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Housing market dynamics: Any news?

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Abstract

This paper explores the link between agent expectations and housing market dynamics. We focus on shifts in the fundamental driving forces of the economy that are anticipated by rational forward-looking agents, i.e. news shocks. Using Bayesian methods and U.S. data, we find that news-shock-driven-cycles account for a sizable fraction of the variability in house prices and other macroeconomic variables over the business cycle and have also contributed to run-ups in house prices over the last three decades. By exploring the link between news shocks and agent expectations, we show that house price growth was positively related to inflation expectations during the boom of the late 1970's but negatively related to interest rate expectations during the mid-2000's housing boom.

Keywords: housing market, Bayesian estimation, news shocks, local identification, financial frictions, survey expectations.

JEL codes: C50, E32, E44.

Non-technical Summary

How important are changes in expectations in explaining run-ups and crashes in the housing market? Survey evidence suggests that house price dynamics are significantly related to macroeconomic expectations and particularly to optimism about future house price appreciation. Even though a growing number of papers recognizes that shifts in expectations may play a role in house price formation, quantitative evidence in general equilibrium models is scant.

This paper quantitatively evaluates the link between household expectations and house prices in a dynamic stochastic general equilibrium (DSGE) model of the housing market, estimated with U.S. data from 1965Q1 and 2007Q4. We focus on future shifts in the fundamental driving forces of the economy anticipated by rational forward-looking agents, i.e. news shocks. News shocks are proven to be relevant sources of fluctuations in output and other aggregate variables but the issue of how news shocks transmit to housing market is still largely unexplored in the literature.

Our findings are based on a medium scale model that features two kind of households (patient and impatient), three sectors of production (consumption and investment goods and housing), and real, nominal and financial frictions. Credit constraints arise because lenders cannot force borrowers to repay. Thus, houses are used as loan collateral. The structure of the model follows Iacoviello and Neri (2010). The rich modeling structure of the framework that we use 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. Differently from most models of the housing market, our model includes not only unanticipated shocks but also anticipated shocks (i.e. news) at different time horizons.

This paper proceeds in three steps: (i) it assesses the role of news-shock-driven cycles in shaping housing market dynamics in the U.S. economy by using likelihood-based Bayesian methods; (ii) it explores the nexus between news shocks and household expectations and the ability of the model to match survey-based expectations; and (iii) it investigates the link between private sector expectations and housing market dynamics during periods of booms and busts in house prices.

Our main results are as follows:

1) The model with news shocks is strongly preferred in terms of overall goodness of fit. In particular, the data favor the inclusion of news shocks over a longer time horizon. In our model, new 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.

2) News shocks are as relevant sources of macroeconomic fluctuations and explain a sizable fraction of 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.

3) 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 "great inflation" period of the 1970's while investment specific news shocks are more relevant after the 1980's.

4) The model suggests that inflation and interest rate expectations play an important role in house price movements. News shocks account for a large fraction of variation of 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. We also find that news shocks contain statistically significant information about survey-based inflation and interest rate expectations.

5) 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, supporting the evidence that higher inflation expectations are strongly related to house prices during the 1970's boom whereas lower interest rate expectations are significantly related to the run up in house prices during the latest boom.

Our results suggest that news and survey expectations could be useful predictors of house price developments and housing booms. Understanding the sources of booms and bust cycles in house prices and credit is a fundamental question for the effectiveness of policy interventions aiming at the stabilization of financial cycles.

1 Introduction

Survey evidence suggests that house price dynamics are significantly related to macroeconomic expectations and more specifically to optimism about future house price appreciation. Expectations of rising house prices played a role in past U.S. housing booms (Case and Shiller (2003)) and beliefs of rising prices also increased during the mid-2000's boom (Piazzesi and Schneider (2009)). Further, by 2006, when the aggregate U.S. price index had already started to decline, expectations of future home price increases were still high in places where the housing market activity continued to accelerate (Shiller (2007)).

This paper quantitatively evaluates the link between household expectations and house prices in a dynamic stochastic general equilibrium (DSGE) model of the housing market. We focus on future shifts in the fundamental driving forces of the economy anticipated by rational forward-looking agents, i.e. news shocks. Our approach allows for anticipation of future macroeconomic developments in the information set of the agents, when forming expectations. As explained by Beaudry and Portier (2013), "the news view of business cycles suggests that these phenomena are mainly the results of agents having incentives to continuously anticipate the economy's future demands. [...] Both the boom and the bust are direct consequences of people's incentive to speculate on information related to future developments of the economy". The news shocks approach has been extensively explored in the context of real and monetary DSGE models.[1] A growing number of papers explores the importance of news shocks as relevant sources of fluctuations in output and other aggregate variables (e.g. Beaudry and Portier (2006); Jaimovich and Rebelo (2009); Milani and Treadwell (2012); Schmitt-Grohé and Uribe (2012); Khan and Tsoukalas (2012)). However, how news shocks transmit to the housing market and the implied spillovers to the rest of the economy are largely unexplored in the news shocks literature. Given the forward-looking nature of house prices, news about future economic conditions would presumably be reflected in the determination of such a variable.Figure 1 plots four periods of run-ups in house prices in the U.S. since the end of the 1960's. The figure illustrates the relationship between run-ups in house prices (solid line) and expectations of rising house prices (solid bar). Following Piazzesi and Schneider (2009), we report the beliefs of future house price appreciation measured by the Michigan Survey of Consumers. The survey asks consumers whether it is a good time or a bad time to buy a house and their reasons for holding a particular view.[2] The fraction of

[1]For an extensive review of the literature and a discussion of the mechanisms by which news can cause business cycle fluctuations driven by changes in expectations, see Beaudry and Portier (2013).

[2]The survey collects information on consumers' attitude and expectations. Regarding the home buying conditions, consumers are asked: "Generally speaking, do you think now is a good time or a bad time to buy a home?". Positive answers regarding the expected change in house prices include "house prices will increase", "capital depreciation" and "housing is a good investment". Overall, consumers assess well home buying conditions. The index of home buying attitudes of households measured by the survey displays a correlation of 0.77 with the sales of new and existing single family homes in millions of units at annual rates.

households that expressed the view that it is a good time to buy a house due to an expected future appreciation in house prices generally increases during boom phases.[3] The relationship between house price dynamics and expectations of future house price appreciation is particularly pronounced during the housing boom of the 1970's. In the early 1970's, the fraction of households that expected future appreciation in house prices reached about 40 per cent in the quarter before the peak in house prices. During the housing boom of the late 1970's, the fraction of households that felt house prices would further appreciate reached about 60 per cent in the early phase of the boom and remained above 45 per cent in the subsequent phase. In the mid 2000's, the fraction of households optimistic about future house prices also increased and rose above 20 percent. Piazzesi and Schneider (2009) documents that during the recent housing boom expectations of future house price appreciations were significantly related to optimism about future economic conditions.

The paper proceeds in three steps. First, it assesses the role of news-shock driven cycles in shaping housing market dynamics in the U.S. economy by using likelihood-based Bayesian methods. Second, it explores the nexus between news shocks and household expectations and the ability of the model to match survey-based expectations. Then, it investigates the link between private sector expectations and housing market dynamics during periods of booms and busts in house prices.

Our findings are based on a medium scale model that features two types of households (patient and impatient), three sectors of production (consumption and investment goods and housing), and real, nominal and financial frictions. Credit constraints arise because lenders cannot force borrowers to repay. Thus, houses are used as loan collateral. The structure of the model follows Iacoviello and Neri (2010). Quantitative models of the housing market generally rely on unexpected changes in fundamentals to explain fluctuations in house prices and residential investment.[4] The model differs from other DSGE models of the housing market in that it includes news shocks about the exogenous driving forces of the economy. As standard in the news shocks literature, we assume that the structural shocks of the model feature an unanticipated component as well as an anticipated component driven by news

[3]The correspondence between expectations of future house price appreciation and rising house prices is less evident during the housing cycle of the late 1980's. It is important to notice that the increase in house prices during the late 1980's and the subsequent decline are limited compared to the other three episodes reported in the figure. As a matter of fact, many authors disregard it as a period of boom in the housing market. See for example Iacoviello and Neri (2010).

[4]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. For other models of the housing market that only rely on unexpected sources of fluctuations, see also Aoki, Proudman and Vlieghe (2004), Finocchiaro and von Heideken (2013), Iacoviello (2005), Kiyotaki, Michaelides and Nikolov (2011), Liu, Wang and Zha (2013) and Justiniano, Primiceri and Tambalotti (2013).

over different time horizons. To quantify the empirical relevance of news shocks, we estimate different versions of the model using U.S. data from 1965Q1 to 2007Q4.

This paper provides several insightful results. We document that the model with news shocks is strongly preferred in terms of overall goodness of fit. In particular, the data favor the inclusion of news shocks over a longer time horizon. In our model, 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, on the basis of local identification analysis, as in Iskrev (2010*a*), 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 affect economic choices and, notably, the housing and credit decisions of households in a different way than unanticipated shocks. In particular, news shocks generate expectations of future house price appreciation along with hump-shaped co-movements in housing and other macroeconomic variables. In response to news shocks over a longer time-horizon the model mimics the run-ups in house prices experienced in the U.S. economy over the last decades.

News shocks explain around 30 percent of business cycle fluctuations in house prices and a sizable fraction of variations in consumption and investment. Under the assumption of debt contracts in nominal terms, changes in current and future real interest rates affect household borrowing decisions. The presence of both real assets (capital and housing) and nominal assets (loanable bonds) in the model generates a role for shocks that directly affect inflation and the interest rate, and, thus, have an immediate impact on the portfolio decisions of the households. News on shocks that influence agents' expectations about future changes in the real interest rate are, thus, reflected in the dynamics of house prices that through the collateral effect further generate spillovers to the rest of the economy. In particular, expectations about future cost-push shocks contribute importantly to business cycle fluctuations. News shocks related to monetary factors account for a larger fraction of variation in house prices and consumption than expectations about future productivity shocks. Nevertheless, news related to productivity explains almost one-quarter of the variability in business investment.

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 "great inflation" period 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 contributed to the increase in house prices during the latest boom, whereas expected downward cost pressures on inflation muted it.

We test the plausibility of the expectation channel featured by the model by mapping the model implied expectations to survey-based expectations. The model suggests that inflation and interest rate expectations play an important role in house price movements. News shocks account for a large fraction of variation of 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.

On the basis of Granger causality tests, we find that news shocks also contain statistically significant information about survey-based inflation and interest rate expectations. 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. The model supports 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 about monetary policy shocks.

The remainder of the paper is organized as follows. In the next subsection, we discuss the related literature. Section 2 describes the model and Section 3 describes the estimation methodology. Section 4 addresses the issue of local identification of the shocks. Section 5 illustrates the news shocks transmission mechanism. Section 6 comments on the results of news shocks as a source of fluctuations in the housing market and Section 7 investigates the role of news shocks in booms and busts of house prices and residential investment. Section 8 relates agent expectations to house prices. Section 9 concludes.

1.1 Related Literature

A number of papers investigate the transmission mechanism of expectations about future fundamentals to house prices in macro models. Expectations of future income available to purchase housing (Hoffmann, Krause and Laubach (2012)) and heterogeneity in households' beliefs either about inflation (Piazzesi and Schneider (2012)) or about long-run fundamentals (Burnside, Eichenbaum and Rebelo (2011)) can shape housing market dynamics. Departures from rationality, such as illusionary investors (Piazzesi and Schneider (2007)), "internal rationality" (Adam, Kuang and Marcet (2012)) and extrapolative expectations (Granziera and Kozocki (2012); Gelain, Lansing and Mendicino (2013)), have also been suggested as important features in explaining excessive borrowing and booms in house prices. Although there is a growing number of papers that recognize that shifts in expectations may play a role in house price formation, quantitative evidence in general equilibrium models is scant.

A recent strand of the empirical macroeconomic literature uses forward-looking variables to document the macroeconomic effects of shifts in expectations of future developments in economic activity. See, among others Barsky and Sims (2012) and Leduc and Sill (2013). Regarding the housing market, Lambertini, Mendicino and Punzi (2013) documents that, in the context of a structural Vector Autoregression Model, shocks to forward looking survey variables, such as expectations of rising house prices and news on business conditions, generate hump-shaped responses in house prices and account for a sizable fraction of fluctuations in house prices, housing investment and household debt. More recently, Soo (2013) argues that investor sentiment helps in forecasting the boom and bust trend of housing prices at a two year lead and predicts the large part of the variation in house price movements.

This paper is closely related to the growing empirical literature that explores the role of news shocks over the business cycle. Since the seminal paper of Beaudry and Portier (2006), who using a VAR approach showed that business cycle fluctuations in the data are primarily driven by changes in agents' expectations about future technological growth, several authors have investigated the importance of expectations-driven cycles as a source of business cycle fluctuations.[5] A first set of papers studies the properties of standard stochastic general equilibrium models that help generating macroeconomic boom-bust cycles in response to news on productivity shocks. This strand of the news shocks literature highlights the importance of a weak short-run wealth elasticity of labor supply (Jaimovich and Rebelo (2009)), of the labor market matching mechanism (Den Haan and Kaltenbrunner (2009)), of variable capital utilization and vintage capital (Flodén (2007)), and of credit constraints on firms (Kobayashi, Nakajima and Inaba (2012)).

Several are also the contributions that quantify the effects of news on a variety of shocks in the context of estimated DSGE models. Fujiwara, Hirose and Shintani (2011) argue that the contribution of news on TFP shocks is often larger than that of the unanticipated TFP shocks. Milani and Treadwell (2012) find that news shocks about the policy rate play a larger role in the business cycle than unanticipated monetary policy shocks. Schmitt-Grohé and Uribe (2012) 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. In contrast, Khan and Tsoukalas (2012) show that, in the presence of wage and price rigidities, non-technology sources of news dominate technology news, with wage-markup news shocks in particular accounting for about 60 per cent of the variance of both hours and inflation. More recently, Gomes, Iskrev and Mendicino (2013) document that, in the context of a standard New Keynesian model, monetary policy news shocks improve the performance of standard

[5] Regarding the effect of news and expectation-driven cycles in VAR models, see, among others, Barsky and Sims (2011) and Barsky and Sims (2012), Leduc and Sill (2013), Kurmann and Otrok (2013).

DSGE models and help to achieve a better match in terms of the covariances of consumption growth and the interest rate. Christiano, Motto and Rostagno (2014) argue that news on risk shocks, i.e. anticipated shocks to the idiosyncratic risk in actual business ventures, are a key driver of business cycles.

We contribute to the news shocks literature 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.

Very few papers analyze the ability of DSGE models to match the dynamics of expectations. Existing 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 (2011) show that a model where agents have perfect information about the value of the policymaker's inflation target allows for a better fit of the dynamics of inflation expectations when inflation expectations are used as an observable in the estimation of a DSGE model. In the context of a standard New Keynesian model Milani and Rajrhandari (2012) document that using data on expectations improves the identification of news shocks. The approach followed by this paper is different in that we rely on the use of survey expectations for an external validation of the model, rather than as additional observables in the estimation of the model. We document that news shocks do not suffer an identification problem in the model estimated in this paper. Further, the model based expectations do not fall far from survey-based expectations.[6]

2 The Model

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. The model builds on Iacoviello and Neri (2010). The framework

[6] Our analysis differs from Milani and Rajrhandari (2012) in that (1) we rely on a model of the housing market; (2) we include house prices in the set of observables. Using survey expectations as additional observables could result into an even larger role of news shocks since these shocks would plausibly help matching the moments of the expectation variables.

we use is particularly appropriate to the purpose of this paper since its rich modeling structure allows for the quantifying of news shocks originating from different sectors of the economy, e.g., the housing market, the production sector, inflationary factors and the conduct of monetary policy. 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.[7] 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:

$$U_t = E_t \sum_{t=0}^{\infty} (\beta^t G_C)^t \upsilon_{z,t} \left\{ \Gamma_c \ln(C''_t - \varepsilon C''_{t-1}) + \varkappa \upsilon_{j,t} \ln H''_t - \frac{\upsilon_{\tau,t}}{1+\eta} \left[\left(N''_{c,t}\right)^{1+\xi} + \left(N''_{h,t}\right)^{1+\xi} \right]^{\frac{1+\eta}{1+\xi}} \right\},$$

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. $\varkappa$ is the housing weight in utility, $\upsilon_{z,t}$, $\upsilon_{j,t}$ and $\upsilon_{\tau,t}$ 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 $a(\bullet)$). 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. The capital stock used in the non-durable goods sector and in the housing sector as well as the housing stock depreciate at (quarterly) rates δ_{kc}, δ_{kh} and

[7] The continuum of households is of measure 1 in each of the two groups.

δ_h. Finally, Lenders receive (*lump-sum*) dividends from owning firms and from labor unions (D_t). Thus, their period budget constraint is:

$$C_t'' + \frac{K_{c,t}}{A_{k,t}} + K_{h,t} + K_{b,t} + q_t H_t'' + p_{l,t} L_t - B_t'' = \frac{w_{c,t} N_{c,t}''}{X_{wc,t}} + \frac{w_{h,t} N_{h,t}''}{X_{wh,t}} +$$

$$+ \left(R_{c,t} z_{c,t} + \frac{1-\delta_{kc}}{A_{k,t}} \right) K_{ct-1} + (R_{h,t} z_{h,t} + 1 - \delta_{kh}) K_{ht-1} + p_{b,t} K_{b,t} + (p_{l,t} + R_{l,t}) L_{t-1} + q_t (1-\delta_h) H_{t-1}''$$

$$+ D_t - \frac{R_{t-1} B_{t-1}''}{\pi_t} - \phi_{c,t} - \phi_{h,t} - \frac{a(z_{c,t}) K_{c,t-1}}{A_{k,t}} - a(z_{h,t}) K_{h,t-1},$$

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.[8] G_{IK_c} and G_{IK_h} are the trend growth rates of capital used in the two sectors of production and $\phi_{c,t}$ and $\phi_{h,t}$ are convex adjustment costs for capital and $a(z)$ denotes the cost of setting the capital utilization rate to z.[9]

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.[10] Borrowers do not own capital, land or firms. They only receive dividends from labor unions. Hence, the borrowers period budget constraint is:

$$C_t' + q_t \left(H_t' - (1-\delta_h) H_{t-1}' \right) - B_t' \leq \frac{w_{c,t}' N_{c,t}'}{X_{wc,t}'} + \frac{w_{h,t}' N_{h,t}'}{X_{wh,t}'} + D_t' - \frac{R_{t-1} B_{t-1}'}{\pi_t}.$$

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

[9] As for the adjustment costs, $\phi_{c,t} = \frac{\phi_{kc}}{2G_{IK_c}} \left(\frac{k_{c,t}}{k_{c,t-1}} - G_{IK_c} \right)^2 \frac{k_{c,t-1}}{(1+\gamma_{AK})^t}$ 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. Regarding the capacity utilization, $a(z_{c,t}) = R_c(\varpi z_{c,t}^2/2 + (1-\varpi) z_{c,t} + (\varpi/2 - 1))$and $a(z_{h,t}) = R_h(\varpi z_{h,t}^2/2 + (1-\varpi) z_{h,t} + (\varpi/2 - 1))$ where R_c and $R_h$are the steady state values of the rental rates for each type of capital. Note that $\zeta = \varpi/(1+\varpi)$ denotes the curvature of the capacity utilization function.

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

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:

$$B_t^{'} \leq m E_t \left(\frac{q_{t+1} H_t^{'} \pi_{t+1}}{R_t} \right),$$

where $m \leq 1$ represents the loan-to-value ratio.[11]

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 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:

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

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

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

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

[11] 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 neighborhood of the steady state. See, among others, Campbell and Hercowitz (2005), Iacoviello (2005), Iacoviello and Minetti (2006), Iacoviello and Neri (2010), Sterk (2010) and Liu et al. (2013).

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.

2.3 Monetary Policy Authority

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

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

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 $\upsilon_{S,t}$ is a persistent shock to the central bank's inflation target. Following Iacoviello and Neri (2010), 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 price along the balanced growth path (in terms of the price of the consumption good), $C_t = C_t'' + C_t'$ denotes total consumption, whereas $IK_t = IK_{c,t} + IK_{h,t} = [K_{c,t} - (1-\delta_{kc}) K_{ct-1}] + [K_{h,t} - (1-\delta_{hc}) K_{ht-1}]$ is total business investment.

2.4 News Shocks

In the model there are seven $AR(1)$ shocks – $\upsilon_{z,t}$, $\upsilon_{j,t}$, $\upsilon_{\tau,t}$, $\upsilon_{S,t}$, $\upsilon_{h,t}$, $\upsilon_{c,t}$ and $\upsilon_{k,t}$ – 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 shocks to 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 $x = \{c, h, k, p, R, s\}$.[12] Thus, at time $t-n$ agents receive a signal about future macroeconomic conditions at time t. As in Schmitt-Grohé and Uribe (2012) we assume

[12]We do not include news on preference shocks since they are of difficult interpretation. Moreover, it is not clear how to relate news on preference shocks to survey-based expectations.

anticipated changes four and eight quarters ahead. This assumption allows for revisions in expectations, e.g., $\varepsilon^8_{x,t-8}$ can be revised at time $t-4$ (up or down, partially or completely, in the latter case $\varepsilon^4_{x,t-4} = -\varepsilon^8_{x,t-8}$) and $\varepsilon^4_{x,t-4} + \varepsilon^8_{x,t-8}$ can be revised at time 0 (again, partially or completely, in the latter case $\varepsilon^0_{x,t} = -(\varepsilon^4_{x,t-4} + \varepsilon^8_{x,t-8})$ 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 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.[13] 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 component of the shocks, we follow, among others, Fujiwara et al. (2011) and we assume that the variance of the unanticipated innovation is equal to the sum of the variances of the anticipated components of each shock.

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

Our priors assign substantial more weight to the variance of the unanticipated shock than to each news shock component, i.e. for each shock, the standard deviation of the unanticipated component $\varepsilon^0_{x,t}$ has a prior mean equal to 0.001, whereas the standard deviation of each of the anticipated components, $\varepsilon^4_{x,t-4}$ and $\varepsilon^8_{x,t-8}$, equals 0.0007. The variance decomposition implied

[13] To perform inference we discard the first 10 per cent of observations. For further details on the estimation and the convergence of the algorithm see Appendix B.

by the priors point towards a major contribution of the unanticipated shocks. In fact, the unanticipated components of the shocks explain above 80 per cent of the standard deviation of most of the observables. See Table 1. Thus, the priors are heavily skewed toward assigning unanticipated shocks a larger role as sources of macroeconomic fluctuations. Choosing priors that weight heavily against news shocks allows us to test if the data are informative regarding the importance of these type of shocks. This restriction is thus only imposed on the priors and not on the posteriors.

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.[14] See Table 2.

3.2 Data

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 sectors, and the nominal wage quarterly change in the consumption and housing sector.[15] 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.[16]

3.3 Parameter Estimates

Tables 3 and 4 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

[14]See, among others, Adolfson, Laseen, Linde and Villani (2007) and Iacoviello and Neri (2010).

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

[16]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 shock has been separately estimated. It is important to stress that, 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. According to Iacoviello and Neri (2010): (1) the addition of a collateral shock does not effect the estimates of the other parameters of the model; (2) the effects of the collateral shock are quantitatively small and insufficient to generate large fluctuations in house prices. See Appendix D of their paper.

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.[17]

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 5 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.[18] Both versions of the model that allow for news shocks display a significantly higher log data density 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.[19] 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 5 we report the Bayes factor using Iacoviello and Neri (2010) data set. The same results hold.

4 Local Identification Analysis

In this section we address concerns related to the identification of news shocks. 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

[17]These differences may also be related to data revision. Iacoviello and Neri (2010) used data from 1965Q1 to 2006Q4. Therefore, we use a different vintage of the data set. A comparison of the series at different release dates highlights substantial revisions in the series for inflation.

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

[19]6.1×10^{12} larger than the prior belief about the model with 4-quarter ahead news shocks.

identification approach. As in Schmitt-Grohé and Uribe (2012) we rely on the methodology proposed by Iskrev (2010*a*). 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.

Let $J_T(\theta)$ 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 moments of the observables (of sample size T) in the model. The Jacobian matrix can be factorized as $J_T(\theta) = \frac{\partial m_T}{\partial \tau} \frac{\partial \tau}{\partial \theta}$, where τ represents a vector collecting the (non-constant elements of the) reduced-form parameters of the first-order solution to the model, $\frac{\partial m_T}{\partial \tau}$ 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 $J(\theta)$ has full column rank at θ_i. Evaluating this Jacobian matrix at the posterior mean of the estimated parameters, we can conclude that all estimated parameters reported in Tables 3 and 4 are locally identified.

4.1 Are News Shocks Different than Other Shocks...

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. Besides indicating whether the estimated parameters are locally identified, these concepts can also be used to investigate differences and similarities among the anticipated and unanticipated components of the shocks both in the solution of the model and in the determination of the statistical properties of the model. In the following, we document that 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 observables used in the estimation.

4.1.1 ...in the model?

Since τ collects the reduced-form parameters of the first-order solution to the model, it fully characterizes the steady state and the model dynamics. Low sensitivity of τ to a particular deep parameter of the model, θ_i, 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. 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. $\frac{\partial \tau}{\partial \theta_i} \simeq 0$, or (2) if the effects on τ of changing θ_i can be offset by changing other parameters, i.e. $corr\left(\frac{\partial \tau}{\partial\ \theta_i}, \frac{\partial \tau}{\partial \theta_{-i}}\right) \simeq 1$.[20]

[20]It is important to notice that if a parameter does not affect the solution of the model ($\frac{\partial \tau}{\partial \theta_i} \simeq 0$) then its value is also irrelevant for the statistical properties of the data generated by the model ($\frac{\partial m_T}{\partial \theta_i} \simeq 0$). Indeed, the statistical and the economic modeling aspects of identification are complementary.

Regarding the identification of the shocks in the model, we measure collinearity between the column of the Jacobian $\frac{\partial \tau}{\partial \theta}$ with respect to the standard deviations of the news shocks, σ_x^4 and σ_x^8, the standard deviation of the unanticipated shocks, σ_x^0, and the autocorrelation parameters, ρ_x. First, we compute the correlation between the columns of the Jacobian for all possible pairs of shocks' parameters. Then, we select the pairs of parameters with the highest correlation among all possible combinations. The results reported in Panel A of Figure 2. Filled cells indicate the parameter reported in the x-axis that displays the highest correlation with a particular parameter reported in the y-axis. The scale on the right indicates the degree of correlation between the pairs of shocks' parameters with the highest correlation, ranging from 0 (no correlation) to 1 (collinearity).

The highest correlation 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, the two components of each shock have distinctive effects on the solution of the model, and thus on the model's policy functions. It is important to notice that the correlation of the columns of the Jacobian across possible sets of shocks' parameters is generally low, suggesting weak collinearity relationships among these parameters with respect to 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 the model's solution is sensitive to changes in both unanticipated and news shocks. See Section 5 for differences in the transmission of the anticipated and unanticipated components of each shock.

4.1.2 ...in the moments?

In the following, we test for local identification in the moments related to the ten observables used in the estimation. Since the model's parameters affect the likelihood function mainly through their effects on the first and second order moments of the observed variables, all statistics reported in this section are based on the first and second order covariances. Panel B of Figure 2 reports pairs of shocks' parameters with the highest correlation among the columns of the Jacobian matrix, $J(\theta)$. Once we evaluate the role of shocks in the selected moments, we find that collinearity is higher with respect to the 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 identification 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 correlation between the investment specific shock and the 8 quarters ahead news shock offers an exception. Notice that the highest correlation is not found among news shocks but it is displayed between the standard deviation of the housing preference shock and the persistence of the same shock. High correlation could indicate problems with the strenght of identification between sets of parameters. However, it is important to stress that no multicollinearity is found across the shocks parameters.

According to Iskrev (2010*b*) 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 3 reports the sensitivity in the moments to the shocks' parameters at the posterior mean, i.e. the norm of columns of the Jacobian matrix, $\frac{\partial m_T)}{\partial \theta}$, 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 identification.

5 Transmission Mechanism

In this section, we highlight key findings regarding the transmission mechanism of news shocks. Anticipations of shocks that would lead to an increase in house prices, such as future loosening of monetary policy, 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 thus fuel current housing demand. As an illustrative example, Figure 4 describes the effect of one-period monetary policy shocks on house prices. In the top panel it displays the response of house prices to an unanticipated shock (left panel) and to 4- and 8-quarters-ahead news shocks (right panel). In the bottom panel it reports the corresponding simulated monetary policy shocks. In response to news shocks, house prices gradually rise, peak at the time in which expectations are fulfilled and, then, slowly decline towards the initial level. The longer the anticipation lag, the more pronounced the run-up in house prices.

Figure 5 displays the effect of a 4-quarter-ahead monetary policy news shock (solid line) on key macroeconomic variables. For comparison, we also report the model's responses to an unanticipated shock (dashed line). In both cases, a 1 percent shock is shown. Signals of lower future policy rates generate expectations of a decline in the real interest rate. Borrowers anticipate this effect and increase their current consumption, as servicing loans are expected to be less expensive. Demand pressure raises current inflation. The anticipation of expansionary monetary policy also creates expectations of higher future housing prices that further induce Borrowers to increase their current demand for housing. As news spread, the value of housing collateral increases and the rise in house prices is, thus, coupled with an

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

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. Savers face a reduction in their current and expected interest income. Thus, for this group of agents, consumption increases by less, current housing investment declines and their labor supply increases significantly.

Given the presence of adjustment costs for capital, firms begin 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 both business and housing investment makes GDP increase at the time of the signal. As a consequence of the current increase in inflation and GDP, the policy rate also increases at the time of the signal, to decline only at the time of the occurrence of the shock. In contrast to standard unanticipated shocks, the peak effect on prices and quantities is not immediate.[22]

News on a variety of shocks could potentially be sources of optimism about future house price appreciation. Figures 6 and 7 report, respectively, the effect of a variety of unanticipated shocks and the corresponding news shocks on key macroeconomic variables. Unanticipated shocks do not generate expectations of rising house prices and hump-shaped dynamics. In contrast, Figure 7 documents hump-shaped co-movement between house prices and other macroeconomic variables in response to a variety of news shocks.[23] Summarizing, news shocks affect economic choices and, in particular, the housing and credit decisions of households differently than unanticipated shocks. The transmission of news shocks relies on two distinguishable features: news shocks can induce optimism about future house price appreciation; news shocks can also generate hump-shaped dynamics in house prices that resemble the patterns observed in the data during periods of housing booms.

6 News Shocks and Housing Market Dynamics: Understanding Historical Data

In the following, we quantify the role of news shocks for housing market dynamics. 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.

[22]A negative unanticipated shock to the policy rule (dashed line) induces agents to increase their current expenditures. Aggregate demand rises. Borrowers significantly increase their level of indebtedness and housing investment. Housing prices rise and the subsequent collateral effect induces a sizable increase in borrowers' consumption.

[23]These findings are in line with the evidence reported by Lambertini et al. (2013) that, using a VAR model, estimate the effect of unanticipated changes in the index of "expectations of rising house prices"and "news heard of recent changes in business conditions" from the Michigan Survey of Consumers. Shocks to forward-looking survey variables generate a macroeconomic boom coupled with a boom in house prices and household credit.

6.1 Business Cycle Fluctuations

We explore the contribution of shocks to the unconditional variance of the observable variables at business cycle frequencies (theoretical variance decomposition). Table 6 reports the variance share accounted by real and nominal sources of fluctuations and by preference shocks.[24] Summing up the variance share accounted by news and unanticipated shocks, we find that the real sources of macroeconomic fluctuations, i.e. productivity and investment specific shocks, account for about one quarter of the fluctuations in investment and house prices. 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 also highlighted by Liu et al. (2013), 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. Overall, nominal sources of fluctuations, i.e. cost-push and monetary policy shocks, are generally more important than productivity and preference shocks as drivers of economic fluctuations. One intuitive reason for this result is that, in a model with debt contracts in nominal terms, shocks that directly affect inflation and the interest rate lead to portfolio adjustments between investment in physical assets and loanable bonds. Due to the presence of a collateral constraint, house price dynamics in the model are coupled with changes in household debt that further affect the economic decisions of agents. Plausibly, news on these type of shocks affect expectations about future macroeconomic prospects that are then reflected in forward-looking variables, such as house prices.

Are news shocks a relevant source of business cycle fluctuations? Table 7 shows the contribution of the anticipated and unanticipated components of the shocks to the unconditional variance of the observable variables. News shocks account for slightly more than 30 percent of the variance in house prices, about 15 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. A comparison between the variance decomposition shares of the anticipated and unanticipated components of the shocks implied at the priors and at the posterior mean suggests that the data are informative regarding the role of news shocks in accounting for business cycle fluctuations.

[24] The real sources of fluctuations refer to shocks to the productivity in consumption, $\upsilon_{c,t}$, and housing, $\upsilon_{h,t}$, and capital investment specific shocks, $\upsilon_{k,t}$; the nominal sources of fluctuations include monetary policy shocks, $\mathrm{u}_{R,t}$ and $\upsilon_{s,t}$, and cost push shocks, $\mathrm{u}_{p,t}$; preference shocks are shocks to the intertemporal preferences, $\upsilon_{S,t}$, housing demand, $\upsilon_{j,t}$, and labor supply, $\upsilon_{\tau,t}$.

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

Regarding the different types of news shocks, news related to cost-push shocks are the most important source of fluctuations among the anticipated shocks. See Table 8. In particular, expectations about future cost push shocks explain around 25 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 the fact that these shocks are able to generate co-movement among a broad set of macroeconomic variables. See Section 5. 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.[26]

As for the unanticipated component of the shocks, monetary shocks explain about 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 9. 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.

[26]The model performs reasonably well in capturing the main features of the data. A set of moments implied by the model with 4- and 8-quarter ahead news shocks as well as the corresponding moments in the data are reported in Appendix C.

7 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 8. In the following, we report the results for the two main house price booms that peak in 1979Q4 and 2005Q4, respectively. We also date the cycles of real housing investment using the same procedure. 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 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, residential investment display a peak in 2000Q3, whereas the decline in housing investment ends in 2003Q1, a few quarters after the through of activity.

Table 10 reports the contribution of the estimated shocks to house prices and residential investment growth during each boom- and bust-phase (historical variance decomposition based on the expected smoothed shocks). 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.

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. See Table 11. 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 particular, expectations of cost push shocks contribute to around 30 percent of the run up in housing prices. As for residential investment, news on cost push shocks contributed by 75 percent to its growth, followed by investment specific news shocks. 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.[27] News on cost push shocks result to be important during the great inflation of the 1970's and could, thus, be 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.[28] In the next section we investigate the relationships between inflation expectations, news shocks and housing market dynamics.[29]

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.[30] See Tables 12. 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 that corresponded to a period of low and stable inflation.

Summarizing, booms and busts 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.

8 Interpreting News Shocks: the Role of Expectations

Given that the effect of news shocks mainly works through expectations, we now investigate the importance of expectations for the transmission of news shocks to house prices. The

[27]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. For further details see Appendix D.

[28]De Graeve, Emiris and Wouters (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 1970's. 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 Galí (2007) and the references therein.

[29]Regarding inflation expectations and credit and real estate dynamics see also Piazzesi and Schneider (2012).

[30]See, among others, Jermann and Quadrini (2007) and Shiller (2000) for detailed account on productivity growth driven by computer technology and the use of new equipment since the mid-1990's.

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.[31] 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.[32] 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.

8.1 Survey- versus Model-based Expectations

Are news shocks related to agents' expectations? Table 13 reports the variance decomposition of the model-based expectations about inflation and interest rates generated over the sample period.[33] 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 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.[34]

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,

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

[32] 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.

[33] 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.

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

which are not part of the information set of the model.[35] 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.[36] 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 9.

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 14 and 15.[37] 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. Using survey expectations as observables could result in a larger role of news shocks since these type of shocks would also help matching the moments of the expectations variables.

8.2 Expectations and House Prices

We also 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.[38]

Table 16 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

[35] 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 (2011).

[36] 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.

[37] 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.

[38] Piazzesi and Schneider (2012) input exogenous 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 (2012), 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.

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 10. One plausible reason for the weaker co-movement of inflation expectations and house prices during the more recent boom, is 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.

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 16. By visual inspection of Figure 10, 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 11.

Overall, 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.

9 Conclusions

This paper quantifies the role of news-shocks-driven cycles for housing market fluctuations in the U.S. News shocks emerge as relevant sources of macroeconomic fluctuations and explain a sizable fraction of 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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Table 1: Variance Decomposition at the Prior Mean: Anticipated vs Unanticipated Shocks

	Anticipated Shocks			**Unanticipated Shocks**
	Total	4 -quarter	8-quarter	Total
House Prices (Q)	18.12	12.03	6.10	81.88
Housing Inv. (IH)	18.87	13.21	5.65	81.13
Consumption (C)	15.33	11.10	4.22	84.67
Business Inv. (IK)	18.25	12.22	6.03	81.75
Inflation (π)	31.99	21.86	10.12	68.01

Notes: Parameters set at the prior mean. HP filtered series. The total contribution of anticipated shocks is the sum of the 4 and 8-quarter ahead news shocks contributions.

Table 2: Calibrated Parameters

Technology			Preferences		
μ_c	Non-durable good: capital share	0.35	β	Lenders' discount factor	0.9925
μ_h	Housing: capital share	0.10	$\beta^{'}$	Borrowers' discount factor	0.97
μ_l	Housing: land share	0.10	ξ	Lenders labor weight across sector	0.66
μ_b	Housing: intermediate good share	0.10	$\xi^{'}$	Borrowers labor weight across sector	0.97
α	Labor income share of lenders	0.79	$\varkappa$	Housing weight in utility	0.12
δ_h	Housing depreciation rate	0.01	η	Lenders labor supply elasticity	0.52
δ_{kc}	Depreciation rate in cap. good sector	0.025	$\eta^{'}$	Borrowers labor supply elasticity	0.51
δ_{kh}	Depreciation rate in housing sector	0.03			
X	Price markup	1.15		Other	
X_{wc}	Wage markup in non-dur. good sector	1.15	m	Loan-to-value ratio	0.85
X_{wh}	Wage markup in housing sector	1.15	ρ_s	AR of inflation objective	0.975
γ_{AC}	Growth rate in non-dur. good sector	0.0032			
γ_{AH}	Growth rate in housing sector	0.0008			
γ_{AK}	Growth rate in business investment	0.0027			

Source: Iacoviello and Neri (2010).

Table 3: 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 gr. response	r_Y	$\mathcal{N}$	0.00	0.10	0.8025	0.7066	0.9018
Autoregressive parameters							
Prod. consumption sector	ρ_C	$\mathcal{B}$	0.80	0.10	0.9531	0.9289	0.9772
Prod. housing sector	ρ_H	$\mathcal{B}$	0.80	0.10	0.9970	0.9943	0.9997
Prod. capital sector	ρ_K	$\mathcal{B}$	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

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

Table 4: Estimation Results (cont.)

Parameter		Prior			Posterior		
		Type	Mean	Stdev	Mean	5%	95%
Stand. deviation - unant.shocks							
Prod. consumption sector	σ_C	$\mathcal{IG}$	0.001	0.01	0.0096	0.0086	0.0106
Prod. housing sector	σ_H	$\mathcal{IG}$	0.001	0.01	0.0187	0.0162	0.0211
Prod. capital sector	σ_K	$\mathcal{IG}$	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}
St. deviation - ant. shocks 4-q							
Prod. consumption sector	σ_{C4}	$\mathcal{IG}$	0.0007	0.01	0.0005	0.0002	0.0010
Prod. housing sector	σ_{H4}	$\mathcal{IG}$	0.0007	0.01	0.0007	0.0002	0.0016
Prod. capital sector	σ_{K4}	$\mathcal{IG}$	0.0007	0.01	0.0006	0.0002	0.0010
Cost push	σ_{p4}	$\mathcal{IG}$	0.0007	0.01	0.0004	0.0002	0.0008
Monetary policy	σ_{R4}	$\mathcal{IG}$	0.0007	0.01	0.0004	0.0002	0.0006
Inflation objective*100	σ_{s4}	$\mathcal{IG}$	0.0007	0.01	0.0250×10^{-2}	0.0156×10^{-2}	0.0344×10^{-2}
St. deviation - ant. shocks: 8-q							
Prod. consumption sector	σ_{C8}	$\mathcal{IG}$	0.0007	0.01	0.0007	0.0002	0.0014
Prod. housing sector	σ_{H8}	$\mathcal{IG}$	0.0007	0.01	0.0040	0.0002	0.0103
Prod. capital sector	σ_{K8}	$\mathcal{IG}$	0.0007	0.01	0.0094	0.0069	0.0120
Cost push	σ_{p8}	$\mathcal{IG}$	0.0007	0.01	0.0026	0.0019	0.0034
Monetary policy	σ_{R8}	$\mathcal{IG}$	0.0007	0.01	0.0004	0.0002	0.0007
Inflation objective*100	σ_{s8}	$\mathcal{IG}$	0.0007	0.01	0.0323×10^{-2}	0.0174×10^{-2}	0.0474×10^{-2}
St. 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

Note: $\mathcal{IG}$ = Inverse Gamma.

Table 5: Model Comparison

	No news	News 4	News 4&8
Benchmark (1965-2007 sample)			
Log Marginal Data Density	4809.53	4838.97	4867.60
Difference	-	29.45	58.08
Implied Bayes factor	1	6.1×10^{12}	1.7×10^{25}
Memo:			
I&N data (1965-2006 sample)			
Log Marginal Data Density	4693.44	4720.69	4743.12
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 6: Variance Decomposition by Type of Shocks

	Sources of Fluctuations		
	Real	Nominal	Preferences
	$\upsilon_{c,t}+\upsilon_{h,t}+\upsilon_{k,t}$	$\text{u}_{p,t}+\text{u}_{R,t}+\upsilon_{S,t}$	$\upsilon_{z,t}+\upsilon_{j,t}+\upsilon_{\tau,t}$
House prices (Q)	22.16	38.92	38.93
Housing Inv. (IH)	28.69	19.80	51.50
Consumption (C)	7.82	65.20	26.97
Business Inv. (IK)	25.92	63.81	10.24
Inflation (π)	3.54	85.71	10.74

Notes: Parameters set at the posterior mean. HP filtered series. Sum of the contributions of both anticipated and unanticipated components of each type of shocks of real sources of fluctuations (shocks to the productivity in consumption, $\upsilon_{c,t}$, and housing, $\upsilon_{h,t}$, production and capital investment specific shocks, $\upsilon_{k,t}$), nominal sources of fluctuations (monetary policy shocks, $u_{R,t}$ and $\upsilon_{s,t}$, and cost push shocks, $u_{p,t}$) and preference shocks (shocks to the intertemporal preferences $\upsilon_{z,t}$ housing demand, $\upsilon_{j,t}$, labor supply, $\upsilon_{t,t}$).

Table 7: Variance Decomposition: Anticipated vs Unanticipated Shocks

	Anticipated Shocks			**Unanticipated Shocks**
	Total	4 -quarter	8-quarter	Total
House Prices (Q)	33.39	1.10	32.29	66.62
Housing Inv. (IH)	15.00	0.62	14.38	84.99
Consumption (C)	54.73	1.65	53.08	45.26
Business Inv. (IK)	72.18	1.77	70.41	27.82
Inflation (π)	63.35	10.62	52.73	36.63

Notes: Parameters set at the posterior mean. HP filtered series. The contribution of anticipated shocks is the sum of the 4 and 8-quarter ahead news shocks contributions.

Table 8: Variance Decomposition

	Anticipated Shocks			Unanticipated Shocks		
	Product.	Cost Push	Mon.Pol.	Product.	Cost Push	Mon.Pol.
	$\upsilon_k + \upsilon_h + \upsilon_c$	u_p	$\mathrm{u}_R + \upsilon_S$	$\upsilon_k + \upsilon_h + \upsilon_c$	u_p	$\mathrm{u}_R + \upsilon_S$
House Prices (Q)	3.50	25.82	4.07	18.66	0.64	8.39
Housing Inv. (IH)	6.40	6.14	2.46	22.29	0.17	11.03
Consumption (C)	4.21	44.56	5.96	3.61	0.76	13.92
Business Inv. (IK)	23.94	44.57	3.67	2.01	0.99	14.58
Inflation (π)	1.34	45.18	16.83	2.20	10.09	13.61

Note: Parameters set at the posterior mean. HP filtered series. The contribution of anticipated shocks is the sum of the 4 and 8-quarter ahead news shocks contributions.

Table 9: Variance Decomposition: News vs No-News

	Unanticipated Shocks							
	Model without News				**Model with News**			
	Product.	Cost Push	Mon. Pol.	Prefer.	Product.	Cost Push	Mon.Pol.	Prefer.
	$\upsilon_k + \upsilon_h + \upsilon_c$	u_p	$\mathrm{u}_R + \upsilon_S$	$\upsilon_j + \upsilon_z + \upsilon_\tau$	$\upsilon_k + \upsilon_h + \upsilon_c$	u_p	$\mathrm{u}_R + \upsilon_S$	$\upsilon_j + \upsilon_z + \upsilon_\tau$
House Prices (Q)	31.05	11.28	11.17	45.98	18.66	0.64	8.39	38.93
Housing Inv. (IH)	30.42	2.94	11.73	54.91	22.29	0.17	11.03	51.50
Consumption (C)	8.13	30.36	33.63	27.88	3.61	0.76	13.92	26.97
Business Inv. (IK)	23.39	29.96	37.41	9.24	2.01	0.99	14.58	10.24
Inflation (π)	1.00	81.85	10.87	6.28	2.20	10.09	13.61	10.73

Notes: Parameters set at the posterior mean. HP filtered series.

Table 10: Shocks Contribution to Booms and Busts

Booms and Busts	% change	Productivity $\upsilon_k + \upsilon_h + \upsilon_c$	Cost Push u_p	Mon.Pol. $u_R + \upsilon_S$	Hous. Pref. υ_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 Q1 - 1979 Q3	22.09	10.62	16.24	3.40	2.21
1979 Q4 - 1983 Q1	-21.25	-13.66	26.63	-23.28	-0.62
1992 Q2 - 2000 Q3	48.86	38.72	-11.81	4.03	-0.88
2000 Q4 - 2003 Q1	-25.65	-13.57	-10.84	-1.90	0.21
2003 Q2 - 2007 Q4	12.81	11.70	-7.31	2.61	1.97

Notes: Parameters set at the posterior mean. Cycles dated by applying the Bry-Boschan algorithm to the real house prices series (Q) and the residential investment series (IH).

Table 11: Shocks Contribution to Booms and Busts: 1970's/1980's

		Shocks Contribution									
		Anticipated					Unanticipated				
Booms and Busts	% change	u_p	υ_h	υ_k	υ_c	$u_R + \upsilon_S$	u_p	υ_h	υ_k	υ_c	$u_R + \upsilon_S$
House Prices											
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
Residential Investment											
1976 Q1 - 1979 Q3	22.09	16.19	1.56	11.33	-0.01	-2.24	0.05	-0.19	0.02	-2.09	5.63
1979 Q4 - 1983 Q1	-21.25	26.40	-1.49	-3.44	-0.01	1.00	0.23	-0.41	0.02	-8.34	-24.28

Notes: Parameters set at the posterior mean. Cycles dated by applying the Bry-Boschan algorithm to the real house prices series (Q) and the residential investment series (IH). The contribution of anticipated shocks is the sum of the 4 and 8-quarter ahead news shocks contributions.

Table 12: Shocks Contribution to Booms and Busts: 1990's/2000's

		Shocks Contribution									
		Anticipated					Unanticipated				
Booms and Busts	% change	u_p	υ_h	υ_k	υ_c	$u_R + \upsilon_S$	u_p	υ_h	υ_k	υ_c	$u_R + \upsilon_S$
House Prices											
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
Residential Investment											
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

Notes: Parameters set at the posterior mean. Cycles dated by applying the Bry-Boschan algorithm to the real house prices series (Q) and the residential investment series (IH). The contribution of anticipated shocks is the sum of the 4 and 8-quarter ahead news shocks contributions.

Table 13: Model-Based Expectations: Variance Decomposition

	Anticipated shocks							Unant. shocks
	Total	Cost Push (u_p)		Inf. target (υ_S)		Inv. specific (υ_k)		
		4-quarter	8-quarter	4-quarter	8-quarter	4-quarter	8-quarter	Total
Inflation exp.								
1 quarter ahead	72.20	1.64	49.26	10.21	9.13			27.77
4 quarter ahead	79.01	0.86	53.21	11.26	12.11			20.98
Int. rate exp.								
1 quarter ahead	72.48	0.11	14.70	14.98	15.41	0.06	22.34	27.48
4 quarter ahead	80.62	0.05	7.44	18.82	27.20	0.01	23.67	19.39

Note: Parameters set at the posterior mean.

Table 14: Granger Causality Tests - Inflation Expectations

	SPF						Michigan Survey		
	1-quarter ahead			4-quarter ahead			4-quarter ahead		
Shock	F-statistic	p-value		F-statistic	p-value		F-statistic	p-value	
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]	***

Notes: The null hypothesis is that the shock does not Granger cause inflation expectations. *** 1%, ** 5%, * 10% significance.

Table 15: Granger Causality tests - Interest Rate Expectations (SPF Data)

	1-quarter ahead			4-quarter ahead		
Shocks	F-statistic	p-value		F-statistic	p-value	
Cost-push (u_p)						
4-quarter ahead	20.569	[0.0000]	***	11.603	[0.0000]	**
8-quarter ahead	19.380	[0.0000]	***	8.431	[0.0000]	***
Inv. specific (υ_k)						
4-quarter ahead	25.476	[0.0000]	***	26.500	[0.0000]	***
8-quarter ahead	30.842	[0.0000]	***	51.915	[0.0000]	***
Inf. target (υ_S)						
4-quarter ahead	15.685	[0.0000]	***	4.451	[0.0011]	***
8-quarter ahead	17.377	[0.0000]	***	2.435	[0.0928]	*

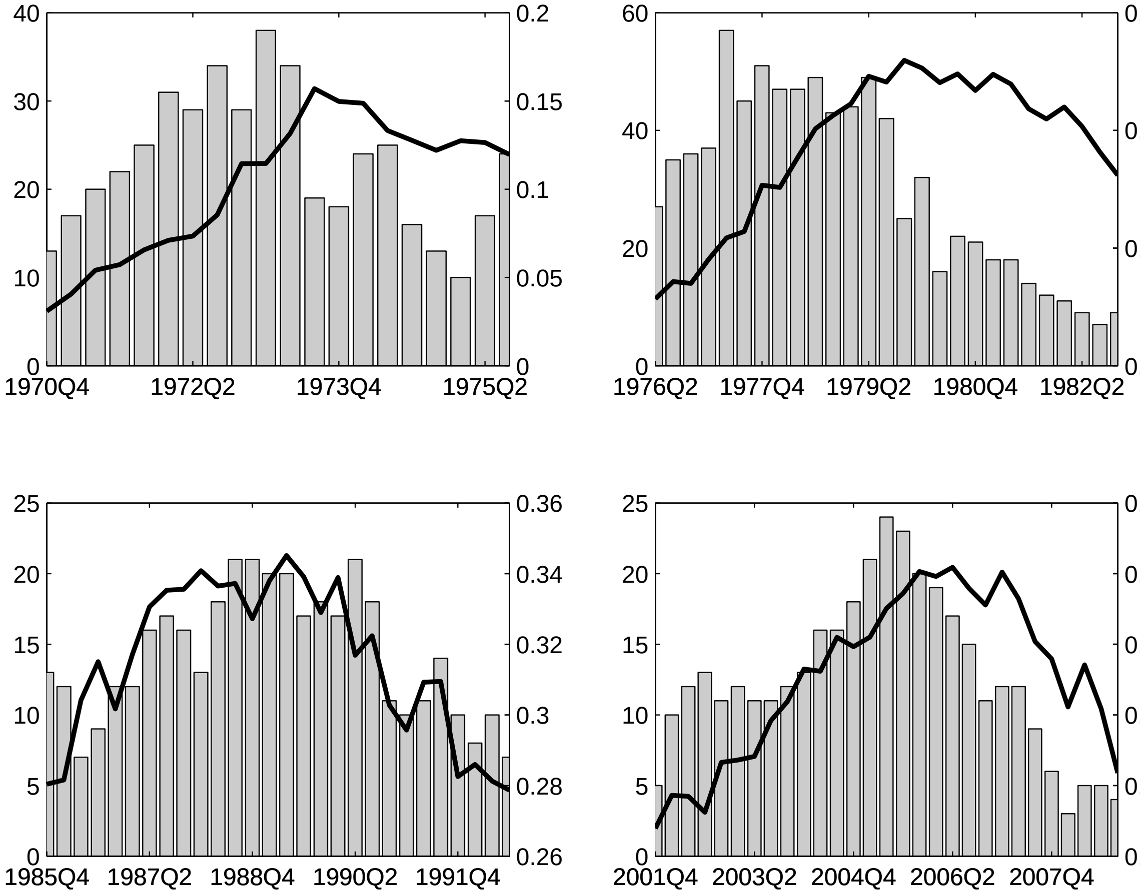
Notes: The null hypothesis is that the shock does not Granger cause inflation expectations. *** 1%, ** 5%, * 10% significance.

Table 16: Expectations and House Prices

	Correlation with House Prices							
	Survey-based Expectations (SPF)				Model-based Expectations			
	Inflation		Interest Rate		Inflation		Interest Rate	
	1-quarter	4-quarter	1-quarter	4-quarter	1-quarter	4-quarter	1-quarter	4-quarter
Booms and Busts								
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 sample								
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

Notes: 1- and 4-quarter ahead expectations. Cycles dated by applying the the Bry-Boschan algorithm to the real house price series (Q).

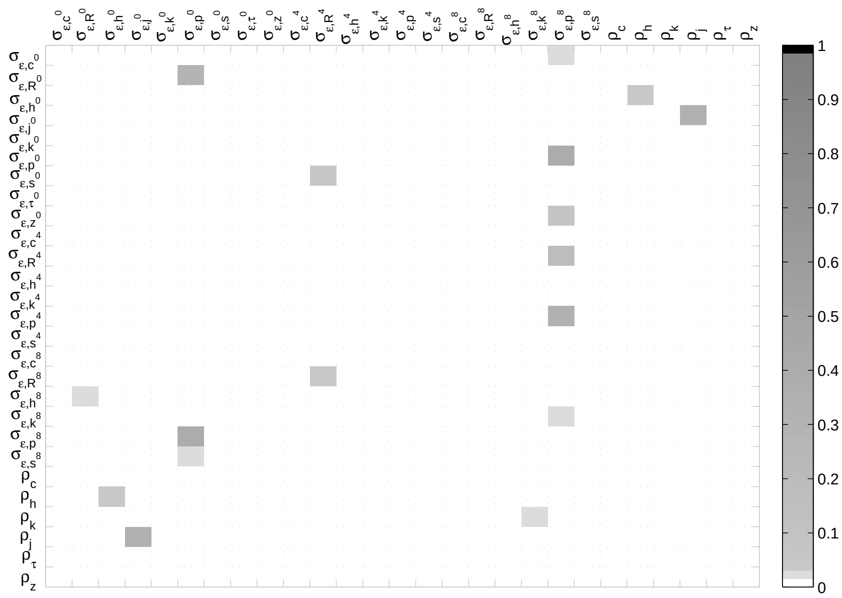
Figure 1: House Prices Run Ups and Expectations of Rising House Prices



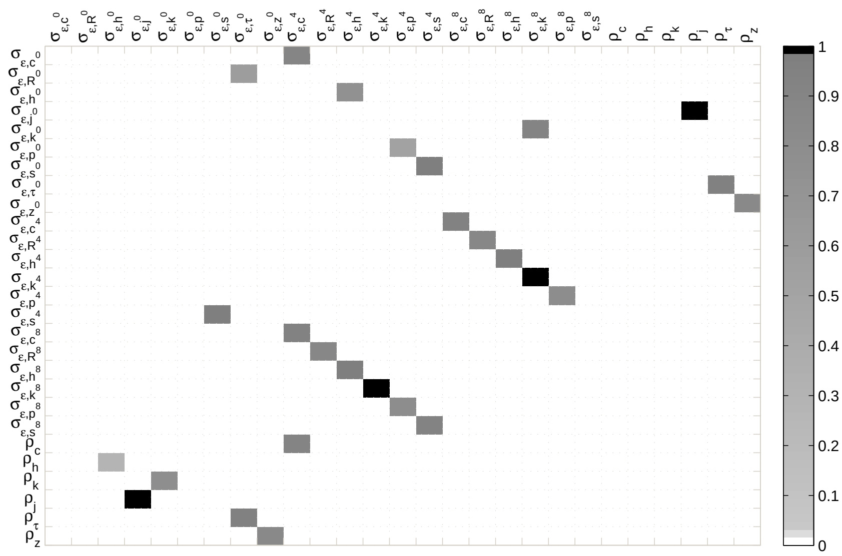
Notes: Solid line (y-axis labeling on the right): Real House Prices - Census Bureau House Price Index (new one-family houses sold including value of lot) deflated with the implicit price deflator for the nonfarm business sector. Real house prices are normalized to zero in 1965Q1. Bars (y-axis labeling on the left): fraction of households in the Michigan Survey of Consumers that express the view that it is a good time to buy a house due to an expected future appreciation in house prices.

Figure 2: Parameters identification

(a) Identification with Respect to the Model solution

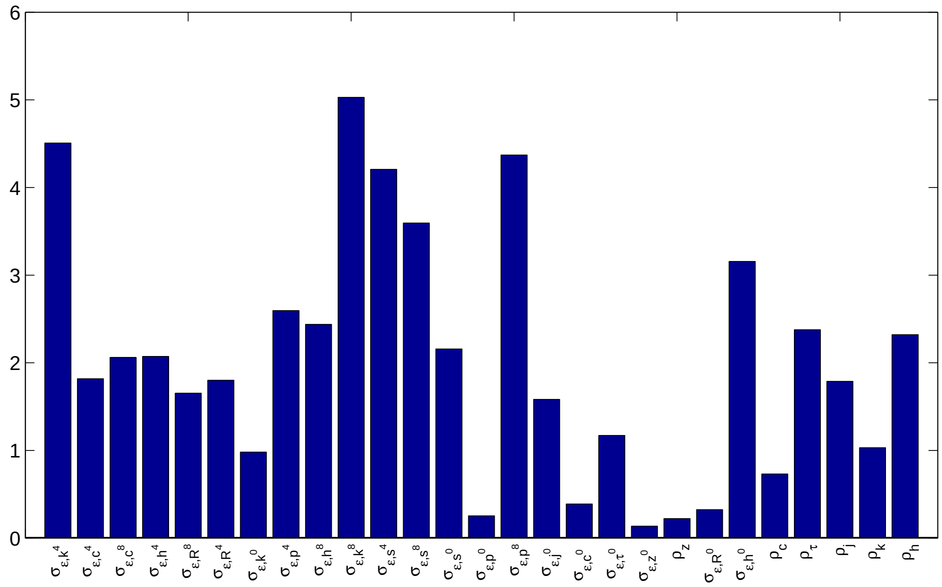


(b) Identification with respect to the model implied moments



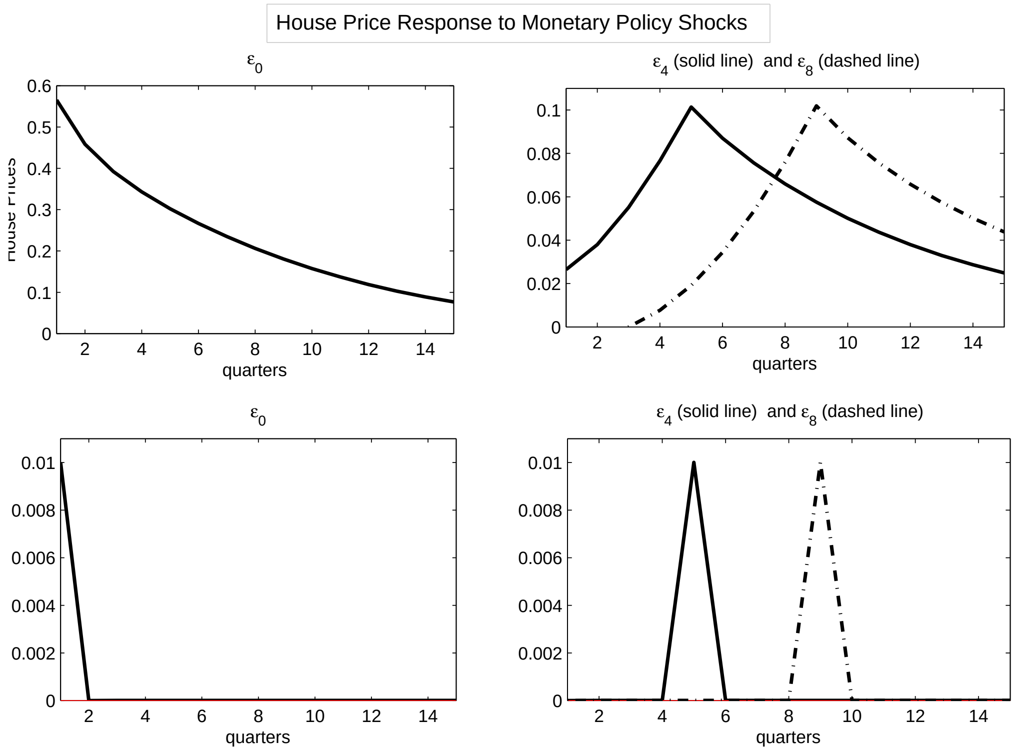
Notes: Pairs of shocks' parameters with the highest correlation among the columns of the Jacobians. Filled cells indicate the parameter reported in the x-axis that displays the higher correlation with a particular parameter reported in the y-axis. The scale on the right indicated the degree of correlation between the pairs of shocks' parameters with the highest cosine, ranging from 0 (no correlation) to 1 (collinearity).

Figure 3: Sensitivity in the Moments



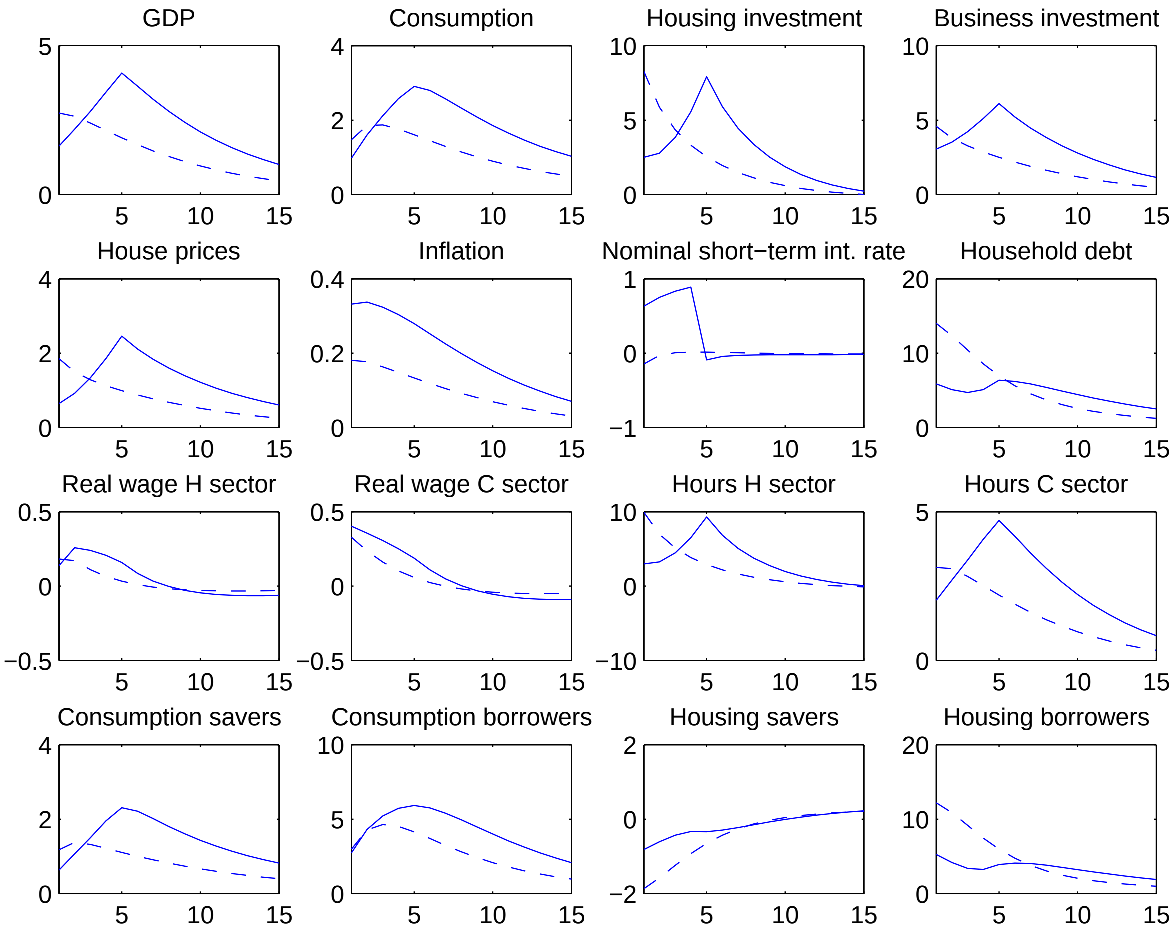
Notes: Y-axis reports the sensitivity of the first and second order moments of the observables to each shock parameter. X-axis reports the shocks parameters.

Figure 4: Real House Prices – Impulse-Response Functions to Monetary Policy News Shocks



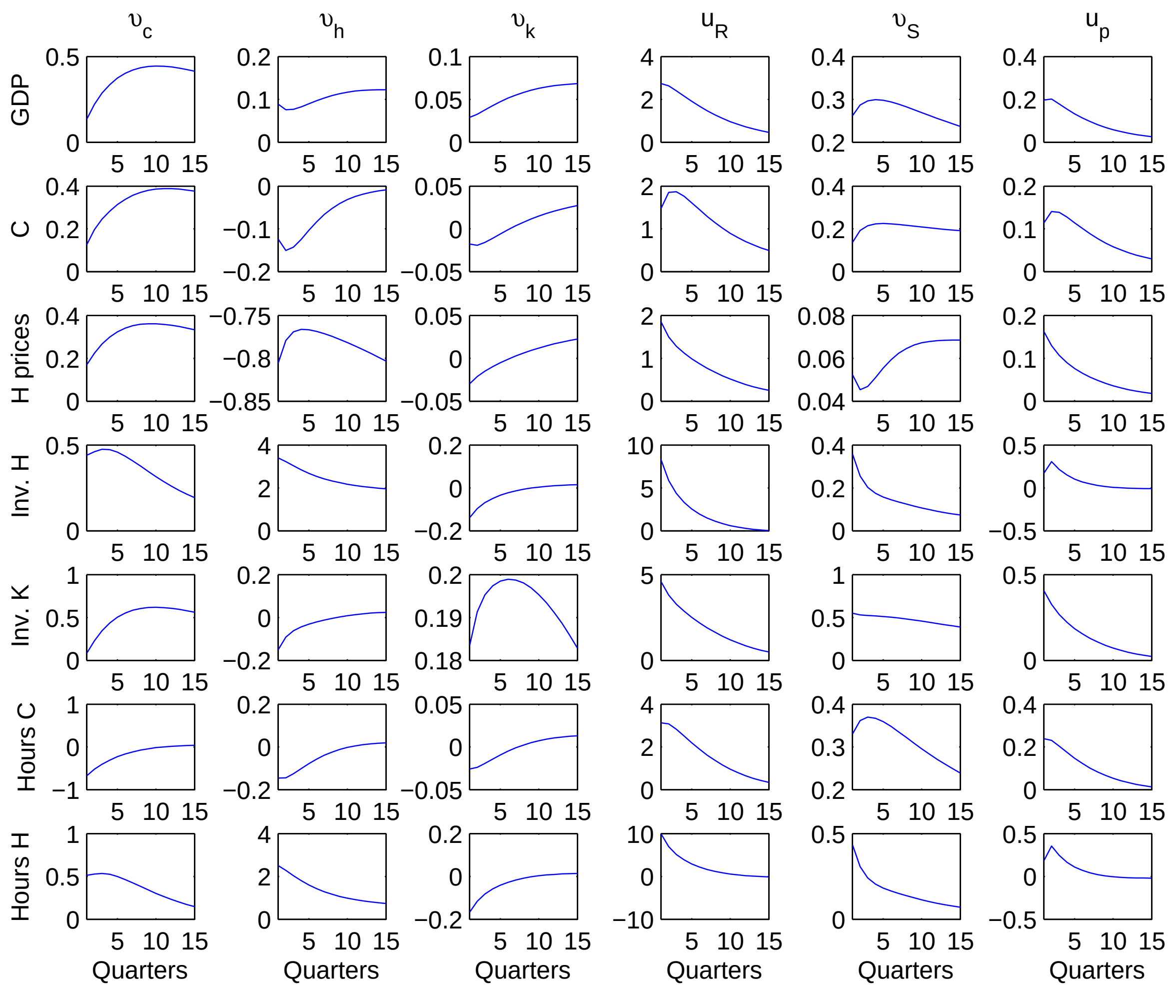
Notes: Percent deviations from the steady state. Top panel: House Price responses to shocks to unanticipated and to 4- and 8-quarter ahead news shocks; Bottom panel: corresponding simulated monetary policy shocks: unanticipated (ε_0) and anticipated 4 (ε_4) and 8 (ε_8) quarters in advance.

Figure 5: Impulse-Response Functions – 4-Quarter Ahead Monetary Policy News Shock *versus* Unanticipated Monetary Policy Shock



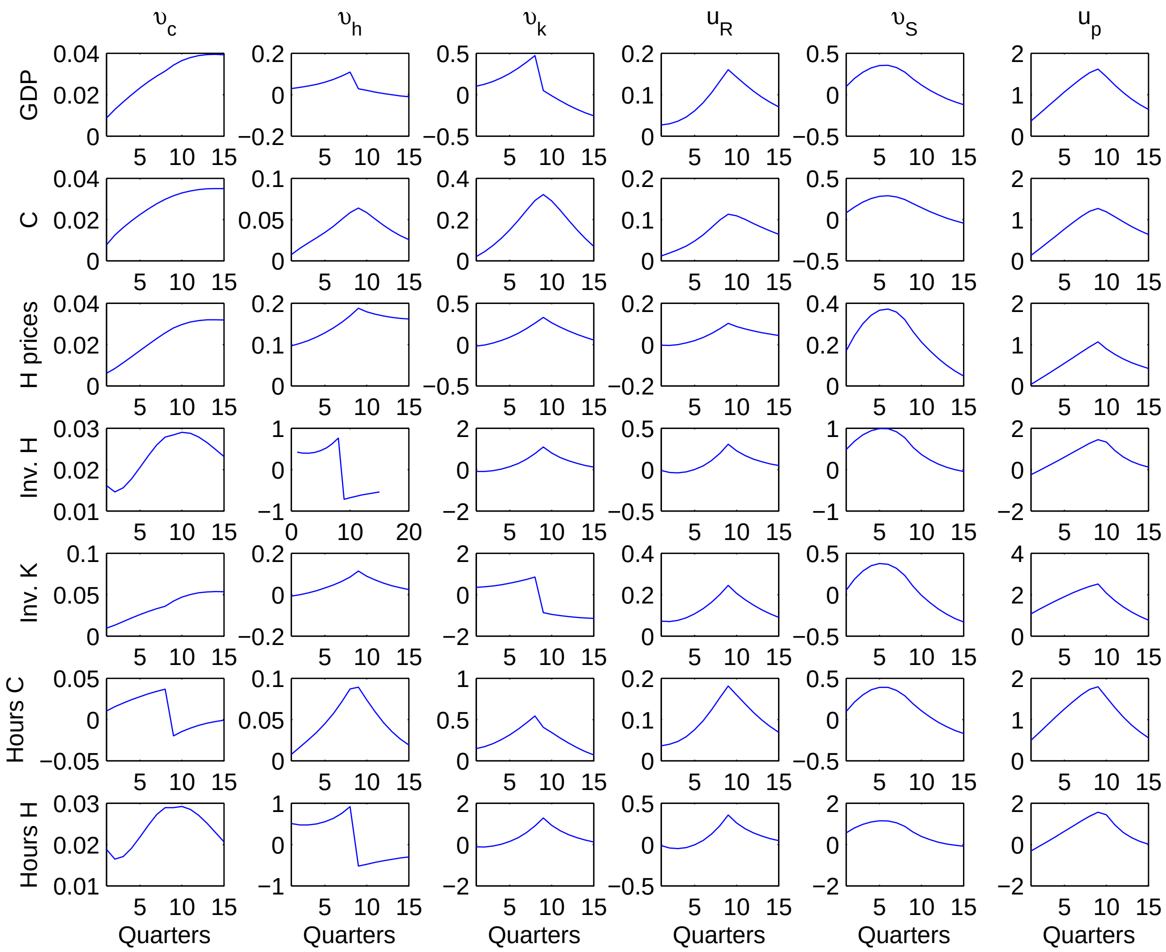
Note: Percent deviations from the steady state except for inflation and the policy rate where percentage points deviations from the steady state are reported. Solid line: 4-quarter ahead monetary policy news shock; dashed line: unanticipated monetary policy shock.

Figure 6: Impulse-Response Functions – Unanticipated Shocks



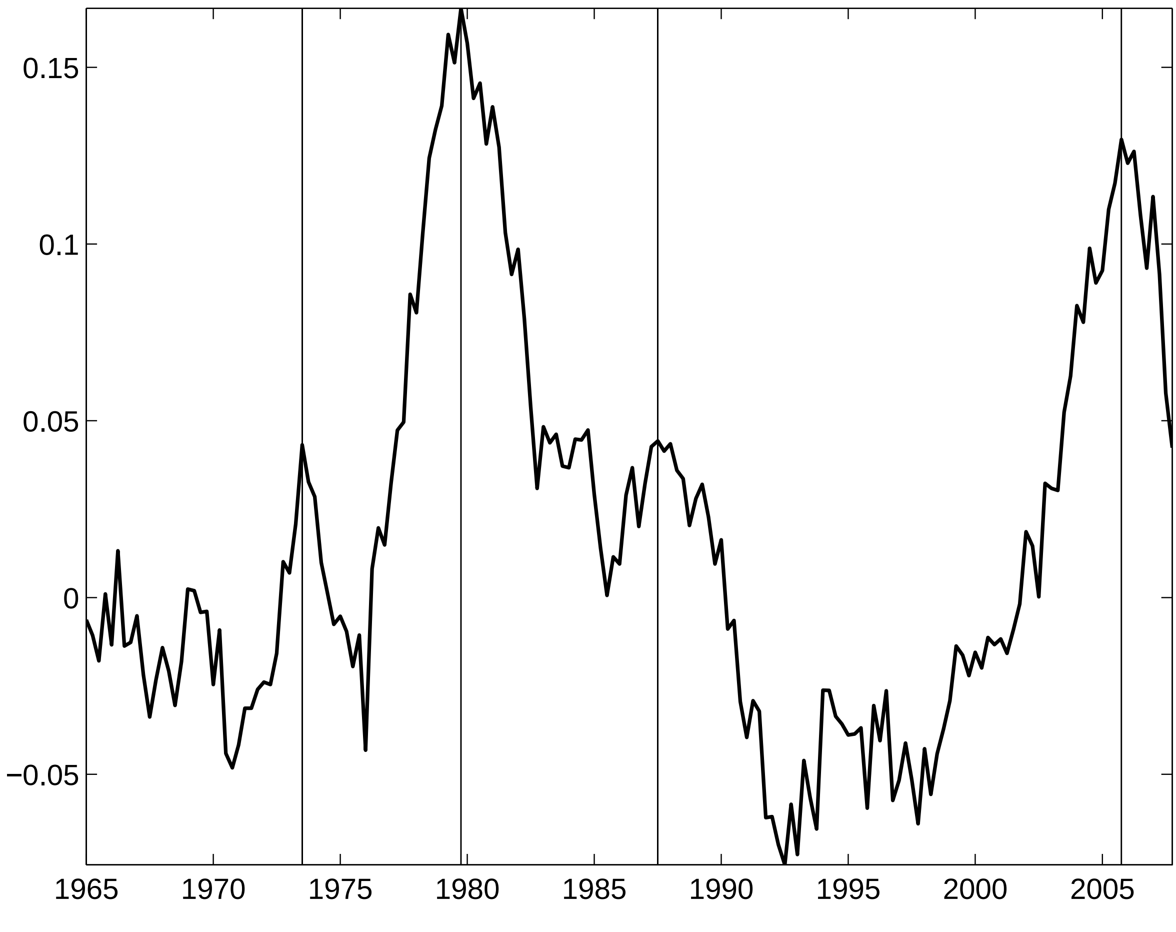
Note: Percent deviations from the steady state. Model responses to shocks to consumption technology (υ_c), housing technology (υ_h), investment specific technology (υ_k) monetary policy (u_R), inflation target (u_S) and cost push (u_p).

Figure 7: Impulse-Response Functions – 8-Quarter Ahead News Shocks



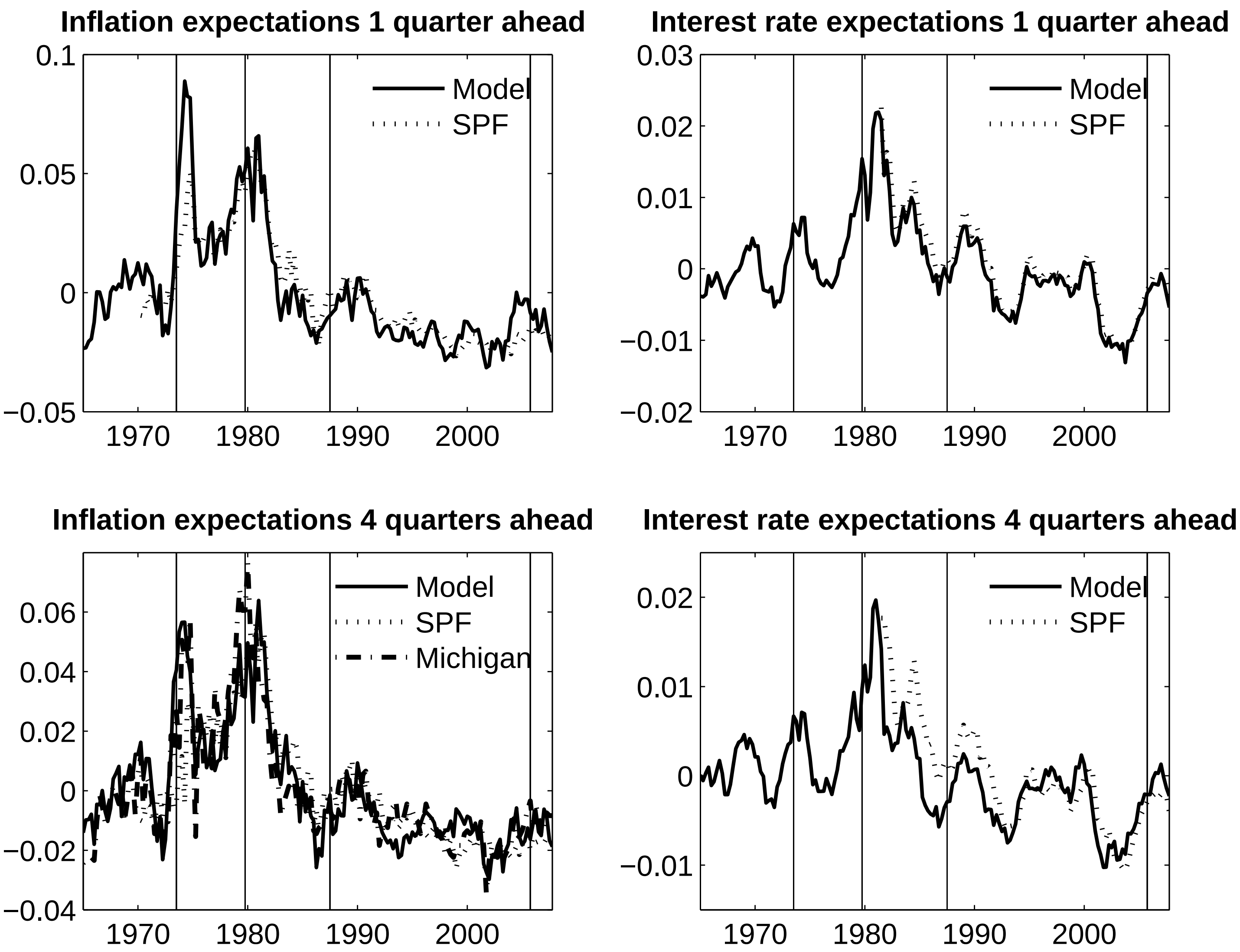
Note: Percent deviations from the steady state. Model responses to shocks to consumption technology (υ_c), housing technology (υ_h), investment specific technology (υ_k) monetary policy (u_R), inflation target (u_S) and cost push (u_p).

Figure 8: Real House Prices



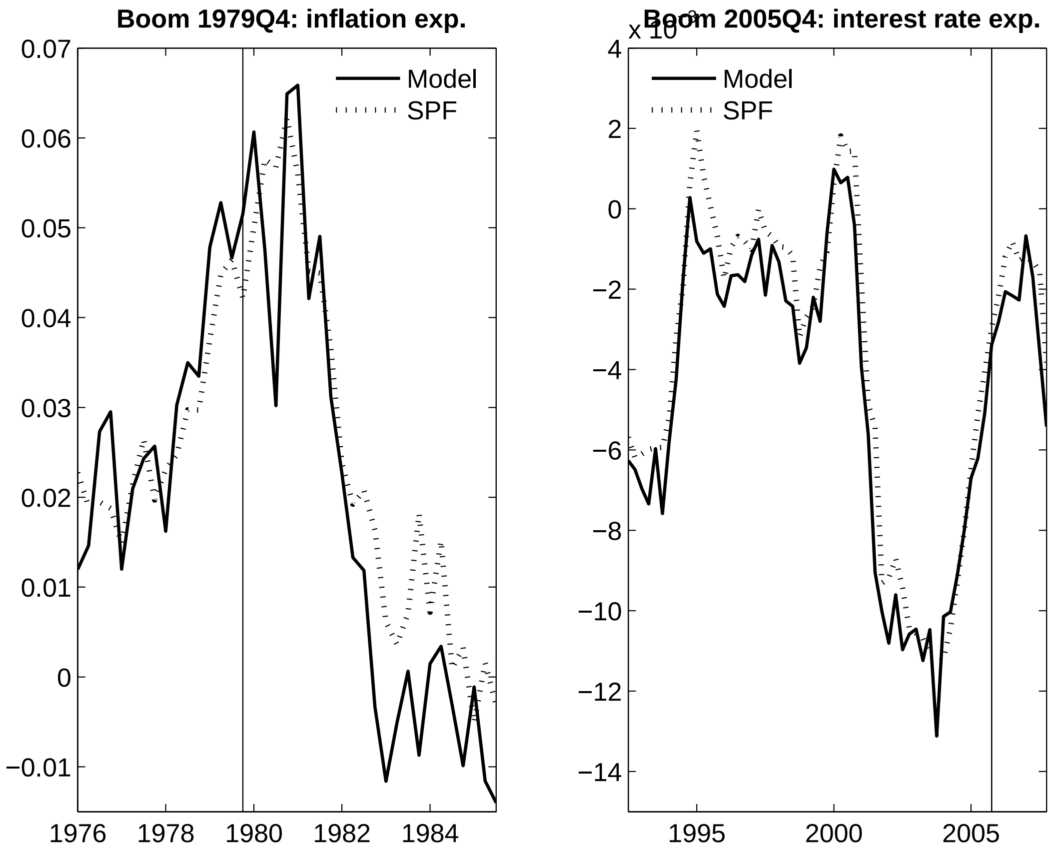
Notes: Real house prices in deviation from model trend. Vertical lines indicate real house prices series (Q) peaks dated based on the Bry-Boschan algorithm.

Figure 9: Model- *versus* Survey-Based Expectations



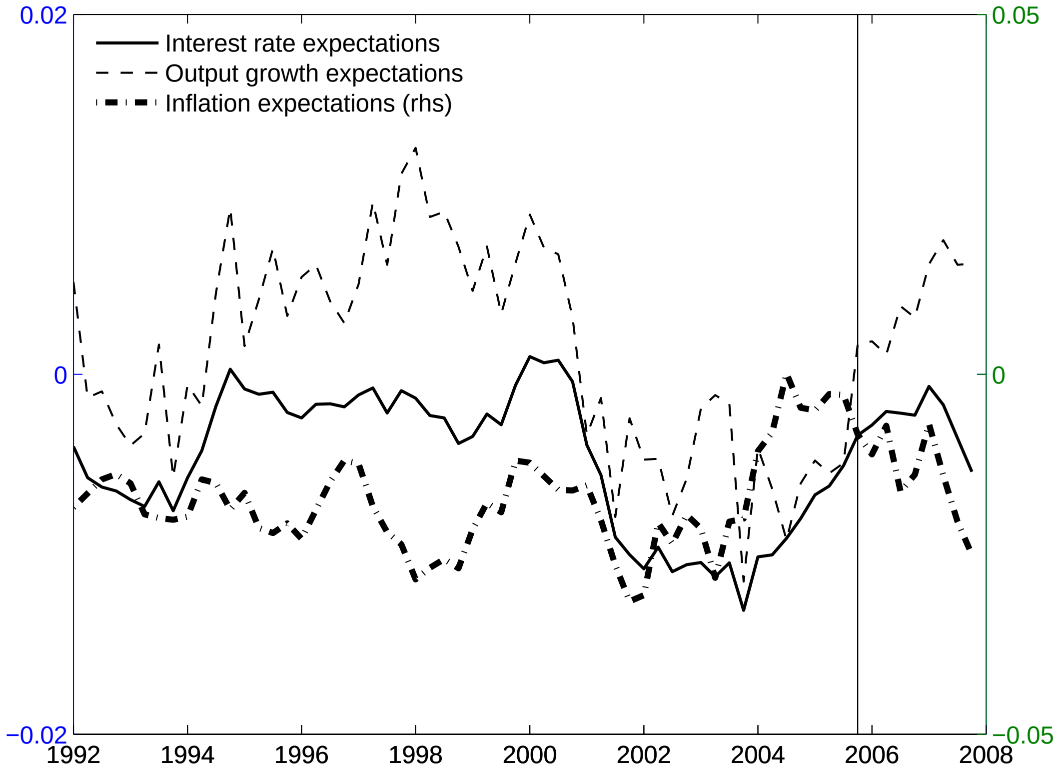
Notes: 1-quarter ahead inflation (left panel) and interest rate (right panel) expectations: Model-based expectations (solid line), Survey of Professional Forecasters (dashed line), Michigan Survey (starred line). Vertical lines indicate real house prices series (Q) peaks dated based on the Bry-Boschan algorithm.

Figure 10: Housing Booms and Expectations



Notes:1-quarter ahead inflation(left panel) and interest rate (right panel) expectations: Model-based expectations (solid line) Survey of Professional Forecasters (dashed line). Vertical lines indicate real house prices series (Q) peaks dated based on the Bry-Boschan algorithm.

Figure 11: GDP Growth Model-Based Expectations 1-Quarter Ahead



Notes:1-quarter ahead model-based expectations. Vertical line indicates real house prices series (Q) peaks dated based on the Bry-Boschan algorithm.