News, Housing Boom-Bust Cycles, and Monetary Policy

Birol Kanik* and Wei Xiao†

October 11, 2009

Abstract

In this paper, 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 buildup 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 cycle, and we then explore what types of monetary policies are appropriate in terms of stabilizing it.

JEL classification: E3, E4, E5

Keywords: business cycle; news; monetary policy.

*Department of Economics, State University of New York at Binghamton, Binghamton, NY 13902. Email: bkanik1@binghamton.edu

†Department of Economics, State University of New York at Binghamton, Binghamton, NY 13902. Email: wxiao@binghamton.edu

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 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, which in turn affect 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. By altering the borrowers' net worth conditions, a housing cycle can have significant repercussions in the aggregate economy. This mechanism is consistent with the so-called "credit view," that asset market conditions are not merely reflections of economic conditions, but also a cause of fluctuations.

Until recently, credit channels are often absent from dynamic general equilibrium models. Bernanke and Gertler (1989) and Williamson (1987) provide the earlier works that consider financial intermediation and agency costs as propagation mechanisms for aggregate shocks in dynamic general equilibrium models.[1] Kiyotaki and Moore (1997) make important progress by examining the role of credit constrained agents and collateralized debts on equilibrium output. Bernanke et. al. (1999) embed a financial accelerator in a sticky price environment, and make monetary policy analysis possible. Finally, 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.[2]

The development of the literature naturally leads to a debate on policy issues. Since Bernanke et. al. (2001) posed the question "should central banks respond to asset prices?", it has become an important area of dialogue. Most research suggests that it is not necessary for inflation-targeting and "Taylor rule" regimes to respond to asset prices, on the ground that asset price movements

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

[2] Other quantitative works in this area include Calza et. al. (2007) and Pariès and Notarpietro (2008).

tend to change output gaps and inflation in the same direction, which can be taken care of by the regime (Batini and Nelson, 2000; Bernanke and Gertler, 2001; Iacoviello, 2005). Some research, however, finds that targeting asset misalignment in addition to inflation and output gaps does improve economic stability (Ceccetti, et. al., 2000). The debate between Bernanke and Gertler (2001) and Ceccetti et. al. (2000) is especially instructional. They both use the Bernanke and Gertler 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 Ceccetti et. al. (2000), the only shock is non-fundamental, and the central bank is aware of the price misalignment.[3] A critical lesson from this debate is that one cannot view the relationship between asset prices and inflation/output as a stylized fact; it depends on the underlying sources of uncertainty.

In this paper, we propose that a 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 easily leads to excessive buildup of housing assets by investors, and creates a housing boom that are not based on fundamentals. When the news is found false or inaccurate, investors 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 (forthcoming). In their works, noisy news about technological progress is an important source of business cycles. This type of cycles are referred to as "Pigou cycles" since the idea dates back to the earlier works of Pigou in 1926.

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 that real housing prices surpassed real rental prices and

[3] 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.

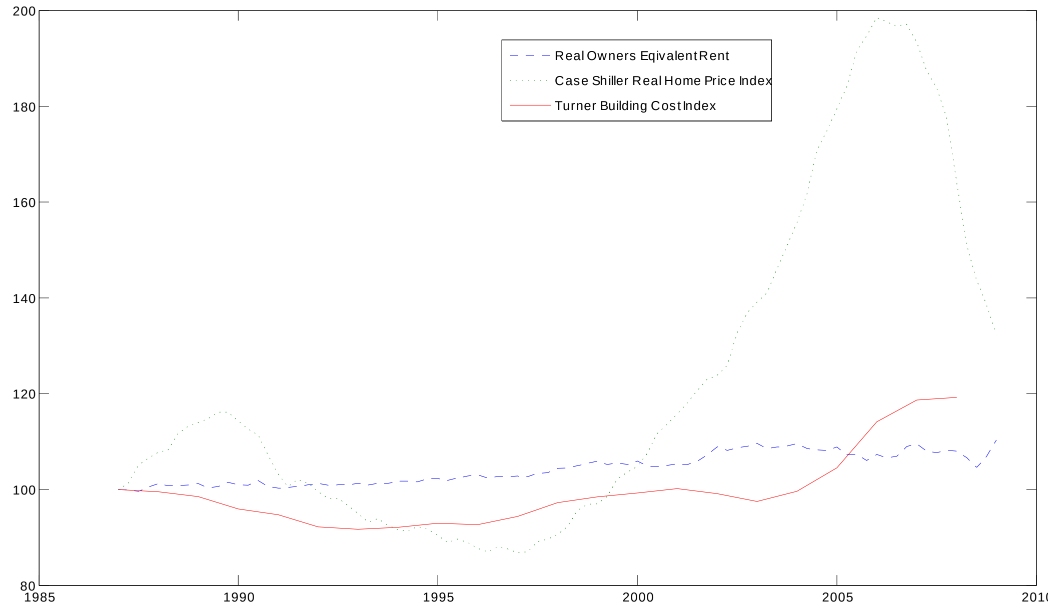

Figure 1: Housing price, construction cost, and owner's equivalent rent

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. 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.

Based on Iacoviello (2005), 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 incorrect optimistic news about future demand, this transmission mechanism creates a housing boom and comovement 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.

A major difficulty with the news-driven business cycle literature is that it is very hard to generate comovement 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 comovement with a multi-sector economy in which investment decisions and consumption decisions are decoupled so that the substitution between the two due to the wealth effect can be minimized. In Jaimovich and Rebelo (forthcoming), adjustment cost, capacity utilization, and preferences that incorporate a weak wealth effect on labor supply are used to generate positive comovement. 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 comovement among economic aggregates. In this paper, we rely on two features of the model to generate comovement. One is the nature of the shock. The driving force of our model is a demand shock – a shock to housing preferences. Unlike an expected productivity shock, news about future demand does not have a wealth effect on all agents and all sectors of the economy. The other is the credit channel. When housing price rises, improved net worth relaxes the borrowing constraint, stimulates aggregate demand and generate an economic boom along with a housing boom.

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 find that the impact of a housing boom-bust cycle does depend on the interest rate policy. If the policy's reaction to the boom is too weak, the impact of the housing cycle on the aggregate economy is large. Finally, we ask whether or not a strong 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. We consider scenarios in which news shocks are mostly noisy, and ones in which they are mostly correct. We also distinguish between cases where uncertainty comes from news about housing demand, and those where news about productivity changes is the major impulse. We run stochastic simulations to search for an optimal policy rule. Our result suggests that the gain from targeting asset prices, in addition to output and inflation, is minimal, if any. The conclusion is reminiscent of Bernanke and Gertler (2001) and similar works. Our contribution to this area of research is therefore to confirm that targeting asset prices is unimportant even when business cycles are mainly driven by optimistic and pessimistic expectations.

The rest of the paper is organized as follows. Section 2 lays out the micro-founded model framework and derives the equilibrium conditions. Section 3 explores whether or not news-driven cycles can arise in this model. Section 4 presents the policy analysis. Section 5 concludes.

2 A benchmark model

The model is based on Iacoviello (2005), Bernanke et. al. (1999) and Kiyotaki and Moore (1997). 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 asset as a 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 and differentiate it into consumption goods, and sell to the households. As in Bernanke et. al. (1999), the retailers are Calvo-type price setters that are the source of sticky prices. Collateralized borrowing, adopted from Iacoviello (2005), provides the critical channel via which changes in net worth affects the aggregate economy.

2.1 Patient household/lender

The lender maximizes a lifetime utility function given by:

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

subject to the constraint

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

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} is hours worked. $b_t = \frac{B_t}{P_t}$ represents real holdings of 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. P_t is the general price level at time t. 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, and 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.

Note that 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

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

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

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

2.2 Impatient household/borrower

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

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

subject to

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

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

A requirement of $\beta_2 < \beta_1$ 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 down payment rate, or think of m_2 as the loan-to-value ratio. As shown in Iacoviello (2005), this setup ensures that the borrowing constraint will always be binding in the steady state.

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 λ_t is the Lagrangian multiplier associated with the borrowing constraint.

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, and 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 are 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

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

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

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

The price index of final goods is

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

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

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

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 set price must satisfy:

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

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

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

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

Finally, 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 housing price. The specific rule will be spelled out later.

2.5 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.

Goods market clear when[4]

$$C_{1t} + C_{2t} = Y_t. \tag{17}$$

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

$$F_t = \frac{X_t - 1}{X_t} Y_t. \tag{18}$$

The loans market equilibrium is

$$b_{1t} + b_{2t} = 0. \tag{19}$$

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

$$h_{1t} + h_{2t} = H. \tag{20}$$

With a fixed total supply and no production required, the variable h is essentially the "land" variable of Kiyotaki and Moore (1997). It seems that a more realistic modelling of housing units should require the combination of land and a housing structure that is produced with labor and materials. Davis and Heathcote (2005), for example, take this latter approach to model housing in a real business cycle model. Is our approach too simplistic? The answer depends on how much generality is lost for our purpose. Between 1975 and 2006, the real price of residential land in the U.S. rose 270%, while the real price of housing structures only rose for about 33% (Davis and Heathcote, 2007). In other words, most of the housing price boom has been a "land price boom." Our model does capture this most important element of housing dynamics, and the abstraction from reality allows us to proceed with much less cumbersome mathematics.[5]

After obtaining the equilibrium, we linearize the model's critical equations around the steady state. We use lower-case letters to denote linearized variables.

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

[5] In reality there are unoccupied land that can be added to total land supply. But as research shows, the amount of unoccupied land near residential areas is limted. This plus land-use regulations have made land supply relatively inelastic (Mishkin, 2007).

2.6 Transmission mechanism

Collateralized borrowing has a significant impact on the monetary transmission mechanism. To see this, consider how the interest rate policy affects 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

$$\begin{aligned} \text{user cost} &= \frac{1}{1-\beta_1} q_t - \frac{\beta_1}{1-\beta_1} E_t q_{t+1} + \frac{\beta_1}{1-\beta_1} r_t \\ &= q_t - \frac{\beta_1}{1-\beta_1}(E_t q_{t+1} - q_t) + \frac{\beta_1}{1-\beta_1} r_t. \end{aligned} \tag{21}$$

Monetary policy (changes in nominal rates) affects user cost via two conventional channels: one, by raising or lowering the real interest rate r_t, defined as $i_t - E_t\pi_{t+1}$; and two, by causing fluctuations in current and future housing prices. In particular, expected monetary tightening lowers the expected housing appreciation (second term on the right-hand-side), and raises current cost of capital. Note that we assume there is no depreciation for housing assets.

For the borrowers, the collateral constraint adds another channel via which monetary policy can affect user cost. Linearize (8) and (9) to obtain

$$\text{u.cost} \approx \frac{1}{1-\gamma_e} q_t - \frac{\gamma_e}{1-\gamma_e} E_t q_{t+1} + \frac{\beta_1}{1-\gamma_e} r_t + \frac{(1-m_2)(\beta_1-\beta_2)}{1-\gamma_e} \lambda_t. \tag{22}$$

The two conventional channels are covered by the first three terms, which are similar to those in (21). The last term in (22) is the key. λ_t is the Lagrangian multiplier for the collateral borrowing constraint (30). It measures the shadow price of borrowing – the marginal benefits 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 (see8). When $\lambda_t = 0$, the collateral constraint is not binding, and the agent is not credit-constrained. The higher the value of λ_t, the tighter the collateral constraint. The tighter the collateral constraint, the more valuable an extra unit of housing asset is – since it can relax the constraint, and the more consumption goods agents are willing to give up to obtain it, and therefore the higher the user cost.

For credit-constrained borrowers, monetary policy affects user costs by tightening or relaxing the borrower's collateral constraint. For example, higher nominal rates lower the value of the collateral housing asset by discounting it more heavily and by lowering its expected future price. This tightens the borrowing constraint and raises user costs. In essence, tighter monetary policy reduces housing demand by worsening the balance sheet of the borrowers. This is the critical credit channel that is absent in a conventional model with unrestricted borrowing.

The credit channel generates interesting dynamics in the housing market. When the nominal rate goes down (so does the real rate), for instance, the user cost of capital decreases for both the lender and the borrower. However, the borrower's user cost decreases more than the lender's due to the extra credit channel. Given a fixed housing supply, the borrower's holding of housing assets will go up while the lender's will go down.

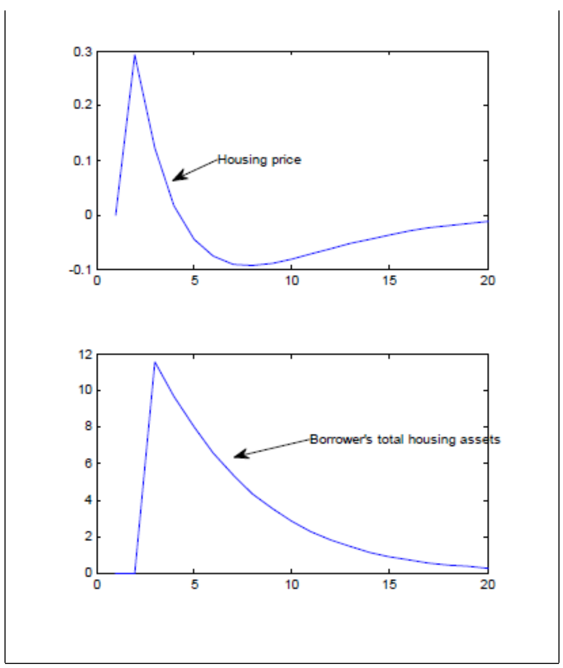

Figure 2: Response of housing price and borrower's housing assets to an expansionary policy shock

In figure 2, we plot the impulse responses of housing price and borrower's housing to an unexpected expansionary interest rate shock. We assume the central bank's policy is simply

$$\begin{aligned} i_t &= \tau_\pi \pi_t + e_t^R, \\ e_t^R &= \rho^R e_{t-1}^R + \upsilon_t, \end{aligned}$$

where $0 < \rho^R < 1$ and υ_t is a shock with mean 0 and standard deviation σ_υ. We let $\tau_\pi = 1.2$ ($\tau_\pi > 1$ is required to obtain a unique rational expectations solution) and $\rho^R = 0.75$. We assume the policy shock is 1% in size. On impact, housing price increases by 0.3%, and borrower's housing assets increase for as much as 12%. Since there is a fixed housing supply, the lender's holdings of housing assets must have gone down.

The credit channel also enhances the impact of the interest rate policy on aggregate economic activities – a point well made by Kiyotaki and Moore (1997) and Iacoviello (2005). High housing values increase the net worth of the borrowers, and allow them to borrow more and spend more; more aggregate demand increases total output and spending, and further increases housing prices and the net worth. This financial accelerator effect is absent when there is no collateralized borrowing. In figure 3, we plot the response of output to an expansionary interest rate shock with and without the collateral constraint. The diagram depicts the strength of the credit channel that we just describe.[6]

3 News driven business cycles

3.1 The basic mechanism

Next we investigate *qualitatively* whether or not economic news can generate boom-bust housing and business cycles.

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 and 2007),

[6]The plot with no credit channel is obtained by simulating a version of the model where there is no collateral constraint, and the two agents are equally patient.

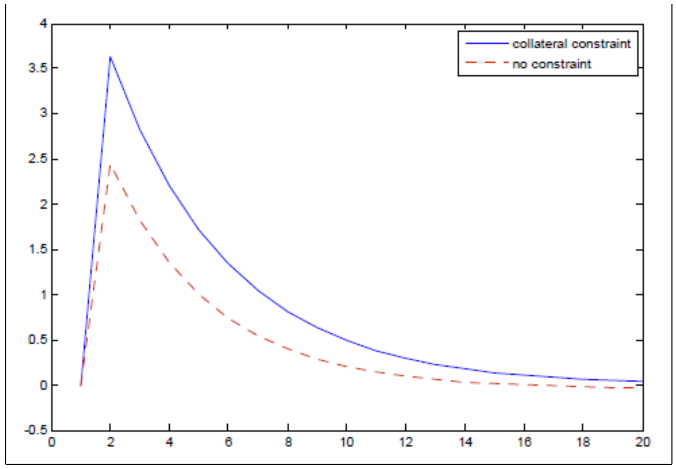

Figure 3: Response of output to an exansionary monetary shock with and without borrowing constraints

for example, it is news about productivity that drives a "Pigou" cycle. While this type of news is very 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. We are trying to understand a housing boom-bust cycle driven by expectations. As Case and Shiller (2003)'s survey reveals, a big motive behind buyers' housing "rush" was the perception of rapid and steady future price increases, which led to but were also confirmed (self-fulfilled) by steady increase in demand. Buyers' actual income or perceived income did not necessarily rise. When productivity news is the main source of cycles, it is the optimism about future income and permanent wealth that raises aggregate demand. That mechanism does not seem to match our situation here.[7] So we consider a different type of news – news about future housing preferences. To be precise, it is news about the variable d_t in the utility function, a rise of which would increase the marginal rate of substitution of housing services against consumption and leisure. An advantage of this approach is that d_t is by definition a demand-side shock; a rise in it would indicate stronger preferences by agents to own housing assets. Moreover, higher demand naturally leads to higher housing prices. Optimistic news about future housing demand can be thought of as optimistic news about higher prices. In fact, if we linearize the housing

[7] Higher future housing prices certainly increase buyers' expected future wealth, but this increase is not related to productivity growth.

price equation (3), we obtain

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

When d_t rises, the housing price variable q_t will shift upward. In other words, d_t is essentially a shock to housing prices. Positive news about future d_t *is* positive news about future housing prices.

We define a realistic news-driven boom-bust cycle as one that meets two conditions: (1) positive news first leads to a boom defined as an increase in housing prices, aggregate output, employment, and consumption, and (2) the realization that news is too optimistic leads to a recession defined as a fall in the same set of variables. The comovement of housing prices and aggregate variables is key to a news-driven cycle.

A major difficulty with the news-driven cycle literature is that in a typical general equilibrium model, it is very hard to generate comovement among aggregate variables. For instance, in a real business cycle model, 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. In order for plausible comovement to arise, researchers often need to consider more refined and sophisticated economic environment. Beaudry and Portier (2004) generate positive comovement with a multi-sector economy in which investment decisions and consumption decisions are decoupled so that the substitution between the two due to the wealth effect can be minimized. In Jaimovich and Rebelo (forthcoming), adjustment cost, capacity utilization, and preferences that incorporate a weak wealth effect on labor supply are used to generate positive comovement. 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 comovement among economic aggregates.

In this paper, we rely on two features of the model to generate comovement. One is the nature of the shock. Unlike an expected productivity shock, an expected demand shock does not have a wealth effect on all agents and all sectors of the economy. The other is the credit channel. When housing price rises, improved net worth should stimulate aggregate demand and generate positive comovement among aggregate variables. We demonstrate this point next.

But before we proceed, we need to calibrate the model's parameters. The discount factor is set at 0.99 for the lender and 0.98 for the more impatient borrower. The elasticity of substitution across intermediate goods, ε, is set a 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 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 value of 0.1.

For a benchmark experiment, we assume the central bank implements a simple inflation targeting rule

$$i_t = 1.2\pi_t.$$

The dynamics we derive with more complicated policy rules are similar to the ones we show here.

Finally, we assume the fundamental shock d_t follows an AR(1) process

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

where e_t^d is a random shock with mean 0 and variances σ_d^2. For our benchmark simulation, we assume $\rho^d = 0.95$.

There is a news shock ξ_t that arrives several periods before the true shock e_t^d is revealed. The timing of the news shock is as follows. At time zero the economy is in the steady state. At time one, unanticipated news arrives. For example, agents might learn that there will be a one-percent increase in e_t^d after p periods. In period $p + 1$, the actual shock to e_t^d is revealed. If the news is accurate, e_t^d will be exactly equal to the value suggested by the news in period one. But if the news is inaccurate, e_t^d can be any value that differs from the news. In our experiment, we let e_t^d to be zero in the inaccurate news scenario, so that without the incorrect news, the economy would have stayed in the original steady state. Also, 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 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. The techniques that we use in this section and next are closely related to the papers that we reference, such as those of Christiano, et. al. (2008).

In figure 4, we plot the impulse response of output/consumption and housing price to news about a 1% future increase in e_t^d. The news is accurate. In figure 9 in the appendix, we show the impulse response functions of more variables such as inflation, total borrowing, total borrower housing, and total labor hours. Although the actual preference shock takes place in period seven, agents learn about it in period one. Agents react to this news by re-optimizing their objectives. Consequently, we see in figure 4 consumption and output increase, and so do housing prices. From figure 9 in the appendix, we can see that the borrower has increased her housing asset and collateralized borrowing, which via the credit channel has contributed to the increased aggregate demand. In period seven, when the actual preference shock is realized, the economy 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 therefore does not alter the agents' newly optimized plan (in period one) for consumption, housing, and output.

How does a news shock generate comovement among housing prices, consumption, labor hours and output? A closer look at figure 9 reveals what happens when the positive news arrives. Both the borrower and the lender now have a stronger urge to hold and consume housing assets, but they cannot both hold more because the supply of housing assets is fixed. Since more housing assets provide the borrower with extra benefits – a relaxed borrowing constraint and the ability to borrow and spend more, the borrower is more willing to pay for the increased housing price. So the borrower's housing assets increase, and the lender's decrease. Higher housing price and more housing assets allow the borrower to borrow more, consume more, and work less. The lender, on

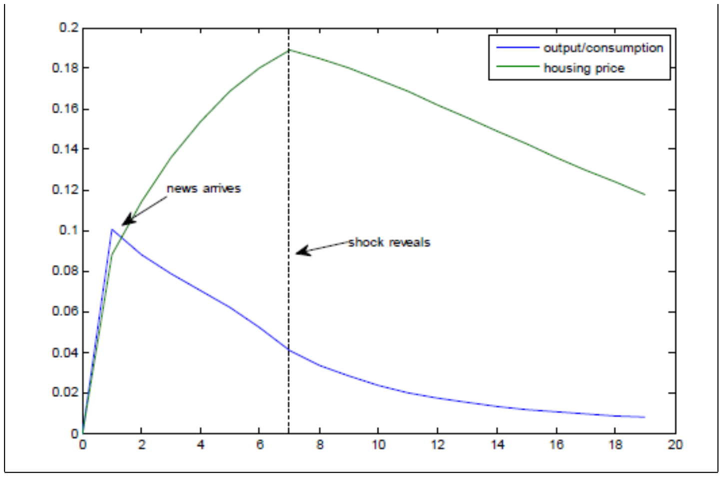

Figure 4: Impulse response of output and housing price to correct news about housing demand

the other hand, must consume less to lend more to the borrower. This extra saving is justified by the rising nominal and real interest rate. Finally, the lender must work more to compensate for her loss of consumption and housing assets. The increase in the lender's labor hours more than offsets the decrease in the borrower's. Hence total hours and total production rise.

Next we consider the scenario where the news shock is exactly incorrect. In period one, agents learn about a 1% increase in the preference shock e_t^d. But in period seven, they observe that there is no preference shock at all. We plot the impulse responses in figure 5 and 10 in the appendix. Upon receiving the news and believing it is accurate, agents' reactions are identical to those in figure 2. In period seven, however, the actual shock is realized and the agents learn that the new has been incorrect. They immediately re-optimize 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 one and seven, almost all variables have experienced a cycle that is shaped like an inverted "U." Moreover, output/consumption went below its steady state value for a considerable amount of time, creating an prolonged recession.

The type of dynamics in figure 5 is what we would like to characterize as a news-driven boom-bust cycle. What is particularly interesting is that throughout the whole episode, there has been no change in fundamental shocks at all. The only change has been some incorrect news that altered agents' expectations between period one and seven. As in Beaudry and Portier (2004), we can define

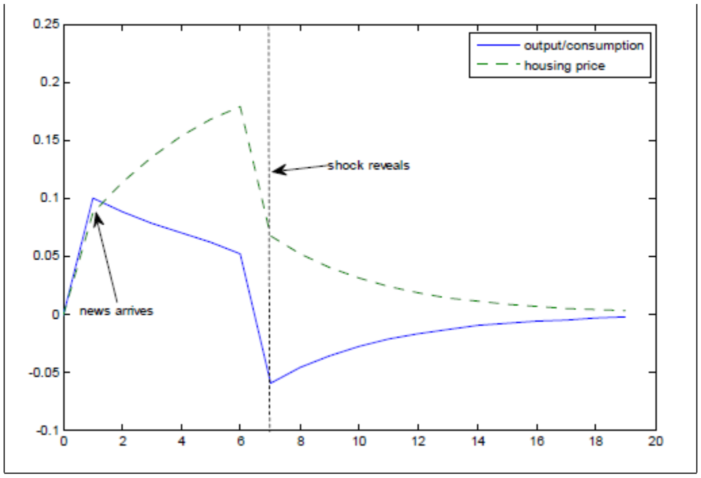

Figure 5: Impulse response of output and housing price to incorrect news about housing demand

"optimism" as the case where agents' expectations are better than reality. Then what figure 5 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 in figure 5 a "bubble."

3.2 Extensions

A noticeable feature of figure 4 and 5 is that given a 1% news shock, the responses in output and housing prices are small in sizes. Housing prices, for example, only increase for about 0.2% at the peak of the response function. This implies that large demand shocks or news about demand shocks are required to generate any significant fluctuations in the housing market and in the aggregate economy. We believe the simplicity of our model is largely responsible for this result. In a model with richer dynamics and a stronger credit channel, the response of aggregate variables to news shocks should be stronger. We proceed to extend our model next. We note that another important reason for considering these extensions is that when we search for an optimal monetary policy (next section), the *quantitative* results do matter. We need a more realistic model.

We add two new features to the benchmark model. The first feature is that the housing asset or land becomes a factor of production, so that the intermediate goods producer must also engage in trading in the housing market; the second feature is that the intermediate goods producer is

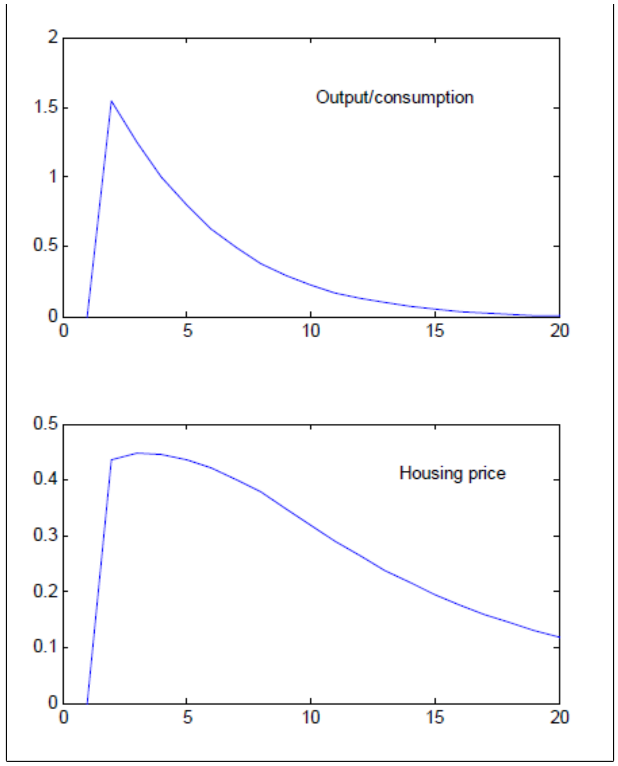

Figure 6: Response to a news shock in the extended model

now credit-constrained, and must borrow collateralized loans. We call this version of the model the "extended model." We list the details of the extension in the appendix.

In figure 6, we plot the impulse response of output/consumption and housing price to a 1% (accurate) news shock in the extended model. As we can see, the response of output/consumption is about 1.5%, while the response of housing price is about 0.45%. Both responses are much stronger than in the benchmark model. In figure 11 in the appendix, we plot the impulse responses of a more complete set of variables for this simulation. Overall, the responses of all variables have increased in magnitude, indicating that the dynamics of the model have been enhanced with the extension.

The model has hitherto been free of any physical capital, which is obviously empirically implausible. An important feature of news-driven cycles is the positive response of investment to optimistic news. In our last version of the model, we build on the extended model and add physical capital. More specifically, we let the intermediate goods producer to be able to make investment decisions and accumulate physical capital, which is now an input for production. We also add adjustment

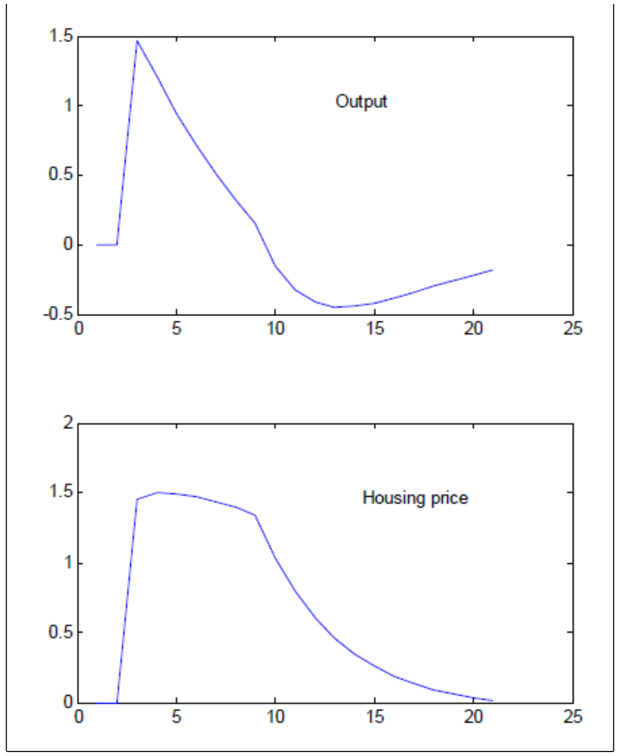

Figure 7: Response to a news shock in the full model

cost to capital and to housing assets. We call this version the "full model."[8] In the appendix, we write down full details of these models and list all the calibrated parameters.

In figure 7, we plot the impulse response of output and housing price to a 1% (accurate) news shock in the full model. This time not only the response of output remains strong, the response of housing price also catches up. On impact the responses of both are about 1.5%. In figure 12 in the appendix, we plot the impulse responses of a more complete set of variables for this simulation. As we expected, on impact of the positive news, there is comovement between investment and housing prices, along with consumption, labor hours, and output.

[8] The full model becomes identical to the quantitative model developed and estimated by Iacoviello (2005).

4 News shock and monetary policy

4.1 Alternative policy rules and the real impact of news

How should the central bank respond to a news-driven housing cycle? Are "keeping the interest rate too low" responsible for the size of the housing "bubble"? In previous simulations, we have assumed a very simple inflation-targeting monetary regime. In this section, we examine what impact the central bank's policy rule has on the size of the housing boom and bust cycles. We are interested in Taylor-type policy rules that target inflation, output and possibly housing prices:

$$i_t = \tau_\pi E_t \pi_t + \tau_y y_t + \tau_q q_t. \tag{23}$$

As a first experiment, we simply consider four alternative policy rules and examine the model's impulse responses to a news shock under each rule. The four rules are:

$$\text{rule one} \quad : \quad i_t = 1.2\pi_t, \tag{24}$$

$$\text{rule two} \quad : \quad i_t = 2.2\pi_t, \tag{25}$$

$$\text{rule three} \quad : \quad i_t = 2.2\pi_t + 0.5y_t, \tag{26}$$

$$\text{rule four} \quad : \quad i_t = 2.2\pi_t + 0.5y_t + 0.5q_t. \tag{27}$$

(24) is the benchmark policy rule that we use for the previous section. Since the reaction parameter to inflation must be bigger than 1 for the model to have a unique equilibrium, we use this rule to represent a regime that responds to inflation relatively weakly.[9] We use (25) to represent a rule that responds to inflation strongly. (3) is a conventional Taylor rule that not only targets inflation, but also targets output gaps. Finally, (27) is a Taylor rule that, in addition to inflation and output targeting, also targets housing prices.

We plot the impulse responses of output and housing prices in the full model in figure 8. Three

[9] With this rule, the nominal rate responds more than one-for-one to inflation, and therefore satisfies the "Taylor principle" and qualifies as an "active policy." In this sense our reference to it as a "weaker" policy is only true when our basis of comparison is a stronger rule like 25.

features are worth noting. One, when pure inflation-targeting is the policy rule, the policy reaction parameter does not seem to make too big a difference as far as the responses of output and housing prices are concerned. Under the first rule (weak targeting) and the second rule (strong targeting), the responses of output and housing prices are both strong, and the sizes do not vary much when the policy rule changes. Two, the Taylor rule is a much better stabilization tool than the pure inflation-targeting rule. With rule three, the responses of both output and housing prices are dampened compared with the previous two rules. In particular, output's response decreases for as much as 50% on impact of the initial shock. Three, when asset price is added as a policy target, both the responses of output and housing prices are substantially dampened. But the response seems to over-react and forces output to go below trend for a prolonged period of time. If measured in volatility, it is unclear whether or not this rule is more stabilizing or not.

Figure 8 makes it clear that monetary policies indeed matter for the impact of the housing boom. Comparing the output responses under rule one and rule three, for example, reveals that if the monetary authority keeps the interest rate relatively low (rule one), the housing market boom would cause a much larger output boom than with higher interest rate (rule three).

4.2 Should the central bank respond to housing prices?

A natural question to ask is whether or not central banks can better stabilize the economy by specifically targeting housing prices, in addition to output gaps and inflation. Such conclusions cannot be drawn by examining impulse response diagrams. We turn to stochastic simulations for some quantitative answers.

We assume that the central bank's loss function comprises the volatility of two variables – output gaps and inflation.[10] The central bank's goal is to pick policy parameters τ_π, τ_y and τ_q to minimize an weighted average of the unconditional standard deviation of the two variables. In our experiments, we allow τ_π to vary between 1.01 and 3 (again, $\tau_\pi > 1$ ensures a determinate, unique equilibrium), τ_y to vary between 0 and 2, and τ_q to vary between 0 and 1. These restrictions are put in place to ensure

[10] To be more precise, y_t and π_t measure the percentage deviations of the two variables from their long-run steady state values.

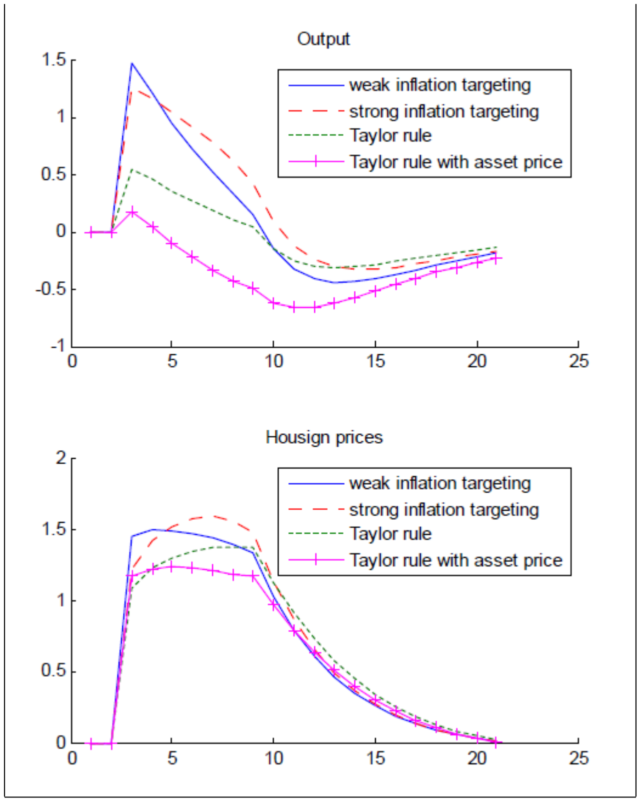

Figure 8: Impact of alternative policy rules on the response to news shock

that the policy parameters are within a (generous) range consistent with empirical estimates. 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.

For each variation of the policy rule, we consider three different calibrations of the news shock. In the first calibration, the news shock is always an accurate prediction of the fundamental shock. In the second calibration, the news shock is positively correlated with the fundamental shock. The news is wrong sometimes, but on average it does help agents make a better forecast. In the third calibration, the news is completely noisy – it is uncorrelated with the fundamental shock and provides no useful information for forecasting. We expect no surprise from the first case. Since the news is always correct, it is essentially a situation where all shocks are anticipated. The policy prescription should not be very different from the case where shocks are observed when they are realized. What might become interesting are the latter two cases where the level of noises in the news increases.

We run our policy experiments for the benchmark model and report the results in table 1. We

Signal quality	**Optimal policy parameters** $(\tau_\pi, \tau_y, \tau_q)$		
	$\min(0.25\sigma_\pi + 0.75\sigma_y)$	$\min(\sigma_\pi + \sigma_y)$	$\min(0.75\sigma_\pi + 0.25\sigma_y)$
Accurate news	$3.05; 2; 0.1$	$3.05; 0.9; 0$	$3.05; 0.5; 0$
$Corr$(news,fund.shock) $= 0.5$	$3.05; 2; 0.05$	$3.05; 1.1; 0$	$3.05; 0.8; 0$
Noisy news	$3.05; 2; 0.15$	$3.05; 0.8; 0$	$3.05; 0.5; 0$

Table 1: Optimal policy parameters:benchmark model

consider three possible weight allocations for the central bank's loss function. We use $0.25\sigma_\pi + 0.75\sigma_y$ to represent a loss function that emphasizes output stabilization, $0.75\sigma_\pi + 0.25\sigma_y$ to represent one that emphasizes inflation stabilization, and a third one that puts equal weights on output and inflation.

The results suggest that the interest rate policy should strongly target inflation, especially when there is more weight on inflation volatility in the loss function; 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. In fact a small response to housing prices is found beneficial only in one case, where the central bank puts a heavy weight on output stabilization and a small weight on price stability.

What is striking is that the optimal policy reaction function seems to be unaffected by the quality of news. For example, the suggested optimal policy reaction is strong for inflation, and is weak for housing prices across all three weight allocations and all three calibrations for news shocks. Most of the experiments suggest zero or near-zero policy reaction for housing prices, with the exception of one case (column 1 of table 1), where the largest policy response parameter for housing prices is 0.15, representing a 1.5 percent increase in the nominal interest rate when housing prices rise by 10%.

Tables 2 shows our simulation results for the extended model. The results suggest an optimal policy that is very similar to that in Table 1. The optimal response to inflation remains strong in nearly all cases, and the optimal response to housing prices continue to be weak. In fact this time the highest policy reaction parameter for housing prices is only 0.05, as opposed to 0.15 in the benchmark model. A major difference between the benchmark model and the extended model is that the latter has a stronger credit channel, which is probably why the optimal response to output

Signal quality	Optimal policy parameters $(\tau_\pi, \tau_y, \tau_q)$		
	$\min(0.25\sigma_\pi + 0.75\sigma_y)$	$\min(\sigma_\pi + \sigma_y)$	$\min(0.75\sigma_\pi + 0.25\sigma_y)$
Accurate news	$1.05; 2; 0.05$	$2.65; 2; 0.05$	$3.05; 0.3; 0$
$Corr$(news,fund.shock) $= 0.5$	$1.05; 2; 0.05$	$2.25; 2; 0.05$	$3.05; 0.9; 0$
Noisy news	$1.05; 2; 0.05$	$2.75; 2; 0.05$	$3.05; 0.8; 0$

Table 2: Optimal policy parameters:extended model

	Optimal policy parameters $(\tau_\pi, \tau_y, \tau_q)$		
Signal quality	$\min(0.25\sigma_\pi + 0.75\sigma_y)$	$\min(\sigma_\pi + \sigma_y)$	$\min(0.75\sigma_\pi + 0.25\sigma_y)$
Accurate news	$1.05; 2; 0.05$	$1.05; 2; 0.05$	$3.05; 1; 0$
$Corr$(news,fund.shock) $= 0.5$	$1.05; 2; 0.05$	$1.05; 2; 0.05$	$3.05; 1.5; 0$
Noisy news	$1.05; 2; 0.05$	$1.05; 2; 0.05$	$3.05; 0.6; 0$

Table 3: Optimal policy parameters:full model

is now higher across all cases.

We report the results for the full models in tables 3. The full model is the most empirically plausible version that not only has a strong credit channel as in the extended model, but also accounts for investment dynamics in the real economy. It turns out that the calculated optimal policy parameters bear very similar characteristics with those suggested by the benchmark and extended models: strong response to inflation, positive response to output in most cases, and very weak response to housing prices. The results suggest that the interest rate policy should strongly target output when stabilizing output gaps has high weights in the central bank's loss function.

Another experiment we run but do not report here is the case where the target π_t is replaced with $E_t\pi_{t+1}$ in the policy rule. This turns the policy into a "forward-looking" rule. All the simulation results under that rule are very similar to those in table 1-3.

The conclusion that responding to asset prices is unimportant is reminiscent of the findings of Bernanke and Gertler (2001) (for general asset prices) and Iacoviello (2005). The purpose of our experiment is to investigate whether or not the existing conclusions need to be modified when business cycles are driven by news. Our result suggests that these conclusions continue to prevail.

5 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. This kind of fluctuations have the feature of "bubbles." We find that if the central bank's response to the housing cycles is weak, the impact of the cycle on the real economy is large. We ask the question "how should central bank respond to news-driven cycles?" To answer the question, we ran stochastic simulations of the model economy, and look for the optimal interest rate policy that minimizes the central bank's loss functions. Our results suggest that the central bank should target inflation and output gaps, and need not target housing prices.

References

[1] Batini, N. and E. Nelson 2000, When the Bubble Bursts: Monetary Policy Rules and Foreign Exchange Market Behavior, working paper, Bank of England.

[2] Beaudry P. and F. Portier 2004, An Exploration into Pigou's Theory of Cycles, Journal of Monetary Economics 51, 1183 - 1216.

[3] Beaudry, P. and F. Portier 2007, When can changes in expectations cause business cycle fluctuations in neoclassical settings?, Journal of Economic Theory, 135 (1), 458-477.

[4] Bernanke, B. and M. Gertler 1989, Agency Costs, Net Worth, and Business Fluctuations, American Economic Review 79 (1), 14 - 31.

[5] Bernanke, B. and M. Gertler 2001, Should Central Banks Respond to Movements in Asset Prices? American Economic Review 91 (2), 253 - 257.

[6] Bernanke, B., M. Gertler and S. Gilchrist 1999, The Financial Accelerator in a Quantitative Business Cycle Framework, in J. Taylor and M. Woodford, eds., Handbook of Macroeconomics, Vol. 1C. Amsterdam: Elsevier Science, North-Holland, 1341 - 1393.

[7] Calza, A., T. Monacelli, and L. Stracca 2007, Mortgage Markets,Collateral Constraints, and Monetary Policy: Do Institutional Factors Matter?" CEPR Discussion Paper No. 6231 (London: Centre for Economic Policy Research).

[8] Carlstrom, C. and T. Fuerst 1997, Agency Costs, Net Worth, and Business Fluctuations: A Computational General Equilibrium Analysis, American Economic Review 87 (5), 893 - 910.

[9] Case K. and R. Shiller 2003, Is There a Bubble in the Housing Market? Brooking Papers on Economic Activity 2, 299 - 362.

[10] Cecchetti, S., H. Genberg, J. Lipsky, and S. Wadhwani 2000, Asset Prices and Central Bank Policy, Geneva Report on the World Economy 2, CEPR and ICMB.

[11] Christiano, L., C. Ilut, R. Motto, and M. Rostagno 2008, Monetary Policy and Stock Market Boom-bust cycles, ECB working paper No. 955.

[12] Cochrane, J. 1994, "Shocks," Carnegie-Rochester Conference Series on Public Policy 41, 295-364.

[13] Davis, M. and J. Heathcote 2005, "Housing And The Business Cycle," International Economic Review 46(3), 751-784.

[14] Davis, M. and J. Heathcote 2007, "The price and quantity of residential land in the United States," Journal of Monetary Economics 54(8), 2595-2620.

[15] Jaimovich N. and S. Rebelo, forthcoming, Can News about the Future Drive the Business Cycle? American Economic Review.

[16] Kiyotaki, N. and J. Moore 1997, Credit Cycles, Journal of Political Economy 105 (2), 211 - 248.

[17] Mishkin, F. 2007, Housing and Monetary Transmission Mechanism, NBER working paper, NO. 13518.

[18] Monacelli, T. 2009, New Keynesian models, durable goods, and collateral constraint, Journal of Monetary Economics 56 (2), 242 - 254.

[19] Pariès, M. and A. Notarpietro 2008, Monetary policy and housing prices in an estimated DSGE model for the US and the euro area, Working Paper Series 972, European Central Bank.

[20] Shiller, R. 2007, Understanding Recent Trends in House Prices and Home Ownership, Cowles Foundation Discussion Paper No. 1630.

[21] Williamson, S. 1987, Financial Intermediation, Business Failures, and Real Business Cycles, Journal of Political Economy 95 (6), 1196 - 1216.

6 Appendix

6.1 Extended Model

The saver maximizes a lifetime utility function given by:

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

subject to the constraint

$$C_{1t} + q_t h_{1t} + \frac{R_{t-1} b_{1t-1}}{\pi_t} = b_{1t} + q_t h_{1t-1} + w_{1t} L_{1t} + F_t, \tag{28}$$

where the subscript “1” is used to tag all variables of the patient household. The subscript “2” and “3” will shortly be used to denote variables of the impatient household and the producer.

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 two, her borrowing capacity is constrained by the discounted future value of the collateral - her housing assets. The problem thus is

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

subject to

$$C_{2t} + q_t h_{2t} + \frac{R_{t-1} b_{2t-1}}{\pi_t} = b_{2t} + q_t h_{2t-1} + w_t L_{2t}, \tag{29}$$

$$b_{2t} \leq m_2 E_t (\frac{q_{t+1} h_{2t} \pi_{t+1}}{R_t}). \tag{30}$$

The producer is the owner of an intermediate goods firm that uses real estate and labor as inputs to produce a homogeneous good Y_t:

$$Y_t = A_t h_{3t-1}^{v} L_{1t}^{\alpha(1-v)} L_{2t}^{(1-\alpha)(1-v)}. \tag{31}$$

After the intermediate goods are produced, retailers purchase them at the wholesale price P_t^w, and 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 utility

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

subject to the budget constraint

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

and a borrowing constraint similar to (30):

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

γ is the entrepreneurs' 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 retailer's problem is the same as in the benchmark model.

6.2 Full model

The full model has the same basic structure as the extended model, except that it has physical capital investment, and adjustment costs for asset accumulation. After adding these features, the model is identical to Iacoviello (2005)'s model.

The production function of intermediate firms becomes

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

There are adjustment costs for both physical capital and housing:

$$\begin{aligned} \xi_{Kt} &= \psi(\frac{I_t}{K_t} - \delta)^2 K_{t-1}/(2\sigma), \\ \xi_{ht} &= \phi(\frac{h_t - h_{t-1}}{h_{t-1}})^2 q_t h_{t-1}/2, \end{aligned}$$

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

The producer's budget constraint becomes

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

The impatient household's budget constraint becomes

$$C_{2t} + q_t h_{2t} + \frac{R_{t-1} b_{2t-1}}{\pi_t} = b_{2t} + q_t h_{2t-1} + w_t L_{2t} - \xi_{ht}.$$

Specifications for all other sectors are the same as the extended model above.

Table 4 shows parameter values that we use for simulations for the full model (Iacoviello, 2005).

All the values were estimated by Iacoviello (2005) using U.S. data.

parameter	value	Description
β_1	0.99	Patient household discount factor
β_2	0.95	Impatient household discount factor
γ	0.98	Entrepreneurs discount factor
d	0.1	Preference weight on housing
$\eta_{1,2}$	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
ϕ	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
$m3$	0.89	Entrepreneur Loan-to-value ratio
$m2$	0.55	Entrepreneur Loan-to-value ratio
r_d	0.85	Persistence of housing preference shock
r_a	0.03	Persistence of technology shock

Table 4: Calibration for the extended and the full model

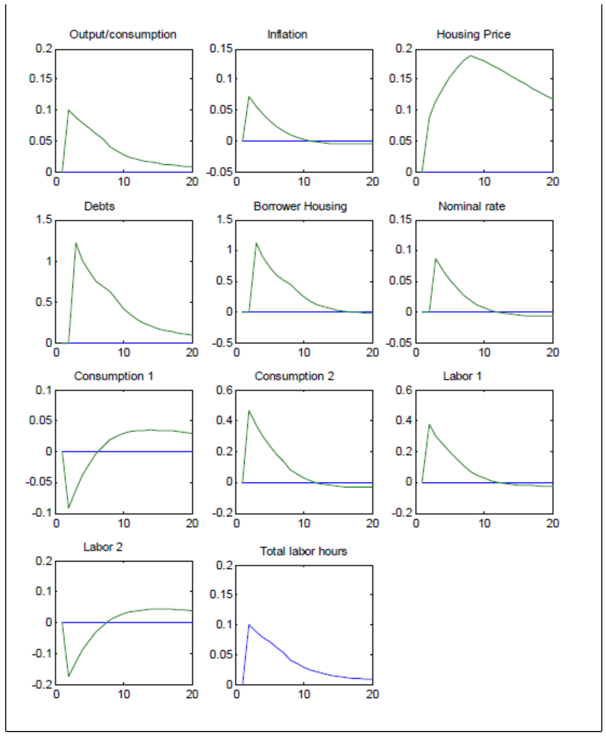

Figure 9: Impulse response to correct news about housing demand

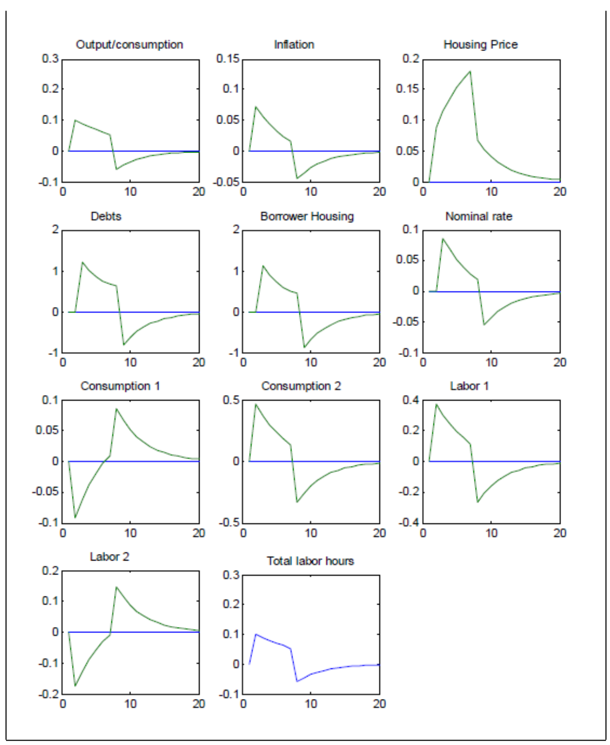

Figure 10: Impulse responses to incorrect news about housing demand

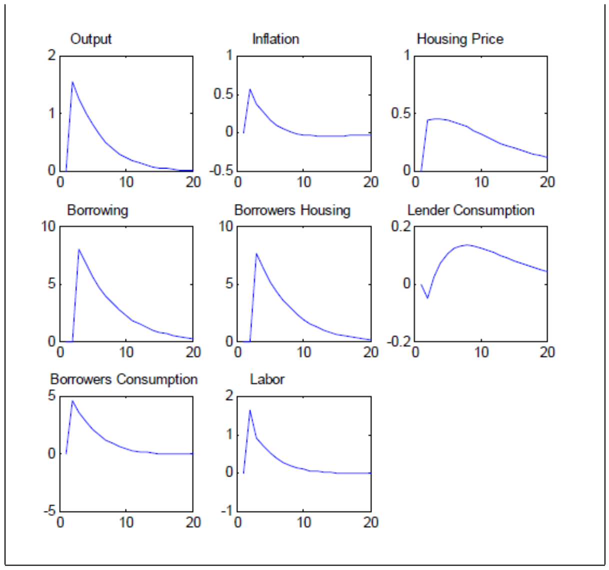

Figure 11: Larger responses to news shocks in the extended model

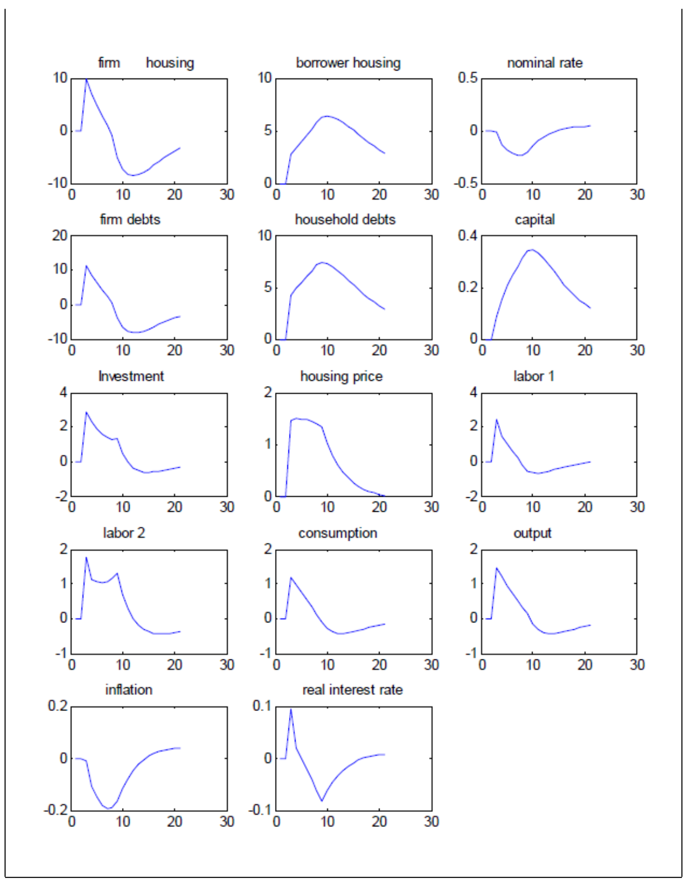

Figure 12: Response to a news shock in the full model