News, Housing Boom-Bust Cycles, and Monetary Policy*

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We explore the possibility that a housing market boom-bust cycle may arise when public beliefs are driven by news shocks. News, imperfect and noisy by nature, may generate expectations that are overly optimistic or pessimistic. Over-optimism easily leads to excessive accumulation of housing assets and creates a housing boom that is not based on fundamentals. When the news is found false or inaccurate, investors revert their actions, and a downturn in the housing market follows. By altering agents' net worth conditions, a housing cycle can have significant repercussions in the aggregate economy. In this paper, we construct a dynamic general equilibrium model that can give rise to a news-driven housing boom-bust cycle, and consider how monetary policies should respond to it.

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1. Introduction

The notion that excessive public expectations can cause housing market booms and busts is now widely accepted by policymakers and the public. Recent research has successfully incorporated

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housing sectors into dynamic general equilibrium models but typically does not consider expectation errors as an independent source of fluctuations. This paper explores the idea that noisy signals or news can generate optimism and pessimism in agent expectations and cause fluctuations in housing demand. When the news is found inaccurate, the subsequent adjustment in expectations and reversal in asset transactions complete a boom-bust cycle. An important feature of the model is that housing assets serve as collateral for credit-constrained agents. Via the collateral constraint, a housing cycle alters the borrowers' net worth conditions and has significant repercussions in the aggregate economy.

This mechanism is consistent with the "credit view" that asset market conditions are not merely reflections of economic conditions but also a cause of fluctuations. Until recently, credit channels were often absent from dynamic stochastic general equilibrium (DSGE) models. Williamson (1987) and Bernanke and Gertler (1989) represent earlier works that consider financial intermediation and agency costs as propagation mechanisms for aggregate shocks.[1] Kiyotaki and Moore (1997) make important progress by adding credit-constrained agents and collateralized debts into DSGE models. Bernanke, Gertler, and Gilchrist (1999) embed a financial accelerator in a sticky price environment and make monetary policy analysis possible. Recent works, such as those by Iacoviello (2005) and Monacelli (2009), specifically incorporate a housing sector into general equilibrium models with collateral constraint and examine monetary policy's proper response to housing market fluctuations.

The development of the literature naturally leads to a debate on policy issues. Bernanke and Gertler (2001) pose the question, should central banks respond to asset prices? Most research suggests that it is not necessary for inflation-targeting and "Taylor-rule" regimes to respond to asset prices, on the grounds that asset price movements tend to change the output gap and inflation in the same direction, which can be taken care of by the policy regime (Batini and Nelson 2000; Bernanke and Gertler 2001; Iacoviello 2005). Some research, however, finds that targeting asset misalignment in addition to inflation and the output gap does improve economic

[1] Carlstrom and Fuerst (1997) build on Bernanke and Gertler (1989) and evaluate the effect of agency cost quantitatively.

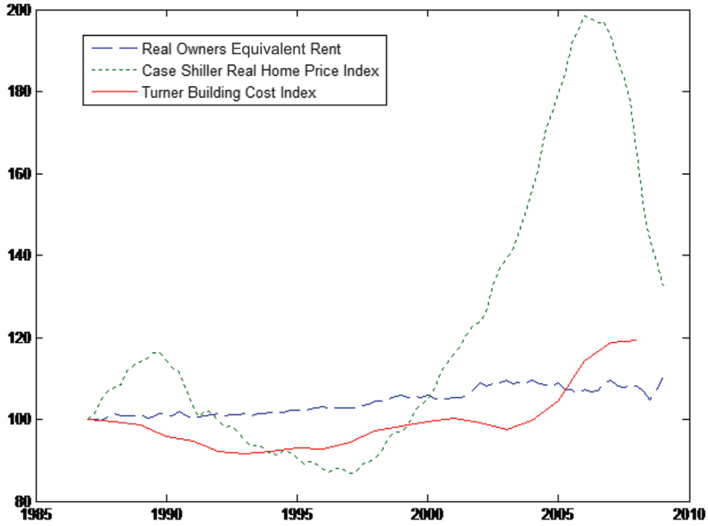
stability (Cecchetti et al. 2000). The debate between Cecchetti et al. (2000) and Bernanke and Gertler (2001) is especially instructional. They both use the Bernanke, Gertler, and Gilchrist (1999) model to search for optimal interest rate rules, but draw distinct conclusions. What makes the difference is that in Bernanke and Gertler (2001), the economy is subject to both fundamental and non-fundamental shocks, and the central bank cannot distinguish them, whereas in Cecchetti et al. (2000), the only shock is non-fundamental, and the central bank is aware of the price misalignment.[2] A critical lesson from this debate is that the appropriate responses of monetary policy to asset movements depend on the underlying sources of uncertainty.

In this paper, we propose that one source of uncertainty—news shocks—is important for the housing market in particular, and for the aggregate economy in general. It is important because news, imperfect and noisy by nature, may generate expectations that are overly optimistic or pessimistic. Over-optimism leads to excessive demand for housing assets and creates a housing boom that is not based on fundamentals. When the news is found false or inaccurate, buyers revert their actions, and a downturn in the housing market follows. This explanation of a housing boom-bust cycle is inspired by the insight of Cochrane (1994), Beaudry and Portier (2004), and Jaimovich and Rebelo (2009). In their works, noisy news about technological progress is an important source of business cycles. These types of cycles are referred to as "Pigou cycles" since the idea dates back to the earlier works of Pigou in 1926. Recent empirical research has provided support for this view. For example, the VAR evidence of Beaudry and Portier (2006), Beaudry, Dupaigne, and Portier (2008), and Beaudry and Lucke (2010) identifies news shocks as a major source of macroeconomic fluctuations.

Our interests in this view of the cycle were also motivated by a salient fact of the recent U.S. housing market. Real housing prices significantly deviated from economic fundamentals during the 1998–2007 episode of housing boom (Shiller 2007). In figure 1, we reproduce with newer data a graph from Shiller (2007), which shows

[2]In one experiment Bernanke and Gertler consider a single non-fundamental shock and find that adding an asset price target is better than pure inflation targeting. However, they emphasize that asset prices can be substituted by output gaps.

Figure 1. Housing Price, Construction Cost, and Owner's Equivalent Rent



that real housing prices surpassed real rental prices and real building costs between 1998 and 2007. Case and Shiller (2003)'s survey results further show that speculative psychology played major roles in homeowners' purchasing decisions during much of the housing boom. Similarly, Piazzesi and Schneider (2009) study the Michigan Survey of Consumers and find that what makes the latest housing boom distinctive is that towards the end of the boom, the percentage of momentum traders—traders who buy because of their optimistic beliefs about future housing prices—rose dramatically. These facts suggest that one needs to look beyond traditional fundamentals for plausible explanations of the recent housing cycle, and we believe the Pigouian explanation is one such candidate.

We construct a general equilibrium model in which credit-constrained borrowers use their housing assets as collateral to finance their purchases. Optimistic news raises these agents' expected future net worth, expands their borrowing capacity, and allows them to purchase more housing and consumption goods. Higher housing demand raises housing prices and creates a housing boom. The housing boom further increases the borrowing agents' net worth and raises their purchases even more. Aggregate demand therefore increases, driving work hours and output up, producing an economic expansion. The opposite works for pessimistic news. This is the major transmission mechanism of the model. We show that when there is overly optimistic news about future demand, this transmission mechanism creates a housing boom and co-movement among aggregate variables, and when the true shock is revealed, the adjustment in expectations generates a sharp decline in housing prices. A recession then follows.

Our theoretical model is based on the work of Iacoviello (2005) and Iacoviello and Neri (2010). In these papers, housing demand and housing price fluctuations can be explained by three major sources of uncertainty at the business-cycle frequency: housing preference shocks, housing technology shocks, and monetary shocks. They do not consider the possibility that news about these shocks can also become an independent impulse mechanism, and non-fundamental fluctuations can be generated when news is inaccurate. Our paper extends their works in this direction. We base our econometric analysis on Iacoviello (2005)'s full quantitative model but add news shocks on top of his original selection of exogenous shocks. Then, we let the data decide which shocks are more significant. We find that housing preference shocks, which Iacoviello (2005) identifies as the largest source of fluctuations, continue to be very important. But news about future housing preferences also becomes an important driving force, and can explain a significant portion of business-cycle fluctuations.

Equipped with a working model, we proceed to ask what monetary policies are appropriate in dealing with news-driven business cycles. We consider Taylor-type interest rules. We ask whether or not a policy reaction entails a specific housing price target in the interest rate rule. An interest rate rule is deemed best if it minimizes the central bank's loss function. Our result suggests that the gain from targeting asset prices, in addition to output and inflation, is small. The conclusion is reminiscent of Bernanke and Gertler (2001) and similar earlier works. Iacoviello (2005)'s experiment with a housing model also draws essentially the same conclusion. Our contribution to this topic is to demonstrate that when news shocks are the driving force of cycles, a Taylor-type monetary policy rule still does best by responding properly to inflation and output variations. To our knowledge, no other work exists that addresses this policy issue using a similar environment, in which business cycles are mainly driven by news shocks.

Our paper makes a contribution to the "news-driven business cycle" literature. In that literature, a major difficulty is that it is very hard to generate co-movement among aggregate variables. In a real business-cycle model, for example, positive news about future productivity changes has a strong wealth effect. It makes economic agents "go on vacation"—consume more, work less and produce less, and invest less to pay for the higher consumption. Good news creates a recession instead of a boom. Beaudry and Portier (2004) generate positive co-movement with a multi-sector economy in which investment decisions and consumption decisions are decoupled so that the substitution effect between the two can be minimized. In Jaimovich and Rebelo (2009), adjustment cost, capacity utilization, and preferences that incorporate a weak wealth effect on labor supply are used to generate positive co-movement. Christiano et. al. (2008) study a sticky wage model with a monetary authority that targets inflation. When there is positive productivity news, the central bank's policy can keep inflation and real wages from rising too quickly, so that unemployment and production losses can be prevented. This helps generate positive co-movement among economic aggregates.

In this paper, we mainly rely on two features of the model to generate co-movement. One is the existence of heterogeneous agents, and the other is the credit channel. When news about higher future housing prices arrives, it is optimal for agents to start increasing their demand for housing today to take advantage of the capital gains. In our setup, the user cost of housing decreases more for the borrower than it does for the lender, because accumulating more housing relaxes the borrower's collateral constraint and allows her to borrow and consume more. This causes the lender to sell houses to the borrower. The reactions of consumption, labor, and output depend on the strength of the credit channel. If the downpayment ratio is high (weak credit channel), substitution effect dominates wealth effect for the borrower's consumption and leisure decisions—she decreases consumption and leisure. If the downpayment ratio is small (strong credit channel), the borrower's consumption and leisure increase. In this case, the lender has a strong incentive to save. So she consumes less and works more. The central bank follows an interest rate rule that reacts more than one-for-one to inflation. When there is sticky price, this policy raises the real interest rate and is consistent the lender's optimal saving behavior. As a result, aggregate labor and consumption co-move positively with output.

Our paper is also generally related to a large literature that attempts to understand how incomplete/dispersed information affects housing and business cycles. One approach is based on the Phelps-Lucas hypothesis that imperfect information about the nature of the economy makes agents react in different ways to changes in market conditions (Phelps 1970 and Lucas 1972). For example, Favara and Song (2011) implement this idea in a user-cost model of housing, where agents are differentiated as optimists and pessimists who receive public and private signals about the nature of the economy. Optimists' expectations dominate the housing market because of a short-sell constraint on pessimists. Similarly, in Burnside, Eichenbaum, and Rebelo (2011), agents have heterogeneous views about the fundamentals of the economy. They change their beliefs because of social dynamics. As a result, agents who have tighter priors become more influential and dictate market outcomes. Our paper is different from these papers in terms of the source of heterogeneity. In our paper there is no difference in the news or signals that agents receive. There is no dispersed information. It is the degree of impatience that differentiates the agents. The more impatient agents become borrowers, and the less impatient ones become lenders.

Another way to model expectations is the adaptive learning approach. Agents are boundedly rational and behave like econometricians (see Evans and Honkapohja 2001 for a survey). They use observed data to estimate the true law of motion of the economy. Inaccurate estimation leads to expectation errors. The economy has a self-referential nature: agents' expectations will affect the true law of motion, which in turn affects agents' expectations. Thus, agents' expectations alone can drive business cycles. Eusepi and Preston (2011) and Williams (2012) study models with learning agents and find that learning can generate housing boom-bust cycles. The difference between this approach and the news-shock approach is that with learning, expectation errors are "intrinsic" in that they are generated by agents' learning behavior. On the other hand, news shocks are extrinsic because they are exogenous shocks.

The rest of the paper is organized as follows. Section 2 lays out the microfounded model framework and derives the equilibrium conditions. Section 3 explores whether or not news-driven cycles can arise in this model. Section 4 establishes the quantitative importance of news shocks with an econometric exercise. Section 5 presents the policy analysis. Section 6 concludes.

2. A Benchmark Model

In this section, we construct a simple model to illustrate the important mechanisms that make a news-driven boom-bust cycle possible. The model is based on Iacoviello (2005), which is in turn related to earlier works of Kiyotaki and Moore (1997) and Bernanke, Gertler, and Gilchrist (1999). Unlike Iacoviello (2005), we assume housing assets do not enter the production function, and we do not model any producers as borrowers.

Consider a discrete-time, infinite-horizon economy where a patient household (lender), an impatient household (borrower), a wholesaler firm, and some retailers reside. The borrower is less patient than the lender because she discounts the future more heavily. Both households consume, work, and demand a housing asset. The borrower uses her housing assets as collateral to borrow from the lender, and her capacity to borrow is limited by the expected future value of her discounted asset holdings. The wholesaler hires labor from both households to produce a homogeneous intermediate good. There are a large number of monopolistically competitive retailers who buy the intermediate good, differentiate it into consumption goods, and sell to the households. As in Bernanke, Gertler, and Gilchrist (1999), the retailers are Calvo-type price setters who are the source of sticky prices. Collateralized borrowing, adopted from Iacoviello (2005), provides the critical channel via which changes in net worth affect the aggregate economy.

2.1 Patient Household/Lender

The lender maximizes a lifetime utility function given by

$$E_0 \sum_{t=0}^{\infty} \beta_1^t \left(\ln C_{1t} + d_t \ln h_{1t} - \frac{L_{1t}^{\eta}}{\eta} \right),$$

subject to the constraint

$$C_{1t} + q_t h_{1t} + \frac{R_{t-1} b_{1t-1}}{\pi_t} = b_{1t} + q_t h_{1t-1} + w_{1t} L_{1t} + F_t, \quad (1)$$

where E_0 is the expectation operator, β_1 is the discount factor, C_{1t} is consumption, h_{1t} is her holding of housing asset, and L_{1t} represents hours worked. P_t is the general price level at time t. $b_t = \frac{B_t}{P_t}$ represents real holdings of a one-period loan, R_{t-1} is the nominal interest rate, $q_t = \frac{Q_t}{P_t}$ is real housing price, $w_{1t} = \frac{W_{1t}}{P_t}$ is real wage, $\pi_t = \frac{P_t}{P_{t-1}}$ is inflation rate, and F_t represents real profits received from the retailers. The variable d_t is a preference shock that shifts the marginal rate of substitution between housing and consumption/leisure. Note that all capital letters represent the nominal counterparts of the defined real variables (except for C and F). The subscript "1" is used to tag all variables of the patient household. The subscript "2" will shortly be used to denote variables of the impatient household. By putting total housing stock into the utility function, we implicitly assume that housing services are proportional to the housing stock.

This is a fairly standard household problem that can be solved to yield the following first-order conditions:

$$\frac{1}{C_{1t}} w_{1t} = L_{1t}^{\eta-1}, \tag{2}$$

$$\frac{q_t}{C_{1t}} = \frac{d_t}{h_{1t}} + \beta_1 E_t \frac{q_{t+1}}{C_{1t+1}}, \tag{3}$$

$$\frac{1}{C_{1t}} = \beta_1 E_t \frac{R_t}{\pi_{t+1} C_{1t+1}}. \tag{4}$$

(2) is a standard condition linking the real wage to the borrower's marginal rate of substitution between consumption and leisure. (3) equalizes the lender's marginal utility of the consumption and the marginal benefit of acquiring housing assets. (4) is a standard Euler equation characterizing the lender's intertemporal choice between current and future consumption.

2.2 Impatient Household/Borrower

The impatient household's problem is similar to that of the patient household, with two differences. First, the impatient household does not own any retailers and does not receive profits, and second, her borrowing capacity is constrained by the discounted future value of the collateral—her housing assets. Thus the problem is

$$\max E_0 \sum_{t=0}^{\infty} \beta_2^t \left(\ln C_{2t} + d_t \ln h_{2t} - \frac{L_{2t}^{\eta}}{\eta} \right),$$

subject to

$$C_{2t} + q_t h_{2t} + \frac{R_{t-1} b_{2t-1}}{\pi_t} = b_{2t} + q_t h_{2t-1} + w_{2t} L_{2t}, \tag{5}$$

$$b_{2t} \leq m_2 E_t \left(\frac{q_{t+1} h_{2t} \pi_{t+1}}{R_t} \right). \tag{6}$$

A requirement $\beta_2 < \beta_1$ ensures that this household is more impatient than the lender and will need to borrow from her. The amount that the debtor can borrow, in nominal terms, is bounded by $m_2 E_t(\frac{Q_{t+1} h_{2t}}{R_t})$, where $0 < m_2 < 1$. In other words, a fraction $1 - m_2$ of the housing value cannot be used as collateral. One can broadly think of $1 - m_2$ as the downpayment rate, or think of m_2 as the loan-to-value ratio.

Solving this problem yields the following conditions:

$$\frac{1}{C_{2t}} w_{2t} = L_{2t}^{\eta-1}, \tag{7}$$

$$\frac{q_t}{C_{2t}} = \frac{d_t}{h_{2t}} + \beta_2 E_t \frac{q_{t+1}}{C_{2t+1}} + \lambda_t E_t m_2 \pi_{t+1} q_{t+1}, \tag{8}$$

$$\frac{1}{C_{2t}} = \beta_2 E_t \frac{R_t}{\pi_{t+1} C_{2t+1}} + \lambda_t R_t, \tag{9}$$

where the interpretations of (7)–(9) are similar to those of (2)–(4). A major difference is the addition of λ_t, the Lagrangian multiplier associated with the borrowing constraint. It represents the shadow value of relaxing the borrowing constraint. It enters both (8) and (9), and has important effects on the model's transmission mechanism. We explain this in detail in the next section.

2.3 Intermediate Goods Firm

The intermediate goods (wholesaler) firm hires labor from both households as inputs to produce a homogeneous good Y_t:

$$Y_t = L_{1t}^{\alpha} L_{2t}^{1-\alpha}, \tag{10}$$

where $0 < \alpha < 1$.

After the intermediate goods are produced, retailers purchase them at the wholesale price P_t^w, transform them into final goods, and sell them at the price P_t. We denote the markup of final over intermediate goods as $X_t = \frac{P_t}{P_t^w}$.

The producer maximizes her profit

$$Y_t/X_t - w_{1t}L_{1t} - w_{2t}L_{2t} \tag{11}$$

subject to (10).

2.4 Retailers

There is a continuum of retailers indexed by i. Retailer i buys the intermediate good in a competitive market, differentiates it at no cost into $Y_t(i)$, and sells it at $P_t(i)$. Total final goods are aggregated from each individual final good as

$$Y_t^f = \left[\int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{12}$$

where $\varepsilon > 1$. Each retailer's demand curve is

$$Y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} Y_t^f. \tag{13}$$

The price index of final goods is

$$P_t = \left[\int_0^1 P_t(i)^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}}. \tag{14}$$

We assume Calvo-type pricing for retailers. Each retailer can only change the price with probability $1-\theta$. The optimal pricing decision is

$$\max_{P_t^o} \sum_{k=0}^{\infty} \theta^k E_t \left\{ \beta_1 \frac{C_{1t}}{C_{1t+k}} \left[\frac{P_t^o - P_{t+k}^w}{P_{t+k}} Y_{t+k}(i) \right] \right\}$$

subject to (13). P_t^o represents the optimal price chosen by the retailer to maximize the objective. The retailers use the lender's discount factor because they are owned by her. Differentiating with respect to P_t^o implies that the optimal price must satisfy

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \beta_1^k \frac{C_{1t}}{C_{1t+k}} \left[\frac{P_t^o(i)}{P_{t+k}} - \frac{X}{X_{t+k}} Y_{t+k}(i) \right] \right\} = 0. \qquad (15)$$

Given that the fraction θ of retailers do not change their price in period t, the aggregate price evolves according to

$$P_t = \left[\theta P_{t-1}^{1-\varepsilon} + (1-\theta) P_t^{o1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}. \qquad (16)$$

These two conditions can be combined to get the new Phillips curve in the linearized version of the model.

2.5 Interest Rate Rule

We assume there is a central bank that implements a Taylor-type interest rate rule that targets the current levels of output gap, inflation, and possibly housing prices. The interest rate rule is of the form

$$R_t = R \left(\frac{\pi_t}{\pi} \right)^{\tau_\pi} \left(\frac{Y_t}{Y} \right)^{\tau_Y} \left(\frac{q_t}{q} \right)^{\tau_q}, \qquad (17)$$

where $\tau_\pi, \tau_Y, \tau_h > 0$ are the reaction parameters of the central bank, and R, π, Y, and q denote steady-state values of the interest rate, inflation rate, output, and housing price. When linearized, this equation becomes the conventional linear Taylor rule, augmented with a housing price component.

2.6 Equilibrium

The equilibrium of the model is a sequence of prices $\{q_t, R_t, P_t, X_t, w_{1t}, w_{2t},\}$ and an allocation $\{h_{1t}, h_{2t}, L_{1t}, L_{2t}, Y_t, C_{1t}, C_{2t}, b_{1t}, b_{2t},\}$ such that all first-order conditions and constraints hold and all markets clear.

The goods market clears when[3]

$$C_{1t} + C_{2t} = Y_t. \tag{18}$$

It is straightforward to show that the retailer profit is equal to

$$F_t = \frac{X_t - 1}{X_t} Y_t. \tag{19}$$

The loans market equilibrium is

$$b_{1t} + b_{2t} = 0. \tag{20}$$

As in Iacoviello (2005), housing assets are assumed to have a fixed total supply H, which leads to the trivial market clearing condition

$$h_{1t} + h_{2t} = H. \tag{21}$$

With a fixed total supply and no production required, the variable h resembles the "land" variable of Kiyotaki and Moore (1997). It seems that a more realistic setup would require that housing assets and land be defined separately, and agents should be allowed to accumulate housing assets over time. In that environment, agents must acquire land first and then use the land to accumulate housing assets. As long as the total amount of land is assumed fixed, the dynamics of housing assets will be quite similar to our simplified setup here.[4]

2.7 Steady State and Calibration

We assume the steady-state inflation rate is zero. The long-run real interest rate is obtained from (4) as

$$R = 1/\beta_1.$$

[3] As in Iacoviello (2005), total output can be approximated by $Y_t^f = \int_0^1 Y_t(i)di \approx Y_t$.

[4] Between 1975 and 2006, the real price of residential land in the United States rose 270 percent, while the real price of housing structures only rose about 33 percent (Davis and Heathcote 2007). In other words, most of the housing price boom has been a "land price boom." There is unoccupied land that can be added to total land supply. But as research shows, the amount of unoccupied land near residential areas is limited. Limited land availability and land-use regulations have made land supply relatively inelastic (Mishkin 2007).

It immediately follows that for a well-defined steady state to exist, the collateral constraint (6) must be binding, for otherwise $\lambda = 0$, and (9) would force the borrower's consumption to shrink over time at the rate β_2/β_1.[5] With a binding collateral constraint, the value of the Lagrangian multiplier associated with the constraint is

$$\lambda = \frac{\beta_1 - \beta_2}{C_2}.$$

Consequently, unlike in a representative agent economy, the steady-state level of borrowing is positive. There are three critical ratios that need to be calculated. One is the consumption/output ratio, which can be obtained from the steady-state versions of (5) and (8):

$$\frac{C_2}{Y} = \frac{(1-\alpha)(1-v)/X}{1 + m_2(1-\beta_1)d/(1-\gamma_e)}.$$

Next is the value of real housing assets over output for the borrower,

$$\frac{qh_2}{Y} = \frac{C_2}{Y}\frac{d}{1-\gamma_e}.$$

Finally, the loans/output ratio is obtained from the borrowing constraint as

$$\frac{b_2}{Y} = \beta_1 m_2 \frac{qh_2}{Y}.$$

Based on these, the corresponding ratios for the lender can be easily calculated from the equilibrium conditions.

We calibrate our parameters as follows. The discount factor is set at 0.99 for the lender and 0.98 for the more impatient borrower. The elasticity of substitution across final goods, ε, is set at 4, a value commonly used in the literature. The inverse of the elasticity of labor supply, η, is set to 1.01, as in Iacoviello (2005), which makes the labor supply curve virtually flat. The fraction of firms that keep their prices unchanged, θ, is given a value of 0.75, which corresponds to an average price duration of about one year. The steady-state value of

[5] It remains a question whether or not the constraint is always binding when the economy deviates from the steady state in response to exogenous shocks. As Iacoviello (2005) demonstrates, the constraint is indeed binding as long as the deviations are small and are close to the steady-state equilibrium.

the preference shock, d_t, is set at 0.1. The share of the lender's labor in the production, α, is set at 0.5. The borrower's downpayment rate, $1 - m_2$, is given a benchmark value of 0.1, but we will experiment with other values for this important parameter in the next section.

We take log-linear approximation of the equilibrium conditions around the steady state, and solve for the rational expectations solution. The following analyses are based on this solution.

3. News-Driven Business Cycles

Our first task is to investigate whether or not news shocks can generate housing boom-bust cycles. We define a realistic news-driven boom-bust cycle as one that meets two conditions: (i) positive news first leads to a boom defined as an increase in housing prices, aggregate output, employment, and consumption, and (ii) the realization that the news is too optimistic leads to a recession defined as a fall in the same set of variables. The co-movement of housing prices and aggregate variables is key to a news-driven cycle.

To facilitate exposition, we will first focus on presenting the result—we show in detail how the economy's aggregate variables respond to the news shock in the next sub-section. Then, in the following sub-section, we will analyze the transmission mechanism and explain why the model is able to generate positive co-movement among economic aggregates.

3.1 Responses to a News Shock

A natural question to ask is, what type of information is contained in the news? Most research in this area favors news about future productivity changes. In Beaudry and Portier (2004, 2007), for example, it is news about productivity that drives a "Pigou" cycle. While this type of news is appropriate in explaining episodes such as the boom of the late 1990s, we believe it is not the best impulse mechanism to consider for our model. During a typical episode of speculative boom, consumers' housing "rush" is often triggered by the perception of rapid and steady future price increases, which leads to but is also confirmed (self-fulfilled) by a steady increase in housing demand. Therefore, we focus on the demand side when introducing news shocks.

There are two ways to model news about housing demand. One way is to model news as anticipated changes to the housing preference shock d_t, a rise of which would increase the marginal rate of substitution of housing services against consumption and leisure for both the borrower and the lender. An advantage of this approach is that it is by nature a demand shock, which matches our understanding of how a housing rush is triggered. In Iacoviello (2005) and Iacoviello and Neri (2010), the housing preference shock is found to be one of the most important driving forces of housing and business cycles.[6]

We assume the variable d_t follows the process (in log linearized form)

$$d_t = \rho d_{t-1} + e_t^d,$$

where $0 < \rho < 1$, and the error term e_t^d is defined as

$$e_t^d = \xi_{t-p} + \varepsilon_t^d.$$

ε_t^d is an innovation to d_t that has mean 0 and standard deviation σ_ε. It is a conventional unanticipated shock. ξ_{t-p} is a news shock about d_t that is revealed to the agent in time $t-p$ but will realize in time t. ξ_t has mean 0 and a standard deviation σ_ξ. Given this definition, ξ_{t-p} is an anticipated shock to d_t. ξ_t and ε_t^d are not correlated over time and with each other.

The drawback of this approach is that the demand shock is narrowly defined to be a preference shock, which cannot capture other types of housing demand variations. A second approach to model the demand shock (and news about the demand shock) is to start with the linearized reduced-form model. In the patient agents' housing demand equation, for example, one can add an exogenous housing demand shock d_t as follows:

$$q_t = \beta_1 E_t(q_{t+1} - c_{t+1}) + c_{1t} - (1 - \beta_1)h_{1t} + d_t.$$

News shocks can then be defined the same way as above. Note that the shock d_t is a direct shock to real housing price q_t. While this

[6]According to Iacoviello and Neri (2010), d_t captures "any social and institutional changes that shift preferences towards housing."

definition makes the demand shock less "microfounded," it has the advantage of allowing a broader interpretation of the shock. Thus, news shocks can be broadly understood as anticipated changes in future housing prices, which could have multiple possible causes.

For our impulse response analysis below, the timing of the news shock is as follows. In time 0 the economy is in the steady state. Then news about future preference shocks arrives. For example, agents might learn from the innovation ξ_0 that there will be a 1 percent increase in d after p periods. This raises the expected values of d and has an impact on all economic aggregates. In period p, d will increase by ξ_0 as anticipated. But what is also realized is the unanticipated shock ε_p^d. If it happens that $\varepsilon_p^d = -\xi_0$, the effect of ξ_0 is cancelled by ε_p^d, and no change occurs to d—the news is exactly "incorrect." On the other hand, if $\varepsilon_p^d = 0$, the news is exactly accurate, because $e_p^d = \xi_0$. In general, as long as $\varepsilon_t^d \neq 0$, the news shock ξ_{t-p} is a noisy signal about d_t. The techniques that we use here closely follow those of Christiano et al. (2008).

In our experiment, we let $\rho = 0.9$, and we set the number of periods between the arrival of news and the realization of shocks p to be 6. If p is too small, we will not be able to observe any interesting economic dynamics between time 0 and p. If p is too large, the predictive horizon of the news seems too long to be realistic. We pick $p = 6$ somewhat arbitrarily to satisfy these two criteria.

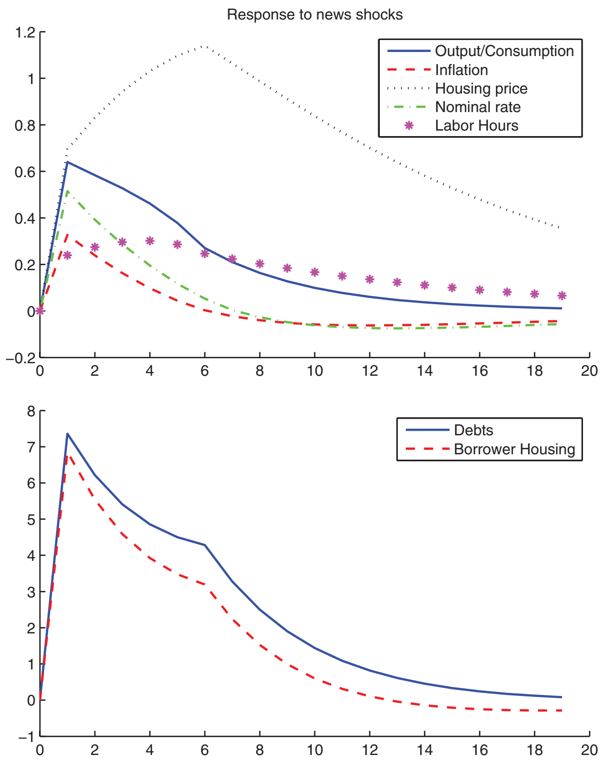
Finally, for our benchmark experiment we assume the central bank follows a simple inflation-targeting rule

$$i_t = \tau_\pi \pi_t,$$

which is the linearized version of the policy rule (17), simplified by setting the policy parameters τ_Y and τ_q to 0. We let $\tau_\pi = 1.2$.

In our simulations, we find that relatively large preference shocks (therefore news shocks) are required for most variables to exhibit significant responses. For example, when there is a 10 percent shock to d_t, housing price deviates from the steady state for about 1 percent. The exceptions are total debts and borrower housing, whose responses are much stronger. This feature is common in similar models. Iacoviello (2005)'s model, for example, also entails large preference shocks. In fact, in his estimation with U.S. data, the standard deviation of preference shocks is more than ten times that of total

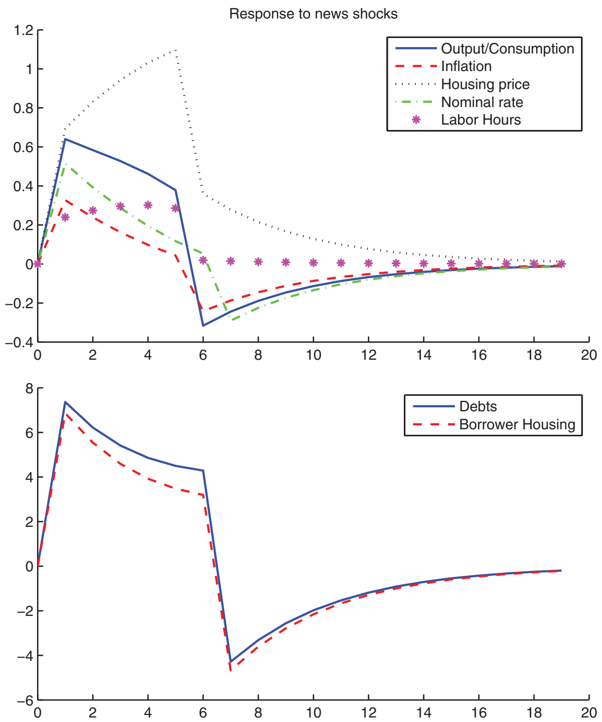
Figure 2. Impulse Responses to Correct News



factor productivity shocks. In the following impulse response analysis, we set the size of the news shock to be 10 percent. We believe this is also consistent with the nature of an expectation-driven cycle—in reality, only strong speculations can generate sizable boom-bust cycles.

In figure 2, we plot the impulse response of the economy to a news shock. The news is assumed to be exactly accurate. Consumption/output and labor hours increase, and so do housing prices. The inflation rate goes up on impulse, accompanied by the nominal interest rate (upper panel). From the bottom panel of the figure, we can see that the borrower has increased her housing asset and collateralized borrowing quite dramatically—a 7 percent increase. In period 7, when the actual preference shock is realized, the economy

Figure 3. Impulse Responses to Incorrect News



is already on its convergent path back to the steady state. Since the news is accurate, the realization of the shock does not bring any new information and does not alter the agents' optimal plan.

Next we consider the scenario where the news shock is exactly incorrect. In period 1, agents learn about an increase in the preference shock d_t. But in period 7, they observe that there is no preference shock at all. We plot the impulse responses in figure 3. Upon receiving the news and believing it is accurate, agents' reactions are identical to those in figure 3. In period 7, however, the actual shock is realized and the agents learn that the news has been incorrect. They immediately reoptimize their objectives by incorporating the new information. There are sharp decreases in output, consumption, labor, housing prices, and the borrower's housing assets and total debts. Between period 1 and 7, almost all variables have experienced a cycle that is shaped like an inverted "U." Moreover, except housing prices, all variables went below trend for a considerable amount of time before converging to the steady state.

The type of dynamics in figure 3 is what we would like to characterize as a news-driven boom-bust cycle. We emphasize that throughout the episode, there have been no fundamental shocks at all. The only change has been some incorrect news that altered agents' expectations between period 1 and 7. As in Beaudry and Portier (2004), we can define "optimism" as the case where agents' expectations are better than reality. Then what figure 3 shows is exactly a case where optimism alone can generate a boom-bust cycle. Indeed, since such a cycle is clearly not fundamental based, one is tempted to call the temporary housing price hike a "bubble."

3.2 Understanding the Mechanism

In a typical general equilibrium model, it is quite difficult to generate co-movement among aggregate variables on impact of news shocks. For instance, in a real business-cycle model, good news creates a recession instead of a boom. Positive news about future productivity brings about a strong wealth effect that makes agents "go on vacation"—consume more, work less and produce less, and invest less to pay for the higher consumption. In our model, three features are responsible for the positive co-movement: agent heterogeneity, the collateral constraint, and nominal rigidity. The first feature ensures that borrowers and lenders do not respond to news shocks in the same way, the second feature links these responses to the strength of the credit channel, and the third feature generates a wedge between the real and nominal interest rates, and enhances the mechanism created by the first two features. The combined effect of these three features is that economic aggregates will display positive movement when there is a news shock. Next, we explain in detail how this mechanism works.

The starting point of our analysis is to explain how the collateral constraint alters the model's propagation mechanism. Consider how rising housing prices affect the user cost of capital (housing) for lenders and borrowers, respectively. Define the user cost of capital as the marginal rate of substitution between housing and consumption U_h/U_c. It measures how many units of consumption goods an agent is willing to give up in exchange for a unit of housing, and can be viewed as the unit price of the housing asset—in terms of consumption goods.

The intuition is more transparent when we consider *linearized* versions of the Euler equations. For lenders, the Euler equations (3) and (4) can be combined to define the user cost as

$$\text{user cost} = q_t - \frac{\beta_1}{1-\beta_1}(E_t q_{t+1} - q_t) + \frac{\beta_1}{1-\beta_1} r_t. \tag{22}$$

The user cost is influenced by three conventional channels: current real housing price q_t; the real interest rate r_t, defined as $i_t - E_t \pi_{t+1}$; and expected housing price appreciation $E_t q_{t+1} - q_t$. Higher current housing prices raise the user cost. Other things equal, a rise in the real interest rate raises the user cost, and an expected housing price appreciation lowers the user cost.[7]

For the borrowers, the collateral constraint adds an additional channel to user costs. Linearize (8) and (9) to obtain

$$\begin{aligned} \text{u.cost} \approx\ & q_t - \frac{\gamma_e}{1-\gamma_e}(E_t q_{t+1} - q_t) + \frac{\beta_1}{1-\gamma_e} r_t \\ & + \frac{(1-m_2)(\beta_1-\beta_2)}{1-\gamma_e}\lambda_t, \end{aligned} \tag{23}$$

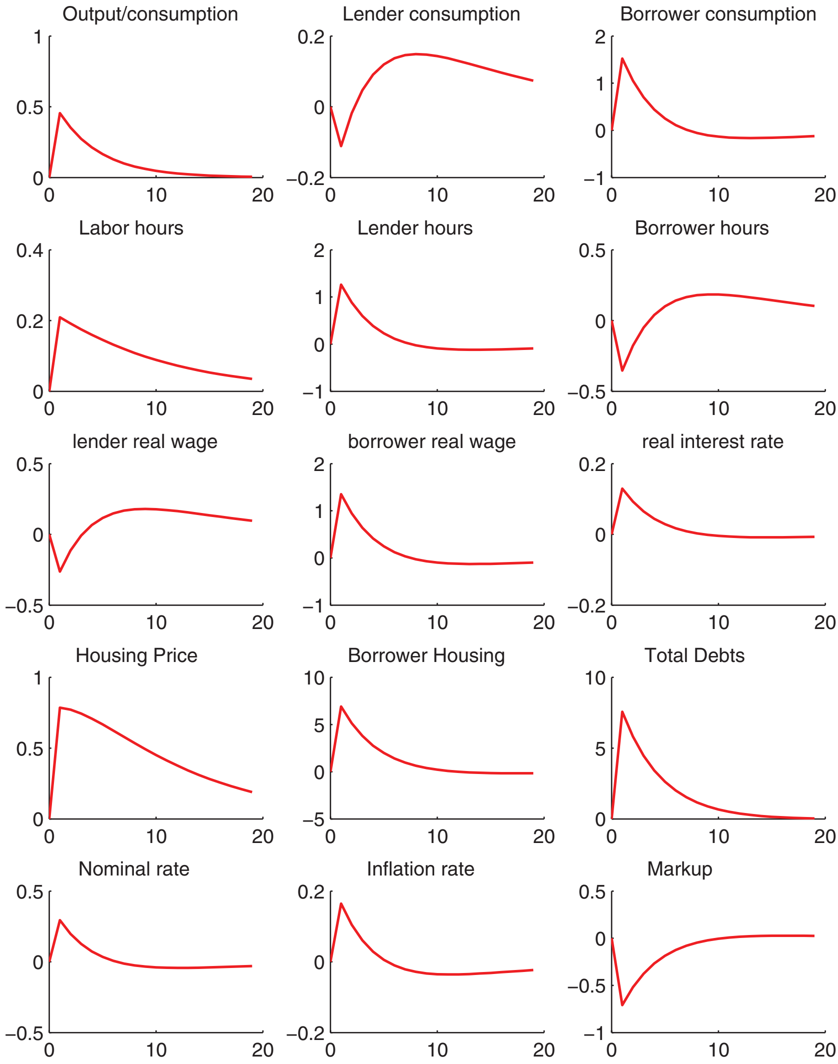
where $\gamma_e = \beta_2 + m_2(\beta_1 - \beta_2)$. The three conventional channels are covered by the first three terms, which are similar to those in (22). The last term in (23) is critical. λ_t is the Lagrangian multiplier for the collateral borrowing constraint (6). It measures the shadow price of borrowing—the marginal benefit of increasing the value of the collateral by one more unit, which relaxes the borrowing constraint and allows the agent to purchase more consumption and housing to improve welfare. When $\lambda_t = 0$, the collateral constraint is not binding, and the agent is not credit constrained. When the value of λ_t goes above zero, the agent becomes credit constrained and becomes increasingly so as λ_t increases. The tighter the collateral constraint, the more valuable an extra unit of housing asset is—since it can relax the constraint. Consequently, agents are willing

[7] Another conventional channel, the depreciation rate of capital, is not in the equation because we assume there is no depreciation for housing assets.

to give up more consumption to obtain it. This creates a positive relationship between the value of λ_t and the user cost of housing. A tighter collateral constraint will thus lead to a higher user cost of housing. When the housing price rises, its impact on the first three channels is almost identical for the lender and the borrower ($\gamma_e \approx \beta_1$). But there is an additional impact on the borrower via the fourth channel: it relaxes the borrowing constraint (decreasing λ_t), increases the borrower's net worth, and reduces the borrower's user cost further. Because of this extra impact, the borrower's user cost always decreases more than the lender's when the housing price rises.

Now we can turn to the co-movement issue. As a starting point, consider what would happen if there is no news and the preference shock is unanticipated. On impact of a preference shock, both the lender and the borrower demand more housing services. Housing price goes up. But the supply of housing assets is fixed, and only one agent can increase her housing purchases. As we explained above, when housing prices increase, the borrower's user cost always decreases more than the lender's due to the relaxation of the collateral constraint. As a result, the borrower gets to accumulate more housing assets. The lender sells housing assets to the borrower. The borrower's consumption decision now depends on the trade-off between two opposing effects. One is a wealth effect induced by the relaxation of the collateral constraint, which tends to make the borrower consume more. The other is a substitution effect that makes agents want to consume more housing and less of other goods. When the model's credit channel is strong, the wealth effect dominates. The borrower uses her housing assets as collateral to finance more housing and final goods purchases, and works less and has more leisure. In order to save enough to make the lending, the lender now must consume less and work more. Rising demand in final goods pushes inflation up, and since the central bank follows the Taylor principle by raising the nominal rate more than one-for-one to inflation, real interest rate also goes up. This enhances the intertemporal substitution effect for the lender and justifies her decision to save more. Interestingly, in this case the lender's increase in labor hours always more than offsets the borrower's reduction in hours, despite the assumption that labor supply elasticities are the same. Total hours and output both go up. The co-movement is strong.

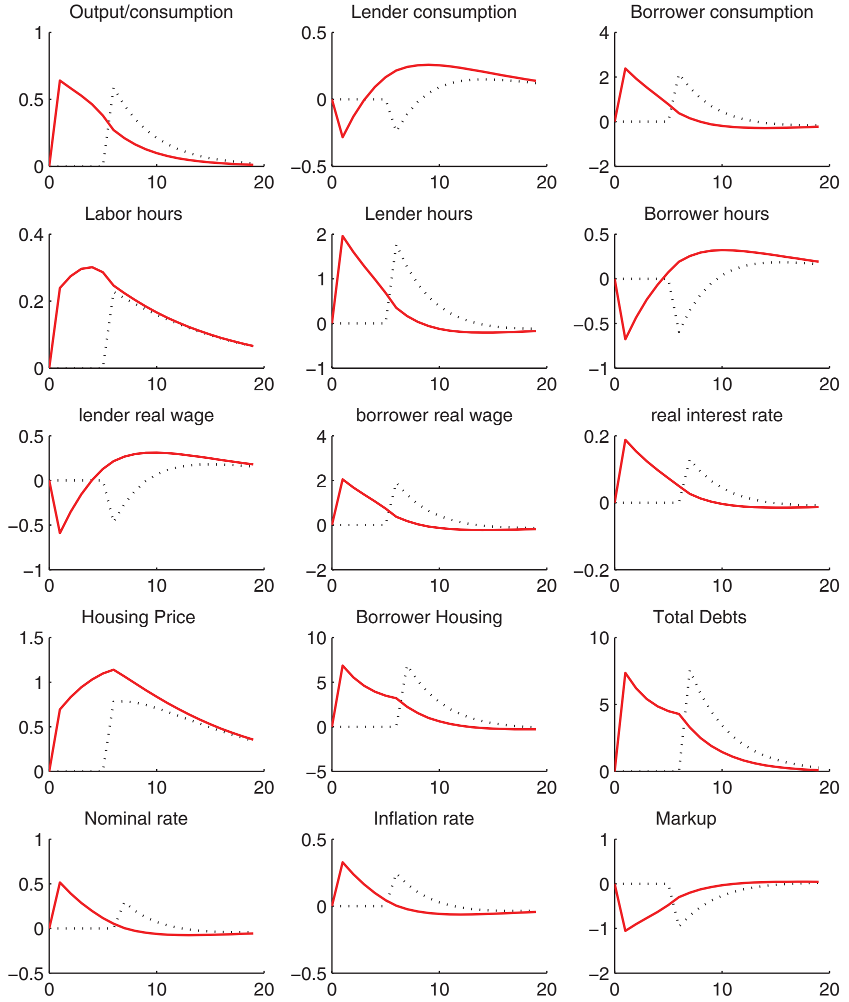
Figure 4. Responses to a Preference Shock



We plot the responses of different variables to a preference shock in figure 4.

What happens if the preference shock is anticipated because of news? We show the impulse responses in figure 5. We use a solid line

Figure 5. Responses to a News Shock (Solid Line) and an Unanticipated Preference Shock (Dotted Line)



to describe what would happen if there is a news shock in period 1 and the news is accurately realized in period 7, and a dotted line to show the case where there is no news and just an unanticipated preference shock in period 7. As the figure shows, news shocks alter the business cycle in two ways. First, they change the timing of cycles by shifting all phases of the cycle several periods earlier. For example, without news, the peak of the output boom happens around period 7. But with news, the output boom takes place in period 1, and in period 7, output is already on its returning path to the long-run steady-state equilibrium. Second, news shocks also magnify the responses of some variables. For example, output, hours, and housing prices all respond more strongly to news shocks than to unanticipated shocks. The reason is that with news, the rise in expected net worth and the change in consumer taste do not take place simultaneously. The rise in expected net worth happens first. Without any substitution effect from a change in preferences, consumption and output increase more strongly.

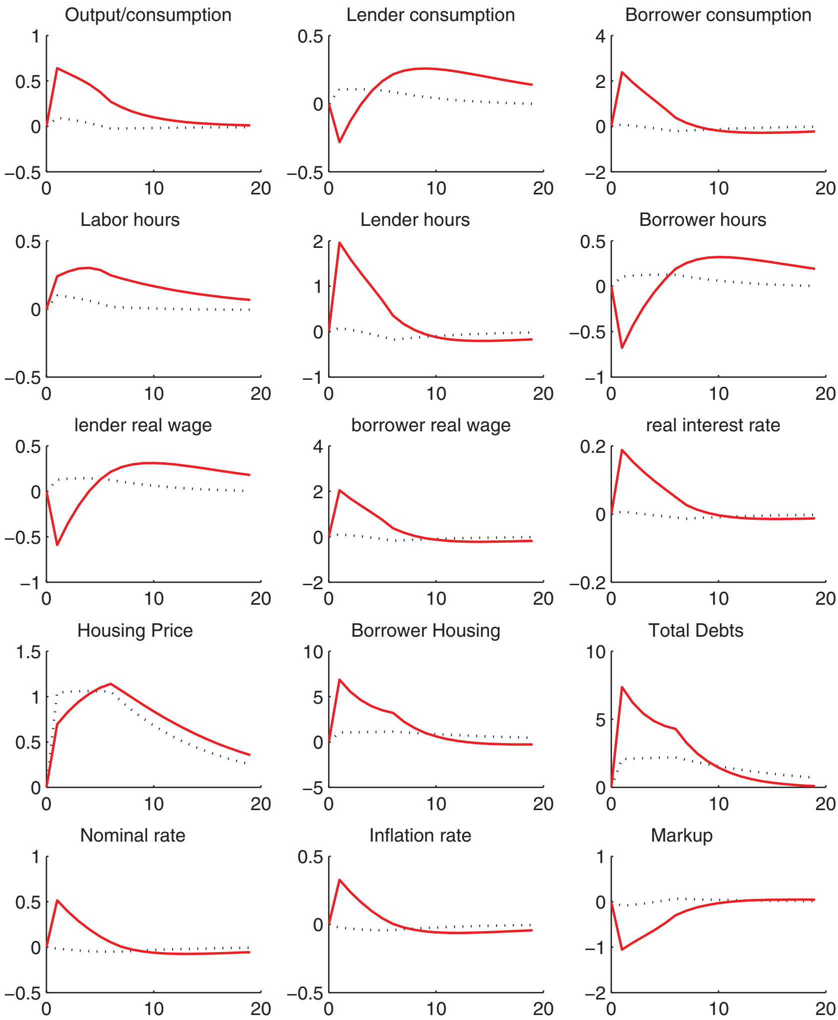
3.3 Robustness

How general is the above mechanism? When model specifications change, how is this mechanism affected? In this section we examine this issue. We will analyze the effect of changes in the strength of the credit channel, changes in price flexibility, and changes in the structure of the labor market.

3.3.1 Strength of the Credit Channel

First, we will try to understand how crucial the credit channel is in facilitating a news-driven boom-bust cycle. We distinguish two cases. In the first case, the downpayment ratio, $1-m_2$, is high. We set it to be 0.5. This means that the maximum amount of credit that the borrower can get is 50 percent of the real expected value of her housing assets. It greatly reduces the size of credit the borrower can get when housing prices go up. We call this the "weak-credit-channel" case. The second case is the benchmark case where $1 - m_2 = 0.1$. We call this the "strong-credit-channel" case. We set up two versions of the model economy, one with a weak credit channel and the other with a strong credit channel. All other specifications of the two economies are identical. In period 1, the two economies are disturbed by the same news shock. Figure 6 displays the impulse responses of both economies in the first twenty periods. The solid lines depict what happens in the strong-credit-channel economy, and the dotted lines do the same for the weak-credit-channel economy.

Figure 6. The Strong-Credit-Channel Economy (Solid Line) vs. the Weak-Credit-Channel Economy (Dotted Line)



In the weak-credit-channel economy, news leads to a similar response in housing prices. But the transmission of housing prices to the rest of the economy differs from the strong-credit-channel economy in two important ways. First, the overall response of the economy is greatly dampened on impact of the news shock. For example, the rise in output is only around 0.1 percent, much less than the 0.7 percent rise in the strong-credit-channel economy. Similar changes happen to almost all other aggregate variables.

Second, the weak-credit-channel economy makes different predictions for some variables. For example, lender consumption increases instead of decreasing, and lender hours decrease instead of increasing for most of the periods after impact. The borrower's responses in consumption and hours also reverse directions correspondingly. The explanation is as follows. Recall that the borrower is subject to two opposing effects: a wealth effect and a substitution effect. In the strong-credit-channel economy, the wealth effect dominates. But when the credit channel is weak enough, the substitution effect starts to dominate. The borrower consumes *less* final goods and leisure (but consumes more housing). The lender, on the other hand, must consume more final goods and leisure to compensate for the loss of housing services. There is still co-movement among aggregate variables, but the causes are quite different from the strong-credit-channel case. We found that with our calibration, a threshold value for m_2 that switches the relative importance of the two effects is about 0.7. When $m_2 > 0.7$, the credit channel is strong enough for the wealth effect to dominate.

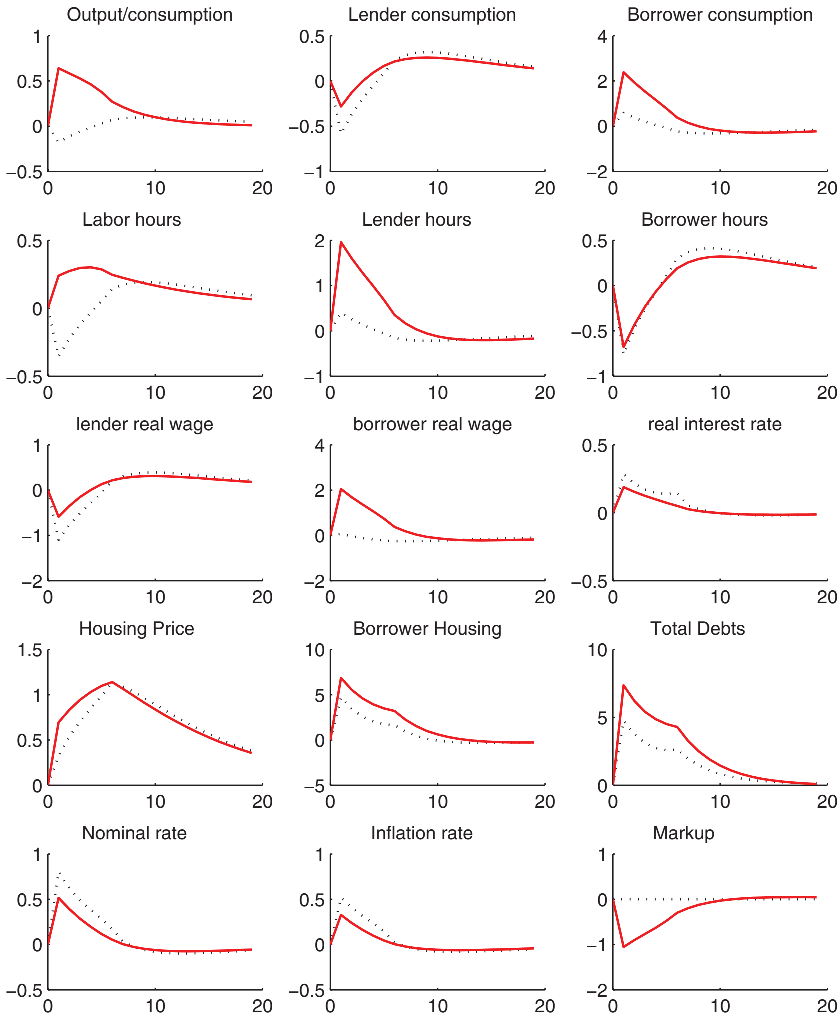
We conclude that one required condition for the news to generate co-movement is a strong credit channel.

3.3.2 Nominal Rigidity

In our benchmark calibration, the Calvo price-setting parameter $\theta = 0.75$. That is, 25 percent of firms are allowed to adjust their prices every period. How sensitive is the model's result to the level of price stickiness? To examine this, we study an alternative version of the model economy, in which all prices are flexible. All firms can set their prices freely, and the new Phillips curve no longer holds. The "classical dichotomy" holds in this economy, in that all real variables are determined independent of the nominal variables. In figure 7, we make a side-by-side comparison of this economy and the benchmark economy.

As the figure shows, with flexible prices, the model cannot generate boom-bust cycles as in the sticky price case. The responses of

Figure 7. Sticky Price (Solid Line) vs. Flexible Price (Dotted Line)



output, hours, and consumption are all negative, while both housing prices and total debts still increase. A news shock now leads to a recession. A closer look at the figure reveals that a major change in the flexible price case is that the borrower's wealth effect is greatly reduced—the third graph in the first row shows that the borrower's consumption increases only by less than 0.5 percent, much less than the 2 percent increase in the sticky price case. In the meantime, the lender's intertemporal substitution effect is strengthened, which leads to higher saving. The figure also shows that with flexible prices, output's response to a news shock is significantly dampened, but the response of real housing price remains strong.

Why do flexible prices lead to a different prediction? Evidently, the key lies in changes in the real interest rate. With sticky prices, the real interest rate is essentially tied to the central bank's interest rate policy. A Taylor-type policy rule ensures that changes in the real interest rate follow the inflation rate. As a result, if prices are sticky enough, the real interest rate will not change dramatically. Relatively sluggish changes in the real interest rate permit borrowers to borrow more without quickly increasing borrowing costs. Things are different with flexible prices. The real interest rate is determined independent of monetary policies. On impact of the news shock, the real interest rate adjusts immediately according to credit market conditions. Higher real interest rate partially offsets the wealth effect of higher housing prices and causes borrower consumption to increase less than in the sticky price case.

In our analysis, we find that the above mechanism exists not only in a flexible price economy but also in sticky price economies. In essence, the level of nominal rigidity must be strong enough for the wealth effect to dominate other effects. The level of nominal rigidity is measured by the parameter θ. We experiment with a series of different values for θ and find that with our calibration, the threshold value is about 0.65. If $\theta < 0.65$, the borrower's wealth effect is not strong enough, and output and labor hours start to react negatively to news shocks. The co-movement breaks down. We note that this result is similar to Christiano et al. (2008), who find that wage rigidity is important in generating news-driven procyclical cycles in the stock market.

3.3.3 Labor Market

In the benchmark economy, the lender's and borrower's labor hours are not perfectly substitutable. There are two separate labor markets with two distinct wage rates. As we have seen in the previous sections, the two wage rates can move in opposite directions. A natural question to ask is, what happens if there is a unified labor market with a single wage rate? Is this feature crucial for a boom-bust cycle to exist?

To address this issue, we slightly modify the model specification as follows. Let the intermediate firm's production function be

$$Y_t = L_t^{\alpha}, \tag{24}$$

where

$$L_t = L_{1t} + L_{2t}. \tag{25}$$

And let there be only one labor market with one wage rate w_t. The intermediate firm's production function becomes

$$Y_t / X_t - w_t(L_{1t} + L_{2t}). \tag{26}$$

All the first-order necessary conditions of the model are changed correspondingly. We simulate the response of this economy to a news shock and report the result in figure 8. We set $\alpha = 1$ in the simulation, so that there is still constant returns to scale in the production function.

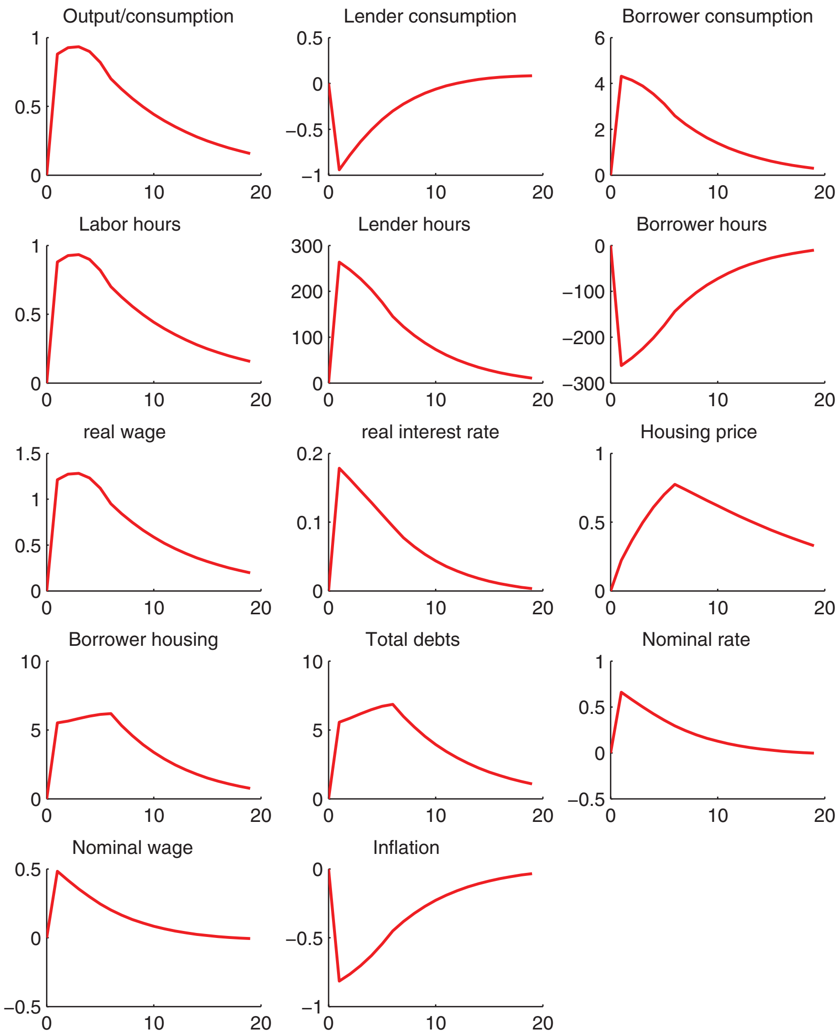
The response of the model economy is very similar to the benchmark economy with separate labor markets. There is still co-movement among major aggregate variables, and all variables respond to the news shocks in the same way as in the benchmark case. The main difference is that the responses of labor hours are now much stronger than before. Both the lender's and the borrower's hours move more than 200 percent from their steady-state value on impact. The net change in total labor supply, however, is only about 1 percent, which is in the empirically plausible range.

Recall that when labor is not perfectly substitutable, the production function is defined as

$$Y_t = A_t L_{1t}^{\alpha} L_{2t}^{1-\alpha},$$

where α is the share of the patient household's labor hours in the production technology. As in Iacoviello (2005), our benchmark calibration for α is 0.5. A natural question to ask is whether or not

Figure 8. Responses to a News Shock when Labor Inputs Are Perfectly Substitutable



the co-movement result is sensitive to the size of α. We experiment with different values for α and examine the co-movement of variables for each case. Our result shows that as long as α is not too big (higher than 0.6), labor hours will be procyclical, and the co-movement result holds. If α is higher than 0.6, labor hours become countercyclical.

4. Estimation

To understand the quantitative importance of news shocks, we need a more comprehensive model that can match realistic properties of macro data. We extend our model according to Iacoviello (2005)'s full empirical model. The model adds a few new features to the benchmark model of section 2. The economy has two credit-constrained agents instead of one. The intermediate goods producer is now credit constrained. She borrows collateralized loans to finance consumption and the production of intermediate goods. Another significant change is that both housing assets and physical capital are added to the production function for intermediate goods. There are capital adjustment costs for housing and physical capital. We present the technical details of the extended model in the appendix.

We specify five sources of uncertainty in our model. These are productivity shocks A_t, policy shocks v_t, cost-push shocks u_t, preference shocks d_t, and news shocks. The first four are conventional unanticipated shocks considered in Iacoviello (2005). The fifth element, news shocks to housing preferences, is our innovation. The first three shocks do not involve any news and can be organized as

$$Z_t = JZ_{t-1} + \epsilon_t, \tag{27}$$

where Z_t is a three-by-one vector of shocks, and ϵ_t is a vector of i.i.d. innovations with mean 0 and standard deviations σ_j for $j = A$, v, and u.

Specifying news shocks is challenging in econometric analysis. In principle, news matters for both the short run and the long run, and should be considered for a wide range of time horizons. Doing so, however, will render the econometric model excessively cumbersome. Some form of simplification is necessary. Schmitt-Grohe and Uribe (2012) capture news by specifying two anticipated shocks that are revealed one year and two years ahead of the realization of the fundamental shocks. The following setup closely follows their paper. To be consistent with our structural model, we only consider news about housing demand.

There are two news shocks. One is learned four periods before the realization of the fundamental shock, and the other is learned eight periods before.

$$d_t = \rho^d d_{t-1} + e_t^d,$$
$$e_t^d = \varepsilon_t^0 + \varepsilon_t^4 + \varepsilon_t^8,$$

where ε_t^0 is an unanticipated change in d_t, and ε_t^4 and ε_t^8 are the two innovations that represent news shocks. ε_t^i for $i = 0$, 4, and 8 is assumed to be i.i.d. normal innovations with zero mean and standard deviations σ_ε^i. In the robustness test reported in the appendix, we also consider various combinations of $i = 2$, 4, 6, and 8.

Our econometrics strategy closely follows that of Iacoviello (2005). Our goal is to examine whether or not news shocks play a significant role in explaining the data. To do so, we divide the model's parameters into two groups. One group of parameters characterize the nature of shocks. These would include the standard deviations and autocorrelation coefficients for the exogenous variables we described above. We put all variables that are unrelated to the exogenous variables into the second group.[8] We calibrate the second group of parameters in a standard way. Then, we let the data decide which of the five sources of uncertainty is important by estimating the first group of parameters. In essence, we search for the properties of the exogenous variables that enable the model to explain the data as well as possible. For example, if news shocks are not important for business cycles, we expect to replicate Iacoviello (2005)'s result, and expect to observe small and insignificant estimates for parameters related to news shocks.

In Iacoviello (2005), some parameter values are selected to match those used in the literature. β, δ, μ, X, θ, and η belong to this group. Some values are estimated using the data. The interest rate rule and the adjustment cost parameters fall into this group. We use these parameters to calibrate our model. Only three parameters do not exactly match those in Iacoviello (2005). m_2 and m_3

[8]We put the standard deviation of policy shocks in the second group because it can be estimated during the calibration process for the policy rule. This closely follows the approach of Iacoviello (2005).

Table 1. Calibrated Parameters

Parameter	Value	Description
β_1	0.99	Patient Household Discount Factor
β_2, γ	0.95	Impatient Agents Discount Factor
d	0.1	Preference Weight on Housing
η_1, η_2	1.01	Labor Supply Aversion
μ	0.3	Variable Capital Share
ν	0.05	Housing Share
ψ	2	Variable Capital Adjustment Cost
δ	0.03	Variable Capital Depreciation Rate
$\emptyset$	0	Housing Adjustment Cost
X	1.05	Steady-State Gross Markup
θ	0.75	Probability of Fixed Prices
α	0.64	Patient Household Wage Share
ρ^R	0.73	Interest Rate Smoothing Parameter
τ_Y, τ_π	0.13, 1.27	Coefficients of the Taylor Rule
σ_R	0.29	Standard Deviation of Policy Shocks
m_2, m_3	0.9	Loan-to-Value Ratio

are not calibrated in his paper. They are instead included in the structural estimation, and the values are found to be 0.9 and 0.55, respectively. In this paper we calibrate them both to be equal to the benchmark value of 0.9. The degrees of impatience for the borrower and the entrepreneur, γ and β_2, are 0.95 and 0.98 in his paper. They are selected from an estimated range of (0.91, 0.99). In this paper we let the degree of impatience be the same for the borrower and for the entrepreneur. So, we set $\gamma = \beta_2 = 0.95$. We make these small adjustments to enhance the strength of the credit channel in our model. All calibrated parameters are presented in table 1.

We use a simulated method of moments to estimate the model. Specifically, we search for parameters that minimize the distance between the impulse responses implied by the model and those computed from actual data. Let Θ represent a vector of parameters that we are interested in, let $M(\Theta)$ represent the impulse responses computed from model simulated data, and let $\widehat{M}$ represent impulse responses computed from actual data. Our interested parameters are $\Theta' = (\rho^A, \rho^u, \rho^d, \sigma_A, \sigma_u, \sigma_d, \sigma_\varepsilon^0, \sigma_\varepsilon^4, \sigma_\varepsilon^8)'$. The simulated method of moments estimator is defined as

$$\Theta = \arg\min[M(\Theta) - \widehat{M}]' W [M(\Theta) - \widehat{M}],$$

where W is a positive-definite weighting matrix.

Iacoviello (2005) uses four data series in his estimation of impulse responses: housing prices, represented by the Conventional Mortgage Home Price Index from Freddie Mac; real GDP; changes in the log of GDP deflator; and the federal funds rate. For a close comparison with his results, we use the exact same impulse response functions he computed using these data.

In a model without news shocks, one can use a VAR estimation to identify four exogenous shocks and match their impulse responses with those generated by the theoretical model. For example, running a VAR of the four data series will conveniently identify a shock to GDP, a housing price shock, an inflation shock, and a shock to the federal funds rate. In Iacoviello (2005), the impulse responses to the four shocks are matched with those to the four exogenous variables of the model.[9] When news shocks are introduced, we can no longer use this standard procedure to make this type of one-for-one match. The reason is that news shocks are not identifiable in a standard VAR estimation. To identify a news shock, one often has to find a proxy for news or implement non-standard identification techniques.[10] To solve this problem, we modify the estimation procedure slightly. For the data, the impulse responses can be computed in the usual way. To obtain corresponding impulse responses from the model, we simulate the model using all five exogenous shocks, and collect the artificial data. We then select the four variables that we are interested in and run a standard VAR to compute impulse responses. This approach has two advantages. First, both impulse

[9]In fact, the impulse responses from the model and from the data are not strictly comparable. For example, the impulse response to a GDP shock in the data and the impulse response to a technology shock in the model are not exactly the same thing. Iacoviello (2005) states this caveat in his paper.

[10]For example, Beaudry and Portier (2006) use anticipated changes in stock prices as proxies for news shocks. Barsky and Sims (2011) suggests a method to identify news shocks that requires more data about fundamental variables. In his paper, productivity data are necessary for the identification of news shocks about future productivity changes.

Table 2. Estimated Parameters and Their Standard Errors

Description	Parameter	Value	S.E.	Iacoviello (2005)
Autocorrelation of Shocks				
Inflation	ρ^u	**0.36**	0.11	0.59
Technology	ρ^A	0.01	0.053	0.03
Housing Preference	ρ^d	**0.796**	0.015	0.85
Standard Deviation of Shocks				
Inflation	σ_u	**0.196**	0.03	0.17
Technology	σ_A	**3.21**	0.26	2.24
Housing Preference	σ_d	**30.59**	3.52	24.89
News (Four Periods Ahead)	σ_4	**11.86**	2.295	–
News (Eight Periods Ahead)	σ_8	0.01	3.755	–

responses (from the data and from the model) are generated by running unrestricted VARs, and the match is one-for-one. Second, this procedure is consistent with our underlying story that news shocks are important for business cycles but are omitted from standard models and VAR analysis.

Estimated parameters are presented in table 2. The first and second columns define the parameters. In the third and fourth columns, we present our estimated parameter values and standard errors. In the fifth column, we list the values of the same parameters estimated by Iacoviello (2005) in a model without news shocks. All significant estimates are shown in bold. The results can be summarized as follows. First, news shocks are important. The estimated standard deviation for the four-periods-ahead news shock is large and significant. The standard deviation is 11.86, larger than that of all other exogenous variables except unanticipated housing demand shocks. Since we use quarterly data, the result suggests that short-term expectations of about one year in time horizon are important in the housing market. Longer-term expectations, however, are not important: the estimate for the eight-periods-ahead news shock is small and insignificant. Second, unanticipated housing demand shocks have the highest volatility. This result is consistent with Iacoviello (2005) and

Iacoviello and Neri (2010). Third, compared with the model without news shocks, the estimated autocorrelation coefficients for inflation, technology, and housing preference shocks are all smaller. This is due to the fact that news shocks are an additional source of persistence, and it reduces the need for persistence in other shocks.

To test the robustness of the above result, we estimate our model using a different method—the maximum-likelihood method. We present the methodology and results in the appendix. The results are remarkably similar to what we obtained in table 2: news shocks and preference shocks are the two most important impulses of fluctuations. We also experimented with news shocks that have different time horizons—we tried two-, four-, six-, and eight-periods-ahead news shocks. Interestingly, the four- and six-periods-ahead news shocks are consistently estimated to have significant and large standard deviations, while the two- and eight-periods-ahead news shocks are always estimated to have small and insignificant standard deviations. It appears that news that predicts events which will happen one year to one-and-a-half years into the future has the most influence on the housing cycle.

One way to quantify the significance of news shocks is to compute their contributions to overall data volatility. We run two separate simulations using the estimated parameters. In the first simulation, we let the four-periods-ahead news shock be the only source of uncertainty. In the second, we allow all five exogenous shocks to affect the economy. All shocks are calibrated using the estimated values. The volatilities for economic aggregates are computed for each experiment. In the first experiment, the standard deviations for housing prices and real GDP are 1.19 and 0.52, respectively. In the second experiment, their values become 2.52 and 1.97. The ratios of the two sets of volatilities are computed as 26 percent and 47 percent. Essentially, news shocks explain 26 percent of the volatility of real GDP and 47 percent of the volatility of housing prices in the model.

5. News Shock and Monetary Policy

A key question is whether or not central banks can better stabilize the economy by specifically targeting housing prices, in addition to the output gap and inflation. We turn to stochastic simulations to answer this question.

We assume that the central bank's loss function comprises the volatility of two variables—the output gap and inflation. The central bank's goal is to minimize a weighted average of the unconditional standard deviation of the two variables over time. Thus the loss function can be defined as

$$-\frac{1}{2}E_0\sum_{t=0}^{\infty}\beta_1^t(\pi_t^2+\lambda y_t^2),$$

where $\lambda > 0$ measures the relative weight given to output stabilization. The central bank's policy tool is an interest rate rule that targets inflation, output, and possibly housing prices:

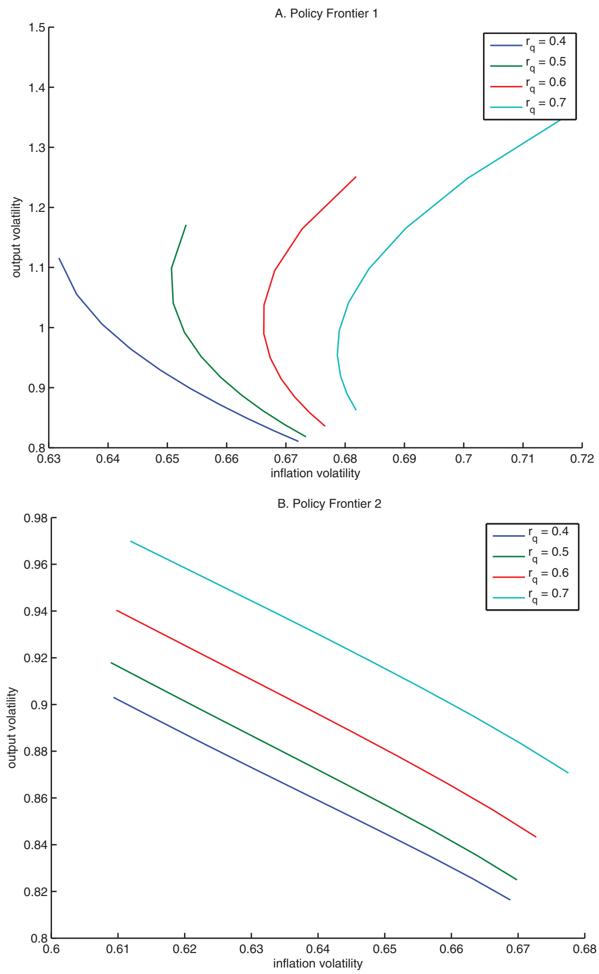
$$i_t = \rho^R i_{t-1} + (1-\rho^R)(\tau_\pi \pi_t + \tau_y y_t + \tau_q q_t). \tag{28}$$

In the following experiments, we simulate the model using various combinations of policy parameters τ_π, τ_y, and τ_q, and search for combinations of their values that minimize the loss function. If the optimal policy coefficient involves a sizable coefficient for housing prices, we conclude that responding to housing prices is beneficial to economic stabilization. Otherwise, we will conclude it is not.

In our experiments, we use the calibrated and estimated parameter values from the previous section. We allow τ_π to vary between 1.01 and 4 (again, $\tau_\pi > 1$ ensures a determinate, unique equilibrium), τ_y to vary between 0 and 4, and τ_q to vary between 0 and 2. These restrictions are put in place to ensure that the policy parameters are within a (generous) range consistent with empirical estimates. In the first round of simulations, we shut down interest rate smoothing ($\rho^R = 0$). We then add it back in to examine the differences in later experiments. For each variation of the policy rule, we run stochastic simulations of the model to calculate the central bank's loss function. The "optimal" policy parameters are the ones that minimize this function.

Our result can be intuitively presented with two plots (figure 9). In both panels of figure 9, the horizontal axis measures the volatility of inflation and the vertical axis measures the volatility of output. Therefore, each point in the diagram represents a simulated value for the central bank's loss function. In panel A, we fix the policy parameter for inflation τ_π at the benchmark value, and vary the

Figure 9. Policy Frontiers



policy weights for output τ_y and housing prices τ_q. A shift of the curve represents a change of the loss function due to a change in τ_q, and a movement along the curve represents a change of loss function due to a change in τ_y. We can see that for given values of τ_q (and τ_π), a rise in the value of τ_y generally reduces output volatility at the expense of higher inflation volatility. In this case we will move along the curve downwards to the right. This simply illustrates the

Table 3. Optimal Policy Parameters for Policy Rule $i_t = \tau_\pi \pi_t + \tau_y y_t + \tau_q q_t$

Loss Function	All Shocks	News Shock Only
$\sigma_\pi^2 + 0.2\sigma_y^2$	$\tau_\pi = 2.86, \tau_y = 1.44, \tau_q = 0.11$	$\tau_\pi = 3.88, \tau_y = 1.44, \tau_q = 0$
$\sigma_\pi^2 + \sigma_y^2$	$\tau_\pi = 1.01, \tau_y = 3.90, \tau_q = 0.21$	$\tau_\pi = 1.01, \tau_y = 2.46, \tau_q = 0.11$
$\sigma_\pi^2 + 2\sigma_y^2$	$\tau_\pi = 1.01, \tau_y = 3.90, \tau_q = 0.21$	$\tau_\pi = 1.01, \tau_y = 2.46, \tau_q = 0.11$

usual policy trade-off between output and inflation volatility. What is important is that when τ_q increases, this trade-off becomes worse as the curve shifts outward, representing higher volatilities for both output and inflation. Obviously, responding to housing prices is not desirable for the central bank. Panel B tells a similar story. We fix the policy weight for output at the benchmark value and vary the policy weights for inflation and housing prices. The results are essentially the same.

The plots are based on values of τ_q that are higher than 0.3. When τ_q is small, the conclusion is not as clear-cut as presented in the plot. So we conduct a more comprehensive search for the optimal policy parameters. We consider three possible weight allocations for the central bank's loss function. We use $\sigma_\pi^2 + 2\sigma_y^2$ to represent a loss function that emphasizes output stabilization, $\sigma_\pi^2 + 0.2\sigma_y^2$ to represent one that emphasizes inflation stabilization, and a third one that puts equal weights on output and inflation. For each loss function, we search for the combinations of τ_π, τ_y, and τ_q that minimize the (infinite) sum of the discounted loss function over time. As before, the ranges allowed for these weights cover all empirically relevant cases. We use an increment step size of 0.01 in our search.

In table 3, we present the search result for a "current data" policy rule that allows the central bank to target the current levels of output and inflation. We distinguish between two cases. In one case, the only shocks to the economy are news shocks, and in the other, all shocks affect the economy. The result suggests that the interest rate policy should strongly target inflation when the loss function puts more weight on inflation volatility; that it should target the output gap, especially when there is more weight on output volatility in the loss function; and that its response to housing prices should be very small, if any. When the central bank cares more about

Table 4. Optimal Policy Parameters for Policy Rule $i_t = \tau_\pi \pi_{t-1} + \tau_y y_{t-1} + \tau_q q_t$

Loss Function	All Shocks	News Shock Only
$\sigma_\pi^2 + 0.2\sigma_y^2$	$\tau_\pi = 1.83, \tau_y = 1.01, \tau_q = 0.21$	$\tau_\pi = 2.45, \tau_y = 1.03, \tau_q = 0.11$
$\sigma_\pi^2 + \sigma_y^2$	$\tau_\pi = 1.01, \tau_y = 1.23, \tau_q = 0.21$	$\tau_\pi = 1.01, \tau_y = 1.44, \tau_q = 0.21$
$\sigma_\pi^2 + 2\sigma_y^2$	$\tau_\pi = 1.01, \tau_y = 1.23, \tau_q = 0.21$	$\tau_\pi = 1.01, \tau_y = 1.64, \tau_q = 0.21$

output, a small weight is given to housing prices. When the central bank mainly cares about price stability, no weight is given to housing prices. The result is also remarkably similar between the single-shock case and the all-shock case.

We then consider the possibility that knowing current housing price data may provide the central bank with an information gain. The logic is that contemporaneous macro data such as output and inflation are often not readily available to the central bank at policy-making time. The same limitation, however, need not apply to asset price data, because asset prices are much more frequently updated and collected, and therefore easier to observe. Consequently, having current asset price data may provide the central bank with a potential information gain. Therefore, we consider a policy rule

$$i_t = \tau_\pi \pi_{t-1} + \tau_y y_{t-1} + \tau_q q_t.$$

The central bank is able to respond to a current housing price change without having to wait for data on output and inflation. We present our result in table 4. Surprisingly, the result is very similar to that of the current data rule case. The optimal policy weights for housing prices remain very small. In fact, the computed optimal values are identical to that case. There is an upper bound of about 0.21 that the policy weights never surpass.[11]

[11] All the tables and plots shown above are based on policy rules without interest rate smoothing. If we add policy smoothing and allow ρ^R to be a positive number, say 0.5, the results remain very similar. The only difference is that the values for all policy weights tend to be larger than the no-policy-smoothing case. This is not surprising, as all policy weights must be discounted by $1 - \rho^R$ with interesting rate smoothing. Due to their similarity with the benchmark case, we do not present these results in tables and figures.

6. Conclusion

We explore the possibility that a housing boom-bust cycle can be driven by news in a dynamic general equilibrium model with collateral constraint. We find that news about housing demand can generate housing boom-bust cycles. Housing values affect agents' net worth and their ability to borrow and spend. A housing cycle can therefore trigger similar movements in aggregate economic activities. When economic news is inaccurate, most of the fluctuations are not based on fundamentals and are later canceled by the realization of the real shocks. These kind of fluctuations have the feature of "bubbles."

We estimate our theoretical model using macro data and find that news shocks are quantitatively important. We then run stochastic simulations of the model economy and look for the optimal interest rate policy that minimizes the central bank's loss functions. Our result suggests that the gain from targeting asset prices, in addition to output and inflation, is small. We conclude that there is no strong case for active interventions in the housing market, even when housing prices respond to optimism and pessimism in consumer expectations.

Given the results in this paper, opportunities now exist to enrich our understanding of housing boom-bust cycles in other respects. One possible extension is to consider other types of monetary policies, such as a money growth rule, or a policy where the central bank directly provides credits to borrowers. We leave these for future research.

Appendix

The Extended Model

The saver maximizes a lifetime utility function given by

$$E_0 \sum_{t=0}^{\infty} \beta_1^t \left(\ln C_{1t} + d_t \ln h_{1t} - \frac{L_{1t}^{\eta}}{\eta} \right),$$

subject to the constraint

$$C_{1t} + q_t h_{1t} + \frac{R_{t-1} b_{1t-1}}{\pi_t} + \xi_{h1t} = b_{1t} + q_t h_{1t-1} + w_{1t} L_{1t} + F_t, \tag{29}$$

where all variables that appeared in the benchmark model are defined in the same way. The variable ξ_{h1t} is new. It represents the adjustment cost of housing asset accumulation and is defined as

$$\xi_{h1t} = \frac{\psi_h}{2}\left(\frac{h_{1t} - h_{1t-1}}{h_{1t-1}}\right)^2 q_t h_{1t-1},$$

where $\psi_h > 0$.

The impatient household's problem is similar to that of the patient household, except for two differences. First, the impatient household does not own any retailers and does not receive profits, and second, her borrowing capacity is constrained by the discounted future value of the collateral—her housing assets. The problem thus is

$$\max E_0 \sum_{t=0}^{\infty} \beta_2^t \left(\ln C_{2t} + d_t \ln h_{2t} - \frac{L_{2t}^{\eta}}{\eta}\right),$$

subject to

$$C_{2t} + q_t h_{2t} + \frac{R_{t-1} b_{2t-1}}{\pi_t} + \xi_{h2t} = b_{2t} + q_t h_{2t-1} + w_t L_{2t}, \tag{30}$$

$$b_{2t} \leq m_2 E_t \left(\frac{q_{t+1} h_{2t} \pi_{t+1}}{R_t}\right), \tag{31}$$

where the adjustment cost is defined as

$$\xi_{h2t} = \frac{\psi_h}{2}\left(\frac{h_{2t} - h_{2t-1}}{h_{2t-1}}\right)^2 q_t h_{2t-1}.$$

The intermediate good producer (entrepreneur) maximizes her utility

$$E_0 \sum_{t=0}^{\infty} \gamma^t \ln C_{3t},$$

subject to three constraints. γ is the entrepreneur's discount rate. Again with $\gamma < \beta_1$, the producer is less patient than the saver, and her net borrowing is positive in the steady state.

The first constraint of the entrepreneur is the budget constraint

$$C_{3t} + q_t h_{3t} + \frac{R_{t-1} b_{3t-1}}{\pi_t} + w_{1t} L_{1t} + w_{2t} L_{2t} + I_t + \xi_{Kt} + \xi_{h3t}$$
$$= \frac{Y_t}{X_t} + b_{3t} + q_t h_{3t-1}, \tag{32}$$

where I_t denotes gross investment in physical capital. The adjustment costs of physical capital and the housing assets are defined as

$$\xi_{Kt} = \frac{\psi_K}{2\delta} \left(\frac{I_t}{K_t} - \delta \right)^2 K_{t-1},$$
$$\xi_{h3t} = \frac{\psi_h}{2} \left(\frac{h_{3t} - h_{3t-1}}{h_{3t-1}} \right)^2 q_t h_{3t-1},$$

where $0 < \delta < 1$ is the depreciation rate of physical capital and $\psi_K > 0$.

The second constraint is the borrowing constraint:

$$b_{3t} \leq \frac{m_3 E_t q_{t+1} h_{3t} \pi_{t+1}}{R_t}. \tag{33}$$

The third constraint is the production function of intermediate goods:

$$Y_t = A_t K_t^u h_{3t-1}^v L_{1t}^{\alpha(1-u-v)} L_{2t}^{(1-\alpha)(1-u-v)},$$

where A_t is a technology shock that follows an AR(1) process defined in section 4.

The fourth constraint is the capital accumulation equation:

$$I_t = K_t - (1 - \delta) K_{t-1}.$$

The retailer's problem is the same as in the benchmark model. As in Iacoviello (2005), we add an inflation shock u_t to the new Phillips curve:

$$\pi_t = \beta_1 E_t \pi_{t+1} + \kappa X_t + u_t.$$

Details of this shock are explained in section 4.

Market clearing requires

$$C_{1t} + C_{2t} + C_{3t} = Y_t,$$
$$b_{1t} + b_{2t} + b_{3t} = 0,$$
$$h_{1t} + h_{2t} + h_{3t} = H,$$

plus two of the three budget constraints defined above.

Finally, the central bank's (linearized) policy rule is

$$i_t = \rho^R i_{t-1} + (1-\rho^R)(\tau_\pi \pi_t + \tau_y y_t + \tau_q q_t) + v_t,$$

where v_t is a policy shock with mean 0 and standard deviation σ_v.

Maximum-Likelihood Estimation

The Likelihood Function

The reduced-form model consists of two parts. The state equation is

$$s_{t+1} = As_t + B\varepsilon_t,$$

and the observation equation is

$$y_t = Cs_t,$$

where s_t is a vector of state and exogenous variables and y_t is a vector of endogenous variables. All parameters to be estimated are included in Θ. Denote the set of past observations of y_t by $Y_{t-1} = (y_{t-1,.....}y_1)$, the conditional expectation of s_t based on Y_{t-1} by $\widetilde{s}_{t|t-1}$, and the mean squared error (MSE) of this forecast by $P_{t|t-1}$. Under the assumption of normally distributed shocks, the density of y_t conditional on Y_{t-1} is

$$f(y_t \mid Y_{t-1}; \Theta) = N(C\widetilde{s}_{t|t-1}, CP_{t|t-1}C').$$

The log-likelihood function is defined as

$$L(\Theta) = -(T/2)\ln(2\pi) - (1/2)\ln|CP_{t|t-1}C'| - (1/2)\sum_{i=1}^{T}(y_t - C\widetilde{s}_{t|t-1})'(CP_{t|t-1}C')^{-1}(y_t - C\widetilde{s}_{t|t-1}),$$

Table 5. Estimated Parameters and Their Standard Errors

Description	Parameter	Estimated Value (MLE)	S.E.	Iacoviello (2005)
Autocorrelation of Shocks				
Inflation	ρ_u	**0.79**	0.018	0.59
Technology	ρ_A	**0.99**	0.001	0.03
Housing Preference	ρ_d	**0.77**	0.055	0.85
Standard Deviation of Shocks				
Inflation	σ_u	**1.48**	0.11	0.17
Technology	σ_A	**3.64**	0.209	2.24
Housing Preference	σ_d	**31.72**	11.44	24.89
News (Four Periods Ahead)	σ_4	**54.68**	15.53	–
News (Eight Periods Ahead)	σ_8	5.77	25.31	–

Note: The news shocks are revealed four and eight periods ahead of the realization of the fundamental shocks, respectively.

where T is the sample size. Then the maximum-likelihood estimator of Θ is

$$\widetilde{\Theta}_{ml} = \max_{\{\Theta\}} L(\Theta).$$

Estimation Results

As we explain in section 4, we calibrate one group of parameters and estimate the rest. The calibrated parameters are based on Iacoviello (2005) and are the same as those in table 1 in section 4.[12] Estimated parameters are listed in table 5. The estimated standard

[12]We find that while our results are generally robust with different calibrations of the discount factor β_2, low values of it do affect one parameter—the significance of the preference shocks. For example, when $\beta_2 = 0.95$, the standard deviation for preference shocks σ_d becomes insignificant. The standard deviation for news shocks, on the other hand, is always significant. In the following tables, we use $\beta_2 = 0.98$ to obtain significant estimates for σ_d.

Table 6. Estimated Parameters and Their Standard Errors

Description	**Parameter**	**Estimated Value (MLE)**	**S.E.**	**Iacoviello (2005)**
Autocorrelation of Shocks				
Inflation	ρ_u	**0.79**	0.016	0.59
Technology	ρ_A	**0.99**	0.001	0.03
Housing Preference	ρ_d	**0.70**	0.10	0.85
Standard Deviation of Shocks				
Inflation	σ_u	**1.47**	0.11	0.17
Technology	σ_A	**3.71**	0.10	2.24
Housing Preference	σ_d	**44.95**	12.30	24.89
News (Six Periods Ahead)	σ_6	**64.08**	23.31	–
News (Eight Periods Ahead)	σ_8	1.57 (not significant)	44.19	–

Note: The news shocks are revealed six and eight periods ahead of the realization of the fundamental shocks, respectively.

deviation for the four-periods-ahead news shock is large and significant. The estimate for the eight-periods-ahead news shock is small and insignificant. Unanticipated housing demand shocks also have a large standard deviation.

Next, we experiment with different horizons for the news shocks. The two pairs of news shocks we tried are six- and eight-periods-ahead and two- and six-periods-ahead shocks. The estimated results are reported in tables 6 and 7, respectively. When news is six and eight periods ahead of the actual events, the six-periods-ahead news shock is significant, and the eight-periods-ahead news shock is insignificant. When news is two and six periods ahead of the actual events, the six-periods-ahead news shock is significant, and the two-periods-ahead news shock is not. These results suggest that four- to six-quarters-ahead news shocks are mostly likely to be the driving forces of housing boom-bust cycles.

Table 7. Estimated Parameters and Their Standard Errors

Description	Parameter	Estimated Value (MLE)	S.E.	Iacoviello (2005)
Autocorrelation of Shocks				
Inflation	ρ_u	**0.77**	0.018	0.59
Technology	ρ_A	**0.99**	0.001	0.03
Housing Preference	ρ_d	**0.85**	0.045	0.85
Standard Deviation of Shocks				
Inflation	σ_u	**1.55**	0.12	0.17
Technology	σ_A	**3.60**	0.22	2.24
Housing Preference	σ_d	**29.96**	7.29	24.89
News (Two Periods Ahead)	σ_2	2.75	16.40	–
News (Six Periods Ahead)	σ_6	**32.08**	12.09	–

Note: The news shocks are revealed two and six periods ahead of the realization of the fundamental shocks, respectively.

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