0.0035	0.02	0.0007	0.0002	0.0014
Prod. housing sector	σ_{AH8}	$\mathcal{IG}$	0.0035	0.02	0.0040	0.0002	0.0103
Prod. capital sector	σ_{AK8}	$\mathcal{IG}$	0.0035	0.02	0.0094	0.0069	0.0120
Cost push	σ_{p8}	$\mathcal{IG}$	0.0035	0.02	0.0026	0.0019	0.0034
Monetary policy	σ_{R8}	$\mathcal{IG}$	0.0035	0.02	0.0004	0.0002	0.0007
Inflation objective*100	σ_{s8}	$\mathcal{IG}$	0.0035	0.02	0.0323×10^{-2}	0.0174×10^{-2}	0.0474×10^{-2}
Stand. deviation - meas.errors							
Hours worked - housing	$\sigma_{n,h}$	$\mathcal{IG}$	0.001	0.01	0.1445	0.1306	0.1587
Wages - housing	$\sigma_{w,h}$	$\mathcal{IG}$	0.001	0.01	0.0081	0.0071	0.0091

$\mathcal{IG}$=Inverse Gamma.

Table 4: Model Comparison

	No news	News 4	News 4&8
Benchmark (1965-2007)			
Log Marginal Data Density	4809.49	4838.97	4867.60
Difference	-	29.48	58.11
Implied Bayes factor	1	6.4×10^{12}	1.7×10^{25}
I&N data (1965-2006)			
Log Marginal Data Density	4693.44	4720.69	4743.11
Difference	-	27.25	49.67
Implied Bayes factor	1	6.8×10^{11}	3.7×10^{21}

Note: Log Marginal Data Density based on the Modified Harmonic Mean Estimator.

Table 5: VarianceDecomposition: Anticipated vs Unanticipated Shocks

	Anticipated Shocks			**Unanticipated Shocks**
	Total	4 -quarter	8-quarter	Total
House Prices (Q)	36.62	1.20	35.42	63.38
Housing Inv. (IH)	12.59	0.52	12.07	87.43
Consumption (C)	54.84	1.65	53.19	45.16
Business Inv. (IK)	72.11	1.77	70.34	27.89
Inflation (π)	63.36	10.62	52.74	36.63

Parameters set at the posterior mean; HP filtered series.

Table 6: Variance Decomposition

	Anticipated Shocks			**Unanticipated Shocks**			
	Production	Cost Push	Mon.Pol.	Product.	Cost Push	Mon.Pol.	Preferences
	AC+AH+AK	UP	UR+AS	AC+AH+AK	UP	UR+AS	j+z+$\mathcal{T}$
House Prices (Q)	3.62	28.52	4.48	10.42	0.70	9.27	42.99
Housing Inv. (IH)	5.18	5.29	2.12	33.43	0.15	9.51	44.34
Consumption (C)	4.22	44.65	5.97	3.41	0.76	13.95	27.04
Business Inv. (IK)	23.91	44.53	3.67	2.10	0.99	14.57	10.23
Inflation (π)	1.33	45.19	16.84	2.19	10.09	13.61	10.74

Parameters set at the posterior mean; HP filtered series.

Table 7: Variance decomposition: News vs No-News

	Unanticipated Shocks							
	Model without News				Model with News			
	Prod.	Cost Push	Mon. Pol.	Prefer.	Prod.	Cost Push	Mon.Pol.	Prefer.
	AC+AH+AK	UP	UR+AS	j+z+$\mathcal{T}$	AC+AH+AK	UP	UR+AS	j+z+$\mathcal{T}$
House Prices (Q)	13.84	14.16	14.70	57.30	10.42	0.70	9.27	42.99
Housing Inv. (IH)	48.89	2.19	8.63	40.30	33.43	0.15	9.51	44.34
Consumption (C)	7.89	30.43	33.70	27.97	3.41	0.76	13.95	27.04
Business Inv. (IK)	23.90	29.77	37.06	9.27	2.10	0.99	14.57	10.23
Inflation (π)	1.23	81.72	10.74	6.31	2.19	10.09	13.61	10.74

HP filtered series.

Table 8: Shocks Contribution to Booms and Busts

Booms and Busts **dated based on Q**	% change	Productivity AH+AC+AK	Cost Push UP	Mon. Pol. UR+AS	H. Pref. j
House prices (Q)					
1976 Q2 - 1979 Q4	17.44	1.21	5.50	-1.03	14.81
1980 Q1 - 1985 Q3	-16.61	-8.62	10.82	-4.61	-11.79
1992 Q4 - 2005 Q4	20.53	14.09	-14.22	3.38	8.58
2006 Q1 - 2007 Q4	-8.72	-0.49	0.66	-3.18	-6.23
Res. investment (IH)					
1976 Q2 - 1979 Q4	20.51	14.22	17.38	-3.37	2.23
1980 Q1 - 1985 Q3	-3.77	-1.49	18.60	-13.73	-1.14
1992 Q4 - 2005 Q4	25.29	28.84	-33.74	9.33	0.81
2006 Q1 - 2007 Q4	6.79	7.18	5.06	-8.55	0.61
dated based on IH					
Res. investment (IH)					
1992 Q1 - 2000 Q3	48.86	38.72	-11.81	4.03	-0.88
2000 Q4-2003 Q1	-25.65	-13.57	-10.84	-1.90	-0.20
2003 Q2-2007 Q4	12.81	11.70	-7.31	2.61	1.97

Parameters set at the posterior mean.

Table 9: Shocks Contribution to Booms and Busts: House Prices (Q)

		Shocks Contribution									
Booms and Busts	**House prices**	**Anticipated**					**Unanticipated**				
Q cycles	% change	UP	AH	AK	AC	UR+AS	UP	AH	AK	AC	UR+AS
1976 Q2 - 1979 Q4	17.44	5.36	2.04	-2.44	-0.01	-1.03	0.14	3.31	-0.01	-1.69	0.00
1980 Q1 - 1985 Q3	-16.61	10.92	-0.88	2.74	0.00	1.11	-0.11	-8.16	0.00	-2.34	-5.71
1992 Q4 - 2005 Q4	20.53	-14.06	2.50	1.51	0.01	-1.01	-0.17	5.57	0.01	4.50	4.38
2006 Q1 - 2007 Q4	-8.72	0.69	-0.39	0.50	0.00	-0.09	-0.03	-0.36	0.00	-0.23	-3.09

Parameters set at the posterior mean.

Table 10: Shocks Contribution to Booms and Busts:Housing Investment (IH)

		Shocks Contribution									
Booms and Busts	**Res. inv.**	**Anticipated**					**Unanticipated**				
Q cycles	% change	UP	AH	AK	AC	UR+AS	UP	AH	AK	AC	UR+AS
1976 Q2 - 1979 Q4	20.51	17.05	1.70	14.69	-0.01	-3.17	0.33	-0.12	0.02	-2.30	-0.19
1980 Q1 - 1985 Q3	-3.77	18.92	-0.61	3.94	0.01	1.37	-0.32	-0.59	0.04	-4.28	-15.10
1992 Q4 - 2005 Q4	25.29	-33.35	0.59	20.02	0.01	-1.64	-0.39	0.18	0.04	8.00	10.98
2006 Q1 - 2007 Q4	6.79	5.13	0.01	8.11	-0.00	0.28	-0.07	-0.30	0.01	-0.66	-8.83
IH cycles											
1992 Q1 - 2000 Q3	48.86	-11.47	0.10	33.91	0.01	-0.53	-0.34	0.20	0.08	4.43	4.56
2000 Q4 - 2003 Q1	-25.65	-10.86	-0.34	-14.60	0.00	-0.38	0.02	0.10	-0.03	1.29	-1.53
2003 Q2 - 2007 Q4	12.81	-7.06	0.80	9.81	-0.00	0.09	-0.26	-0.43	0.01	1.52	2.52

Parameters set at the posterior mean.

Table 11: Model-based Expectations: Variance Decomposition

	Anticipated shocks							Unanticipated shocks
	Total	Cost Push (UP)		Inf. Target (AS)		Inv. Specific (AK)		
		4-quarter	8-quarter	4-quarter	8-quarter	4-quarter	8-quarter	Total
Inflation exp.								
1 quarter ahead	72.19	1.64	49.27	10.21	9.13			27.78
4 quarter ahead	78.97	0.86	53.20	11.26	12.10			21.01
Int. rate exp.								
1 quarter ahead	72.04	0.11	14.63	14.90	15.33	0.06	22.23	27.95
4 quarter ahead	80.38	0.05	7.42	18.78	27.14	0.01	23.62	19.65

Parameters set at the posterior mean.

Table 12: Granger causality tests - Inflation expectations

	SPF						Michigan Survey		
	1 quarter ahead			4 quarter ahead			4 quarter ahead		
	F-statistic	p-value		F-statistic	p-value		F-statistic	p-value	
Cost-push (UP)									
4 quarter ahead	6.8299	[0.0000]	***	3.2492	[0.0417]	**	15.743	[0.0000]	***
8 quarter ahead	14.570	[0.0000]	***	11.8680	[0.0000]	***	31.954	[0.0000]	***

The null hypothesis is that the shock does not Granger cause inflation expectations.

*** 1%, ** 5%, * 10% significance.

Table 13: Granger causality tests - Interest rate expectations (SPF)

	1 quarter ahead			4 quarter ahead		
	F-statistic	p-value		F-statistic	p-value	
Cost-push shock (UP)						
4-quarter ahead	20.569	[0.0000]	***	11.603	[0.0000]	**
8-quarter ahead	19.380	[0.0000]	***	8.431	[0.0000]	***
Prod. K shock (AK)						
4-quarter ahead	25.476	[0.0000]	***	26.500	[0.0000]	***
8-quarter ahead	30.842	[0.0000]	***	51.915	[0.0000]	***
Inf. Target shock (AS)						
4-quarter ahead	15.685	[0.0000]	***	4.451	[0.0011]	***
8-quarter ahead	17.377	[0.0000]	***	2.435	[0.0928]	*

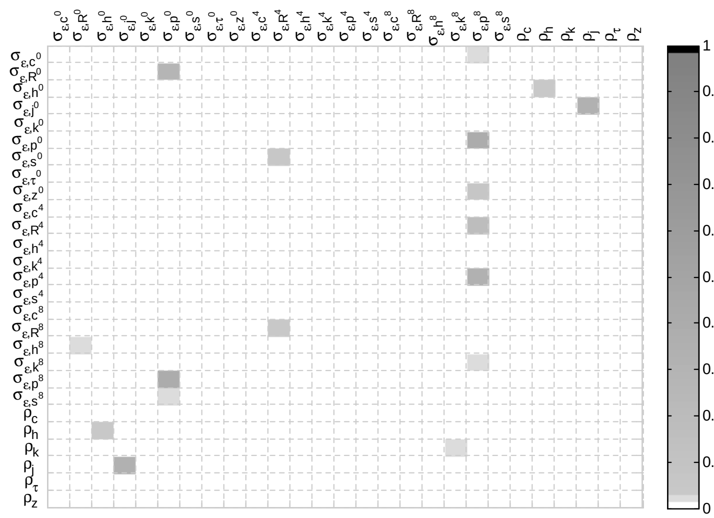
The null hypothesis is that the shock does not Granger cause interest rate.

expectations. *** 1%, ** 5%, * 10% significance.

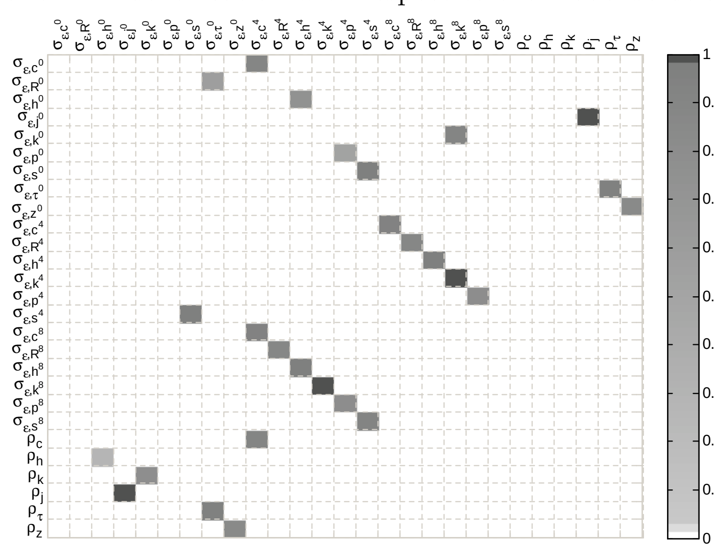
Table 14: Expectations and House Prices

	Correlation with House Prices							
	Survey-based Expectations (SPF)				Model-based Expectations			
	Inflation		Interest Rate		Inflation		Interest Rate	
	1Q	4Q	1Q	4Q	1Q	4Q	1Q	4Q
Booms and Busts Cycles								
1976 Q2 - 1979 Q4	0.885	0.782			0.839	0.836	0.946	0.941
1980 Q1 - 1985 Q3	0.938	0.922	0.873	0.880	0.926	0.873	0.741	0.833
1992 Q4 - 2005 Q4	-0.356	-0.482	-0.551	-0.512	0.553	-0.101	-0.513	-0.333
2006 Q1 - 2007 Q4	-0.144	0.317	0.631	0.601	0.915	0.803	0.773	0.471
Overall								
1970 Q4 - 2007 Q4	0.967	0.495			0.486	0.465	0.461	0.501
1980 Q1 - 2007 Q4			0.223	0.176			0.193	0.242

1- and 4-quarter-ahead expectations.



Panel A - Identification with respect to the model solution.



Panel B - Identification with respect to the model implied moments

Figure 1: Parameters identification (pair of shocks' parameters with the highest cosine).

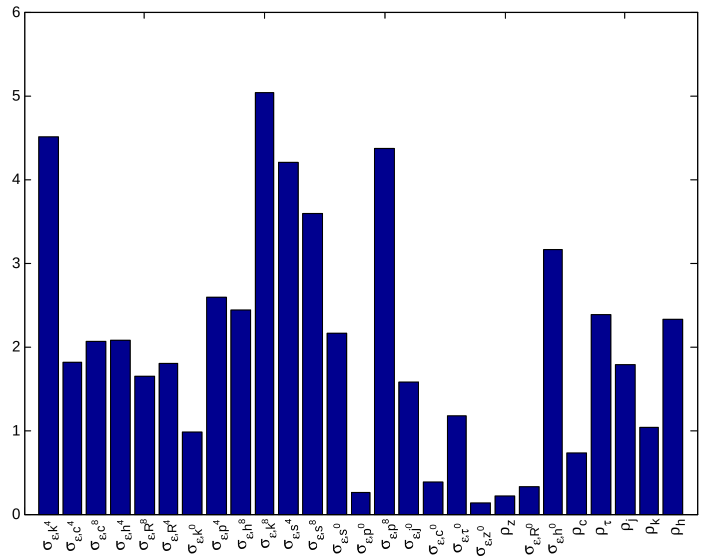


Figure 2: Sensitivity in the moments

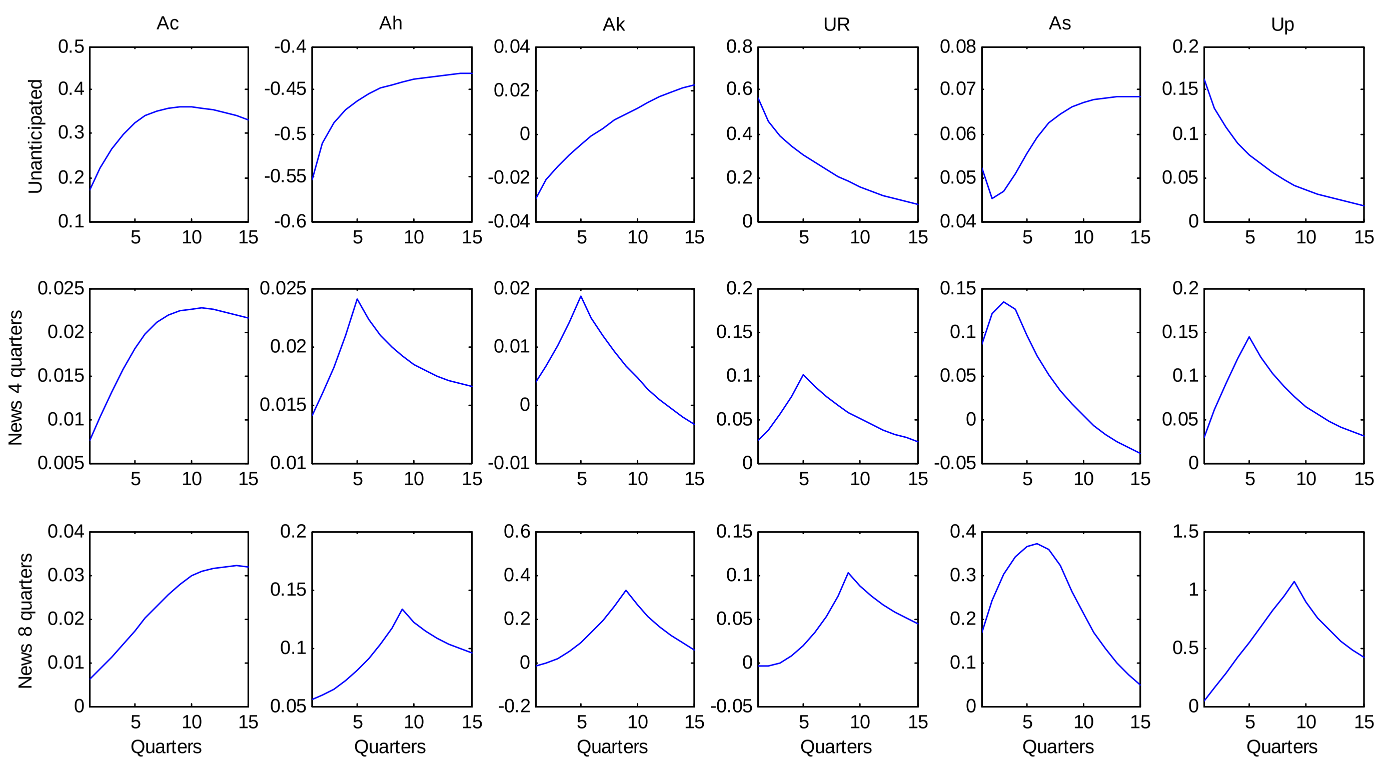


Figure 3: Real house prices - impulse response functions to unanticipated and anticipated shocks

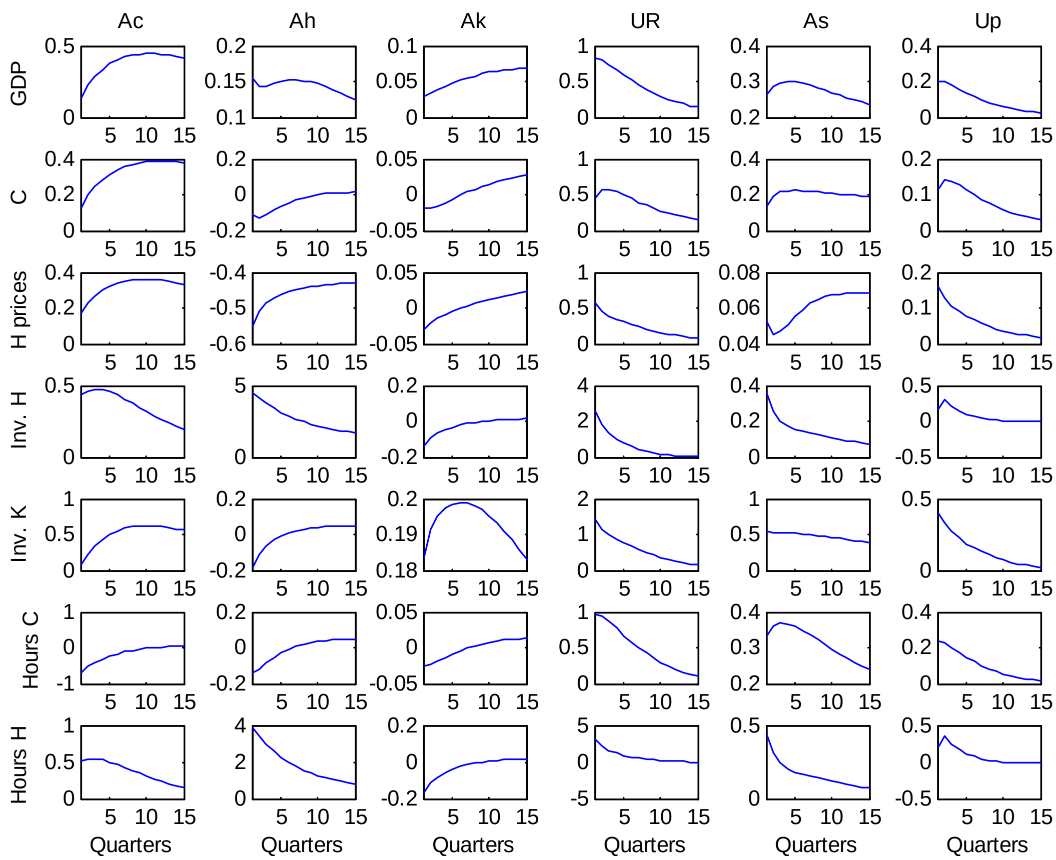


Figure 4: Impulse-Response Functions - Unanticipated Shocks

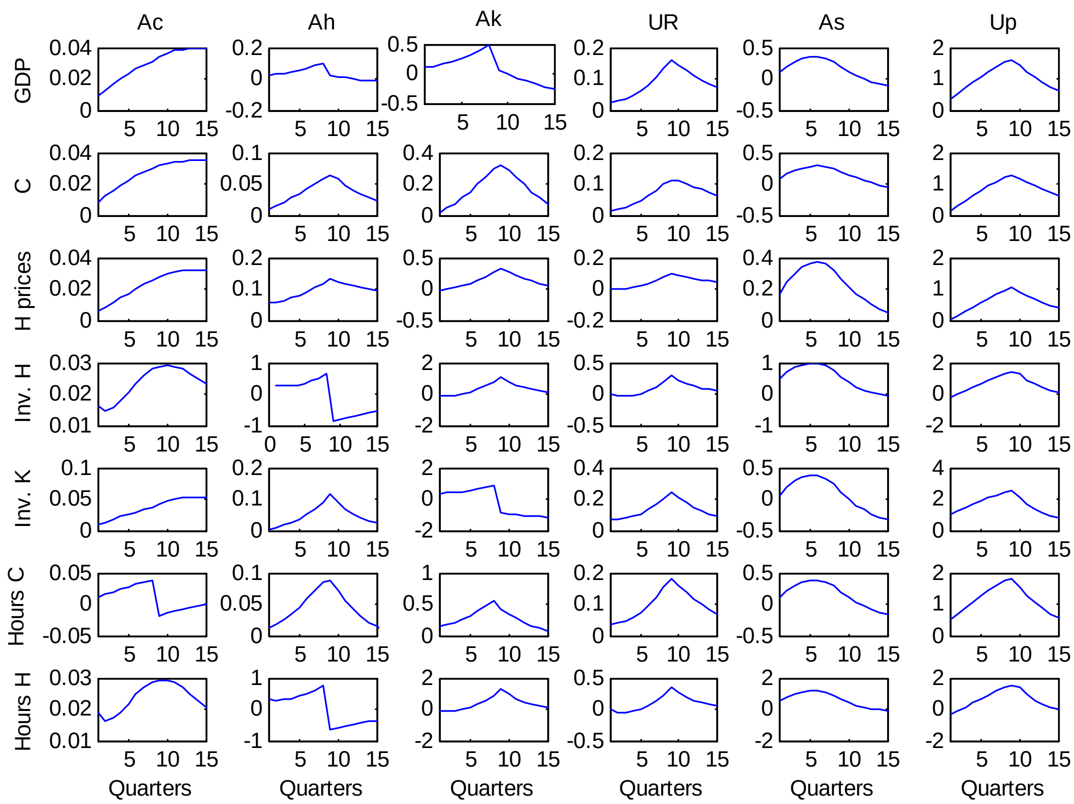


Figure 5: Impulse-Response Functions - 8-Quarter Ahead News Shocks

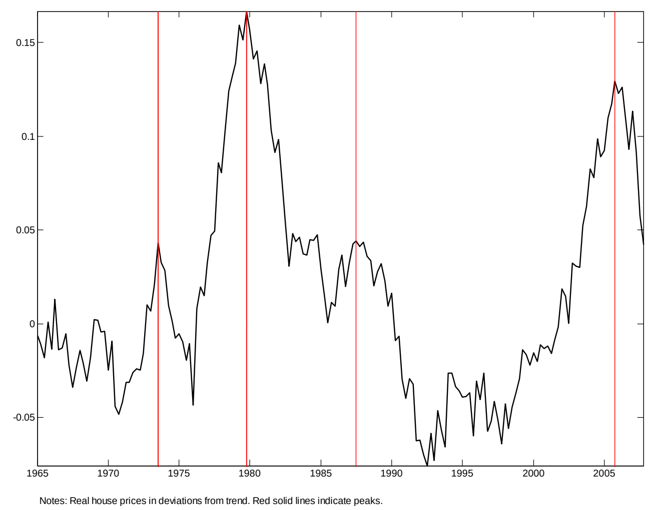


Figure 6: Real House Prices

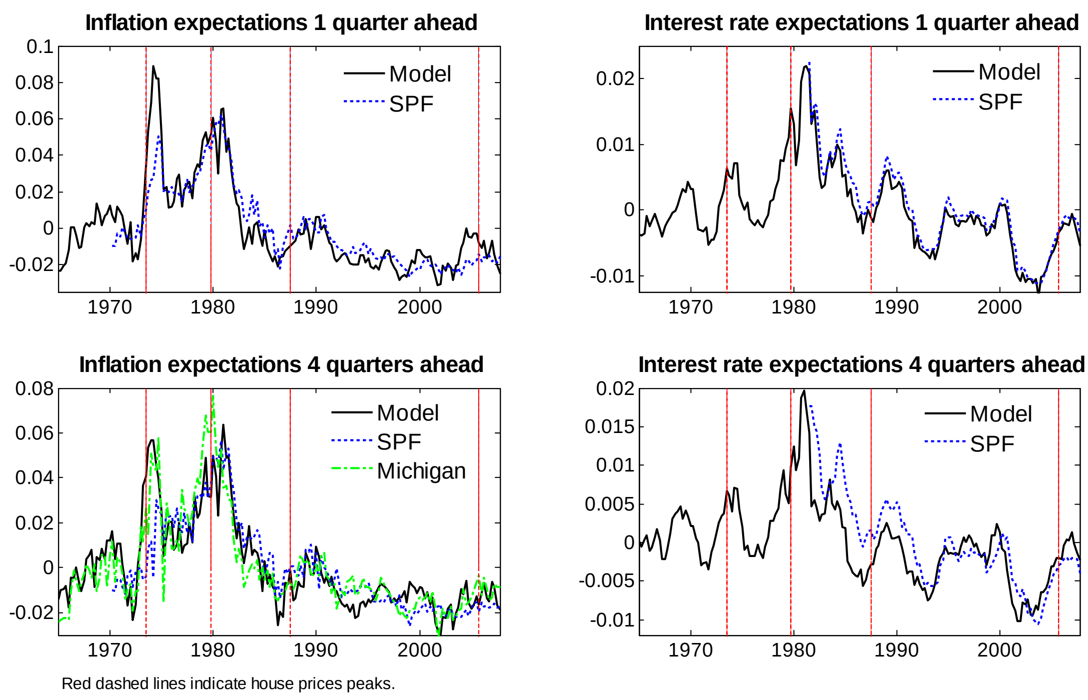


Figure 7: Model- vs Survey-Based Expectations

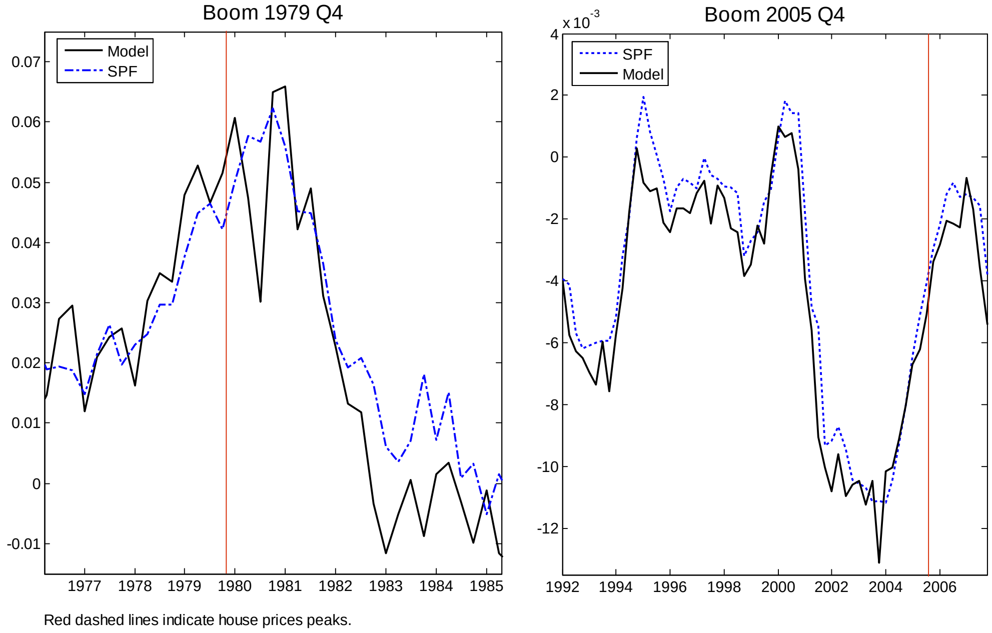


Figure 8: Housing Booms and Expectations

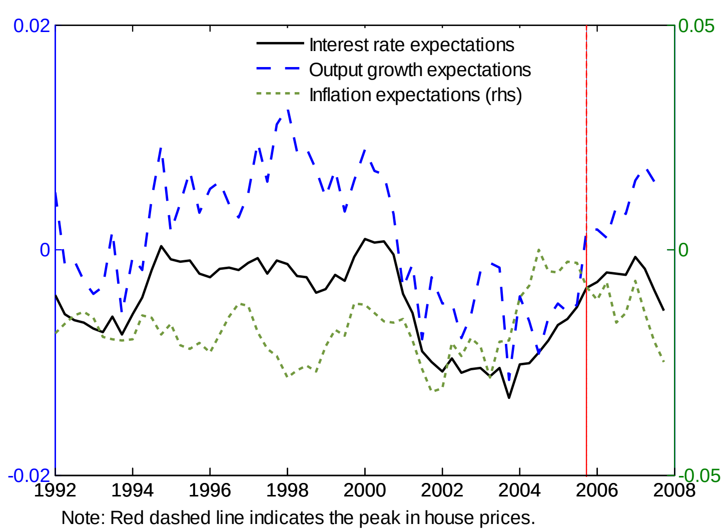


Figure 9: GDP Growth Model-based Expectations 1-quarter ahead