The Effects of the Monetary Policy on the U.S. Housing Bubble from 2001-2006

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Abstract:

This paper presents a dynamic stochastic general equilibrium model to test the relative significance of monetary policy and financial market innovations in creating the U.S. housing bubble between 2001 and 2006. The model generates a trajectory of house price that mimics the Case–Shiller index fairly well when actual Federal Fund rates are taken as inputs. It fails to do so when the monetary policy follows the Taylor rule (Taylor 1993) even if mortgage-backed securities (MBS) are introduced. Aided by the structural model, we identify several transmission mechanisms of monetary policy with an emphasis on the financial accelerator (BGG 1999) and explain why monetary policy played a more important role in the making of the bubble. Furthermore, the model predicts that the lending standards of banks will go down with the benchmark interest rate. Equivalently, financial institutions respond rationally to a policy rate cut by taking more risks. Consistent with these results, our data and event analyses show that most market anomalies occurred when the Federal Fund rate deviated substantially from the Taylor rule.

Key Words:

Monetary Policy; Housing Bubble; Financial Innovation; Mortgage Backed Securities

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I. INTRODUCTION

What caused the financial crisis of 2008? There are two schools of thought. One, represented by the erstwhile Chairman of the Board of Governors of the Federal Reserve System, Ben Bernanke, blames financial deregulation and the consequent excessive risk taking in the form of financial innovations (Bernanke 2010). The other, advanced by John Taylor (Taylor 2008, 2012) and others, holds monetary policy as the primary contributing factor for the unprecedented U.S. housing boom that eventually led to the crisis. Bernanke defends the Fed's policy prior to the crisis as nothing unusual, whereas Taylor notes considerable deviations from the dictates of the Taylor rule (Taylor 1993) between 2001 and 2005.

Dokko et al. (2009) provide the most comprehensive defense of the Fed's monetary policy to date. The authors run simulations of the Federal Reserve Board/U.S. (FRB/U.S.) model with actual federal fund rates as the inputs. They compare the simulation results with those when the interest rates are set according to the Taylor rule. The level of housing market activities (measured by residential investment/GDP) under actual policy rates is only slightly higher than that under the Taylor rule (see Edge et al. (2009) for the FBR/EDO model and similar conclusions). Consistent with their model simulations, the vector autoregression (VAR) analysis of Dokko et al. (2009) yields an insignificant correlation between monetary policy and housing price. Based on these findings, the authors suggest that the quick rise in house prices for the period 2002 to 2006 cannot be attributed primarily to the macroeconomic environment. The major causes of the housing bubble should be found elsewhere, for example, in unconventional financial products and financial deregulation (also see Bernanke 2010).

This paper investigates the relative importance of the two sets of factors, that is, monetary policy and financial market conditions, in fostering asset bubbles. Since the VAR analysis is unable to reveal the transmission mechanisms of monetary policy and is sensitive to sample selection (Del Negro and Otrok 2007; Jarocinski and Smets 2008), we employ structural models with financial accelerators introduced by Bernanke, Gertler, and Gilchrist (1999; henceforth, BGG) for this task. As argued by BGG (1999), net worth of borrowers plays a crucial role in an imperfect credit market. In such a market, external shocks are amplified via the net worth effect, and they cause considerably large fluctuations in macroeconomic aggregates such as the output and price level. We conjecture that the financial accelerator could strengthen the impacts of monetary shocks and help generate asset bubbles significantly larger than the predictions of the FRB/US model.

Following BGG (1999), we develop a New Keynesian general equilibrium model in this paper with frictions in the financial market and imperfect competition in the goods market. Our model simulations show that persistently low interest rates *alone* can produce housing bubbles of the scale comparable to that in the U.S. prior to the 2008 crisis.

Our model includes six types of agents, all of which, except entrepreneurs, are representative. The household buys consumer goods and housing service to maximize utility. The entrepreneurs make investments to acquire houses, some of which are let for rental income, and some are sold for capital gain. Investments of entrepreneurs are financed partly by their own net worth and partly by bank credit. As a financial intermediary, the bank draws the household's savings deposits and pays the household a risk-free interest rate (the benchmark or policy rate) set by the central bank. The bank then makes a mortgage loan to every entrepreneur according to a contract negotiated in each period. The contract specifies the loan quantity and interest rate, which are determined by the entrepreneur's net worth, among other things. The firm purchases labor service from the household and entrepreneurs, and rents houses from entrepreneurs to produce intermediary goods. The retailer packages intermediary goods into final consumer goods. The developer hires labor to build houses. Both the retailer and the developer have no essential decisions to make, and they perform certain functions merely for the technical convenience of our model building.

When the central bank cuts the benchmark interest rate, it affects the housing price through several channels in our model. As savings with lower interest rate on deposits become less attractive, the household spends more on housing service and consumer goods. The house price goes up immediately, and the increased demand for consumer goods will drive it up further. In response to the rise in demand for consumer goods, the firm will increase production by employing more labor. To attract labor, the firm has to raise the real wage rate, which will, in turn, lead to even greater demand for houses. Besides this traditional transmission mechanism of monetary policy, asset price is further reinforced by credit expansion of the bank. Entrepreneurs respond to lower interest rates of mortgages by leveraging up (Proposition 1 in Section II). More importantly, with the windfall in net worth due to the appreciation of house value, entrepreneurs have more to put up as collateral, and hence, they are able to borrow a greater amount. Meanwhile, as the expected default rate falls with improved investment returns in a bull market, the bank will offer more favorable terms, such as lower interest rates and less collateral, or equivalently, higher loan-to-value ratio (LTV). Monetary shocks are thus enlarged by the positive feedback between housing price and bank credit via the financial accelerator. As a result, a housing bubble emerges in our model, while it does not occur in the FRB/US model without the financial accelerator.

We calibrate our model with the U.S. data and feed actual Federal Fund rates into the model for simulations. The model generates a housing price trajectory that mimics the movement of the Case–Shiller index fairly well. In contrast, when the monetary policy follows the Taylor rule, no dramatic asset price inflation can be observed.

We also conduct experiments to gauge the significance of financial innovations, as compared to monetary policy, in creating housing bubbles. Massive use of mortgage-backed securities (henceforth, MBS) turn illiquid mortgages into liquid assets and allow banks to issue more loans (Salmon 2010; U.S. Financial Crisis Inquiry Report 2011). The improvement in banks' liquidity is captured in our model by an increase in supply of loanable funds for the bank or a positive shock to the loan-to-deposit ratio (henceforth, LTD ratio). To measure the liquidity shocks, we divide the actual value of MBS issuance by U.S. household savings for the period 1997 to 2008. The extra liquidity provided by MBS was around 4% of household savings before 2001. It rose sharply in 2001q3 and continued the upward trend through 2003q3 to reach a peak of 14% (see figure 6 in Section III). These numbers suggest that the U.S. housing bubble cannot be fully explained without considering the role of MBS. We model the liquidity effect of MBS to enlarge the household saving pool accordingly, for example, by 4%, for the years prior to 2001.

Model simulations under the MBS-induced liquidity shocks yield a housing bubble substantially smaller than that under the monetary shocks. The intuitions behind this result are not difficult to understand. While the use of MBS loosens the constraint on fund supply for the bank and helps increase lending, a monetary easing can further stimulate lending. A policy rate cut not only reduces the bank's interest payment for savings deposits and releases more funds for the bank to make loans, but it also directly lowers interest rates on mortgage. By contrast, the use of MBS affects mortgage rates only indirectly through the liquidity effect. Furthermore, changes in the benchmark interest rate cause the household to substitute savings for housing and consumption, which adds to the upward pressure on property price. This substitution effect does not exist when MBS are used. Having argued so, we warn against rushing to conclusions on the relative importance of monetary policy and unconventional financial products in creating asset bubbles. Restricted by the simple structure, we cannot include all effects of the two sets of factors into our model. For instance, MBS and other financial products may change risk preferences of market participants (Mian and Sufi 2009; Nadauld and Sherlund 2009). This issue is dealt with primitively in this paper by varying the LTV exogenously.

Extensive use of exotic financial instruments might encourage financial institutions to take more risks (Schmidt Bies 2004; Schwartz 2009) and so could deregulations (Bernanke 2010). We treat more risk taking as equivalent to a higher LTV ratio of the bank or lower requirement for down payment (Duca, Muellbauer, and Murphy 2010). In doing so, we replace individual loan contracts in the baseline model with an aggregate and exogenous LTV raito (Kiyotaki and Moore 1997; Iacoviello 2005; Iacoviello and Neri 2010). The actual LTV ratio of the U.S. banking system was, by and large, stable between 1998 and 2001, with an average of around 0.87. It began to rise in 2002 and reached a peak of 0.97 in 2006. Had this ratio been applied to mortgages, it would mean nearly zero down payment, a practice often seen in the precrisis years. We plug the time series of real LTV ratio into our model and run simulations with interest rates set in line with the Taylor rule. The increases in the LTV ratio turn out to have no material impacts on housing price. This result is not surprising, given the structure of the model. Without financial accelerators under exogenous LTV ratio, the positive feedback between asset price and bank lending in the baseline model is largely broken. Furthermore, on the demand side, the entrepreneurs' willingness to borrow is self-restrained, because getting deeper into debt today would undermine their position to borrow in the near future.

We provide empirical and anecdotal evidence in Section IV of this paper to support our theoretical results. Following a study of the Euro zone (Ahrend, Cournède, and Price 2008), we run a regression analysis for 11 Asian economies for the period 1990 to 1996, and we obtain a significant positive correlation between property price inflation and policy rate deviations from the Taylor rule. Housing booms in these economies have little to do with sophisticated financial products, and thus, they can be attributed mainly to monetary policies.

When interpreting the U.S. data, we refer to the literature to explore possible causalities between monetary policy and changes in the behavior of financial market players. The long period of low policy rate was associated with bank asset expansion and shifting toward riskier assets (Rajan 2005, 2010; Ziadeh-Mikati 2013). The Fed's own bulletin in 2010 admitted that, "Greenspan slashed interest rates and kept them too low for too long. Banks and shadow banks leveraged themselves to the hilt, loaning out money as if risk had been banished." Loans were granted to riskier borrowers (subprime mortgages) at interest rates lower than what they could afford (McDonald and Stokes 2013). Easy credit fueled the housing boom, and rising prices led to even looser standards of lending (Krugman 2009). Consistent with these arguments, data anomalies in the U.S. occurred *after* the Fed's interest rate policy began to diverge from the Taylor rule in the early 2000s. For instance, the U.S. mortgage origination surged above the trend line and so did the affordability index (see figure 12 in Section IV). In fact, the explosive growth of high-risk financial instruments, such as subprime MBS and credit default swaps (CDS), did not take place until interest rates fell to historical lows between 2001 and 2005 (see figures 14 and 15 in Section IV). We are inclined to explaining, at least partially, these unusual phenomena as rational responses of financial institutions to monetary policies.

The remainder of this paper is organized as follows. Section II describes and calibrates the general equilibrium model in details. Section III reports simulation results, based on which we discuss the relative importance of monetary policy and financial innovations. Section IV presents some empirical and anecdotal evidence to aid our theoretical analysis of the previous section. Section V concludes the paper.

II. The Model and Effects of Monetary Policy

The model to be constructed is a dynamic stochastic general equilibrium (DSGE) model with sticky price (Barsky, House, and Kimball 2007) and financial rigidities. BGG (1999) use an endogenous financial contract to describe the borrowing constraint and the role of financial accelerator. Our baseline model is similar to BGG's in many aspects except that we include the housing sector. Iacoviello (2005) uses an exogenous borrowing constraint model (also see Kiyotaki and Moore 1997; Iacoviello and Neri 2010) to study the housing market. We use this model as later an extension to study the effect of financial innovation.

Consider an economy in an infinite time horizon, with a representative household accounting for Ψ of the population, with the rest of the population $(1 - \Psi)$ being entrepreneurs. The householder lives forever on wages, profits from trading houses, and dividends from holding a company. He/she buys consumer goods and housing services to maximize utility and saves the rest of his/her income as deposits at a representative bank. The bank then channels household savings to entrepreneurs in an imperfect credit market under asymmetric information. In each period t, risk-neutral entrepreneurs make investments to acquire houses. The acquisitions are financed by entrepreneurs' own net worth and loans from the bank.[3] Since net worth plays a crucial role in such a market, we take a detour to the financial sector before formulating the behavior of market players in the other sectors.

A. Investment Demand for Housing and the Financial Contract

Entrepreneurs are assumed to possess more information than the bank. They know the returns on their investment in housing, but the bank does not. Entrepreneurs may take the informational advantage by choosing to default even when they have the ability to repay. The bank can learn about the true state of affairs only if it spends a verification cost. If the lender holds entrepreneurs' net worth as collateral and liquidates it in case of a default, the borrowers will have more to lose when they declare bankruptcy strategically. This mechanism reduces the likelihood of opportunistic behavior of entrepreneurs and hence mitigates the agency problem (Carlstrom and Fuerst 1997; BGG 1999). As seen later, it is through net worth that monetary shocks cause a positive feedback between bank credit and housing price, eventually leading to an asset bubble.

At the beginning of period t, entrepreneur i with net worth X_t^{Ei} chooses an investment in house H_t^{Ei}, which will be rented for the production of consumer goods in period $t + 1$. Given the real price of house q_t, the value of his/her investment is $q_t H_t^{Ei}$. To cover the gap between investment and net worth, he/she must borrow $b_t^{Ei} = q_t H_t^{Ei} - X_t^{Ei}$ from the bank.

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[3] Following Iacoviello and Neri (2010), we assume that entrepreneurs are impatient, in the sense that they discount future incomes more heavily than the household. This assumption is made to avoid entrepreneurs from accumulating enough net worth to fully fund their investments. In other words, they must borrow in every period.

The bank uses the household's savings deposits to make loans and pays the household the risk-free interest rate R_t^n set by the central bank.

The ex post return on the entrepreneur's investment depends on the aggregate return R_{t+1}^H and an idiosyncratic shock ω_{t+1}^i, namely, $\omega_{t+1}^i R_{t+1}^H q_t H_t^{Ei}$.

R_{t+1}^H is determined by the marginal product of the house used in the consumer goods sector and house price inflation. The idiosyncratic shock ω_{t+1}^i is independent and identically distributed (i.i.d.) across time and entrepreneurs, with distribution $F(\omega)$, density $f(\omega)$, non-zero support, and a mean of unity. $F(\omega)$ is assumed to have the same properties as those in BGG (1999).[4]

We assume that ω_{t+1}^i is only observable to the entrepreneur after production but not to all the other agents, particularly the bank. This information asymmetry creates an agency problem, as entrepreneurs may wish to misreport ω_{t+1}^i. The bank has to pay a verifying cost, expressed as a share of investment return $\mu\omega_{t+1}^i R_{t+1}^H q_t H_t^{Ei}$, to know the true value of ω_{t+1}^i. The loan contract is signed before realization of the idiosyncratic shock ω_{t+1}^i; thus, it is not possible (or optimal) to write the contractual terms contingent on ω_{t+1}^i. In fact, as Gale and Hellwig (1985) show, in such an environment, the optimal contract contains a fixed interest rate Z_t^i and quantity of borrowing b_t^{Ei}. The bank will verify true return rates only when entrepreneurs default.

Entrepreneur *i*'s profit from investment after he/she repays the loan is $\omega_{t+1}^i R_{t+1}^H q_t H_t^{Ei} - (1+Z_t^i)\, b_t^{Ei}$. This gives a threshold value of the idiosyncratic shock $\overline{\omega}_{t+1}^i$ that satisfies

$$\overline{\omega}_{t+1}^i R_{t+1}^H q_t H_t^{Ei} = \left(1 + Z_t^i\right) b_t^{Ei}. \quad (1)$$

If $\omega_{t+1}^i \geq \overline{\omega}_{t+1}^i$, the entrepreneur repays the loan and makes a profit of $\omega_{t+1}^i R_{t+1}^H q_t H_t^{Ei} - (1+Z_t^i)\, b_t^{Ei}$. The bank gets an amount $(1+Z_t^i) b_t^{Ei}$. In case of an unfavorable shock, that is, $\omega_{t+1}^i < \overline{\omega}_{t+1}^i$, the entrepreneur has to default. The bank then spends a fraction μ of the investment return to verify the shock and confiscates the entrepreneur's investment. The bank's net receipt is $(1-\mu)\omega_{t+1}^i R_{t+1}^H q_t H_t^{Ei}$, while the entrepreneur gets nothing. Under the assumptions about ω_{t+1}^i and μ (Townsend 1979), we can express the entrepreneur's borrowing b_t^{Ei} as a linear function of his/her net worth X_t^{Ei}, the coefficient being the same for all entrepreneurs (Equation 6). This allows us to significantly simplify the aggregation.

The banking sector is assumed to be perfectly competitive. This translates to zero economic profit for the bank, or the bank charges an interest rate Z_t^i on a loan to entrepreneur i so that the expected net return equals the opportunity cost of the fund b_t^{Ei}. Formally, we have the following equation.

$$\left[1 - F\left(\overline{\omega}_{t+1}^i\right)\right]\left(1 + Z_t^i\right) b_t^{Ei} + (1-\mu)\int_0^{\overline{\omega}_{t+1}^i} \omega R_{t+1}^H q_t H_t^{Ei}\, dF(\omega) = R_t^n b_t^{Ei}.$$

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[4] The following inequality holds for the hazard rate $h(\omega)$.

$$\frac{\partial(\omega h(\omega))}{\partial\omega} > 0, \text{ where } h(\omega) = \frac{f(\omega)}{1 - F(\omega)}.$$

This assumption is made to guarantee interior solutions, as discussed in BGG (1999). It is satisfied by most conventional distributions, including the log-normal distribution in our model.

This equation is often called the "participation constraint" (Carlstrom and Fuerst 1997), for banks are willing to participate in the credit market only if this constraint is satisfied. When R_t^n is too high, we cannot find a Z_t^i to satisfy the above constraint. In other words, the borrower is "rationed." Following BGG (1999), we rule out the possibility of rationing equilibria.

Knowing how Z_t^i is determined, the entrepreneur chooses an investment in house H_t^{Ei} and borrowing b_t^{Ei} to maximize his/her expected return

$$\text{Max} \int_{\overline{\omega}_{t+1}^i}^{\infty} \omega R_{t+1}^H q_t H_t^{Ei} dF(\omega) - \left[1 - F\left(\overline{\omega}_{t+1}^i\right)\right]\left(1 + Z_t^i\right) b_t^{Ei}, \tag{E0}$$

$$\text{s.t.} \quad \left[1 - F\left(\overline{\omega}_{t+1}^i\right)\right]\left(1 + Z_t^i\right) b_t^{Ei} + (1-\mu)\int_0^{\overline{\omega}_{t+1}^i} \omega R_{t+1}^H q_t H_t^{Ei} dF(\omega) = R_t^n b_t^{Ei}, \tag{E1}$$

$$b_t^{Ei} = q_t H_t^{Ei} - X_t^{Ei}, \text{ and} \tag{E2}$$

$$\overline{\omega}_{t+1}^i R_{t+1}^H q_t H_t^{Ei} = \left(1 + Z_t^i\right) b_t^{Ei}. \tag{E3}$$

Substituting (E3) for $(1+Z_t^i)\, b_t^{Ei}$ in (E0) and (E1), and (E2) for b_t^{Ei}, we solve the optimization problem for H_t^{Ei}.

$$H_t^{Ei} = \frac{X_t^{Ei}}{q_t\left[1 - \left(\Gamma\left(\overline{\omega}_{t+1}^i\right) - \mu G\left(\overline{\omega}_{t+1}^i\right)\right)\dfrac{R_{t+1}^H}{R_t^n}\right]}, \tag{2}$$

where

$$\Gamma\left(\overline{\omega}_{t+1}^i\right) \equiv \int_0^{\overline{\omega}_{t+1}^i} \omega dF(\omega) + \overline{\omega}_{t+1}^i\left[1 - F\left(\overline{\omega}_{t+1}^i\right)\right],$$

$$G\left(\overline{\omega}_{t+1}^i\right) \equiv \int_0^{\overline{\omega}_{t+1}^i} \omega dF(\omega),$$

and $\overline{\omega}_{t+1}^i$ is given by

$$\frac{\Gamma'\left(\overline{\omega}_{t+1}^i\right)}{\left(1 - \Gamma\left(\overline{\omega}_{t+1}^i\right)\right)\left(\Gamma'\left(\overline{\omega}_{t+1}^i\right) - \mu G'\left(\overline{\omega}_{t+1}^i\right)\right) + \left(\Gamma\left(\overline{\omega}_{t+1}^i\right) - \mu G\left(\overline{\omega}_{t+1}^i\right)\right)\Gamma'\left(\overline{\omega}_{t+1}^i\right)} = \frac{R_{t+1}^H}{R_t^n}. \tag{3}$$

Note that from the right-hand side of Equation (3), $\overline{\omega}_{t+1}^i$ is the same for all entrepreneurs. We drop the superscript i in $\overline{\omega}_{t+1}^i$ hereafter without causing any confusion. Furthermore, our assumption about the hazard rate of ω guarantees that $\overline{\omega}_{t+1}$ monotonically increases in R_{t+1}^H / R_t^n. Thus, we can rewrite $\overline{\omega}_{t+1}$ as a function of R_{t+1}^H / R_t^n.

$$\overline{\omega}_{t+1} = \lambda\left(\frac{R_{t+1}^H}{R_t^n}\right), \text{ with } \lambda' > 0 \text{ (see Appendix B)}. \tag{4}$$

Plugging Equation (4) into Equation (2), we write the i^{th} entrepreneur's investment demand as a linear function of his/her net worth.

$$q_t H_t^{Ei} = s\left(\frac{R_{t+1}^H}{R_t^n}\right) X_t^{Ei}, \tag{5}$$

where $s\left(\frac{R_{t+1}^{H}}{R_{t}^{n}}\right)=\frac{1}{1-\frac{R_{t+1}^{H}}{R_{t}^{n}}\left[\Gamma\left(\lambda\left(\frac{R_{t+1}^{H}}{R_{t}^{n}}\right)\right)-\mu G\left(\lambda\left(\frac{R_{t+1}^{H}}{R_{t}^{n}}\right)\right)\right]}$, with $s'>0$ (see Appendix B).

From E2, the entrepreneur's borrowing is also a linear function of his/her net worth.

$$b_{t}^{Ei}=\left[s\left(\frac{R_{t+1}^{H}}{R_{t}^{n}}\right)-1\right]X_{t}^{Ei}. \tag{6}$$

Because $s\left(R_{t+1}^{H}/R_{t}^{n}\right)$ is increasing in R_{t+1}^{H}/R_{t}^{n}, it follows from Equations (5) and (6) that, *ceteris paribus*, a cut in the policy rate R_t^n will stimulate demand of investment in housing and hence bank credit. However, a booming property market does not come without cost. Risk rises in the housing sector as well as in the financial industry, as can be seen in the next subsection.

B. Low Rate–High Risk Scenario

Proposition 1: Decreases in the policy rate R_t^n raise entrepreneurs' investment demand and their leverage ratio, *ceteris paribus*.

Proof: We have already shown that investment demand increases when the policy rate is lower. The leverage is defined as loan over net worth $L_{t}^{i}=q_{t}H_{t}^{Ei}/X_{t}^{Ei}=s\left(R_{t+1}^{H}/R_{t}^{n}\right)$. Because $s'(.)>0$ and $\lambda'(.)>0$, L_{t}^{i} rises with decreasing R_t^n. *QED*

Proposition 1 states the central theme of this paper, that *ceteris paribus*, particularly the given aggregate return R_{t+1}^{H}, low policy rates encourage entrepreneurs to take more risks by leveraging up. However, in a general equilibrium framework, effects of monetary policy on investment and leverage are ambiguous, as rate cuts also have a negative impact on investment return R_{t+1}^{H}. This is because increased investment, and hence house supply, reduces the physical marginal product of the house employed in the production of consumer goods. On the other hand, as shown in the next section, an interest rate cut also leads to an increase in house price, which brings about an enhancement of R_{t+1}^{H} (Equation (16)). With a reasonable combination of parameters for the model, the value appreciation of the house could well offset the decline in physical marginal product to yield a net increase in investment and leverage. The phenomenon of monetary easing to cause high leverage has been documented in empirical studies (e.g., Kashyap, Stein, and Wilcox 1993; Leary 2009). In our model, increased risk taking by entrepreneurs can be interpreted as a *rational* response to changes in monetary policy. It is not necessary to rely on "animal spirit" or deregulation to explain the excessive risk taking of market players in the precrisis years.

We make the following proposition for the bank.

Proposition 2: Decreases in the policy rate R_t^n increase the bank's LTV raio, *ceteris paribus*.

Proof: Recall that the LTV ratio is defined as the loan over the value of the entrepreneur's total assets. Using Equations (5) and (6), we can write the ratio as $LTV_t=\frac{s(R_{t+1}^{H}/R_{t}^{n})-1}{s(R_{t+1}^{H}/R_{t}^{n})}=1-\frac{1}{s(R_{t+1}^{H}/R_{t}^{n})}$. Since $s(.)$ is increasing in its argument, given R_{t+1}^{H}, the LTV ratio increases as R_{t}^{n} falls. *QED*.

Again, in a general equilibrium, there are conflicting forces unleashed by monetary easing. The signs of the changes in R_{t+1}^{H} depend on whether house price inflation outweighs the decrease in its physical marginal product. As argued above, for a set of parameters based on observations of the real economy, our model simulations show that the LTV ratio goes up with lower policy rates. The theoretical result is consistent with the observed behavior of LTV ratio in the U.S. (see figure 4 in

Section III.B). Monetary policy is thus identified as an impetus of high LTV ratio or low lending standard in addition to deregulation (Bernanke 2010) and financial innovations (Duca et al. 2010).

Once set in motion by a policy rate cut, the deterioration of credit quality continues through the financial accelerator. Rising property prices boost entrepreneurs' net worth, against which they can borrow even more, causing another round of credit and investment expansion. Recognizing the increased risk of the loan, the bank would have raised the risk premium to prevent the lending from getting out of control. However, the return from house investment depends on $\omega_{t+1}^{i}R_{t+1}^{H}$. With windfall gains from house price appreciation, the expected R_{t+1}^{H} increases. This gives the bank the impression that the ability of borrowers to repay is strengthened. As a result, the bank raises the LTV ratio and lowers the lending standard in a reassuring way. If the policy rate cut is transitory, this phenomenon is narrowed because the bank would soon recognize the increasing risk and charge higher risk premium in response. If the policy rate cut is persistent, the house price appreciation gains momentum, and the risk premium stays low, fueling the housing bubble. These phenomena are shown in our simulation.

C. Evolution of Net Worth and Aggregation of Entrepreneurs

Having stressed the key role of net worth, we move on to complete the construction of the model. In cases of no default, the net worth of entrepreneur i evolves as follows: His/her net worth in the next period equals the current period's investment return plus labor income minus loan repayment to the banks and his/her consumption of consumer goods C_t^{Ei}. Namely, in real terms,

$$E_t\left[(1+\pi_{t+1})X_{t+1}^{Ei}\right]=\int_{\overline{\omega}_{t+1}}^{\infty}\omega R_{t+1}^{H}q_tH_t^{Ei}dF(\omega)-\left[1-F(\overline{\omega}_{t+1})\right](1+Z_t^i)(q_tH_t^{Ei}-X_t^{Ei})+w_{c,t}^{E}N_{c,t}^{Ei}+w_{H,t}^{E}N_{H,t}^{Ei}-C_t^{Ei},$$

where π_{t+1} is the consumer goods price inflation targeted by the central bank. We assume C_t^{Ei} to be a fraction of net investment return:

$$C_t^{Ei}=\gamma\left\{\int_{\overline{\omega}_{t+1}}^{\infty}\omega R_{t+1}^{H}q_tH_t^{Ei}dF(\omega)-\left[1-F(\overline{\omega}_{t+1})\right](1+Z_t^i)(q_tH_t^{Ei}-X_t^{Ei})\right\}. \tag{7}$$

This assumption is made to prevent entrepreneurs from accumulating enough net worth so that they do not even need to borrow (BGG 1999). Also, the linearity of the consumption function enables us to simplify the model's calculation.

Substituting Equation (E1) for $\left[1-F(\overline{\omega}_{t+1})\right](1+Z_t^i)(q_tH_t^{Ei}-X_t^{Ei})$, we can rewrite the entrepreneur's net worth as

$$E_t\left[(1+\pi_{t+1})X_{t+1}^{Ei}\right]=R_{t+1}^{H}q_tH_t^{Ei}-\mu G(\overline{\omega}_{t+1})R_{t+1}^{H}q_tH_t^{Ei}-R_t^{n}(q_tH_t^{Ei}-X_t^{Ei})+w_{c,t}^{E}N_{c,t}^{Ei}+w_{H,t}^{E}N_{H,t}^{Ei}-C_t^{Ei}. \tag{8}$$

On the other hand, in the case of default, the entrepreneur loses his/her investment and consumes nothing. His/her net worth in the next period is simply labor income or

$$E_t\left[(1+\pi_{t+1})X_{t+1}^{Ei}\right]=w_{c,t}^{E}N_{c,t}^{Ei}+w_{H,t}^{E}N_{H,t}^{Ei}. \tag{9}$$

$N_{c,t}^{Ei}$ is the hours he/she works in the consumer goods sector, and $N_{H,t}^{Ei}$, in the housing sector. $w_{c,t}^{E}$ and $w_{H,t}^{E}$ are the corresponding real wages, which are determined by Equations (18) and (21) respectively. Each entrepreneur supplies 1 unit of labor inelastically, with the elasticity of substitution between the consumer goods and housing sectors being ε. Because labor supply is the same among all entrepreneurs, we drop the subscript i without causing confusion.

$$1 = \left[{N_{c,t}^{E}}^{1+\varepsilon} + {N_{H,t}^{E}}^{1+\varepsilon} \right]^{\frac{1}{1+\varepsilon}} . \quad (10)$$

The optimal labor supply for each sector is given by Equations (10) and (11).

$$\left(\frac{N_{c,t}^{E}}{N_{H,t}^{E}} \right)^{\varepsilon} = \frac{w_{c,t}^{E}}{w_{H,t}^{E}} . \quad (11)$$

To calculate the general equilibrium solutions to the model, we must aggregate individual entrepreneurs' investments and borrowing. This is easy, as these variables are linear functions of net worth with common coefficients. Specifically, from Equation (6), the total borrowing of entrepreneurs is given by

$$b_t^E = \left[s\left(\frac{R_{t+1}^H}{R_t^n} \right) - 1 \right] X_t^E . \quad (12)$$

To ensure that the total lending of the bank equals the total funds available, we assume that the bank simultaneously negotiates loan contracts with all entrepreneurs. The bank knows the net worth of each entrepreneur, and it follows Equation (6) to distribute funds among them. In the meantime, it adjusts interest rate Z_t^i, which is also identical for all entrepreneurs, so as to clear the credit market.[5]

Likewise, from Equation (5), the aggregate investment is given by

$$q_t H_t^E = s\left(\frac{R_{t+1}^H}{R_t^n} \right) X_t^E . \quad (13)$$

The aggregate net worth can be obtained by combining Equations (8) and (9) for all entrepreneurs. Thus,

$$E_t\left[(1+\pi_{t+1}) X_{t+1}^E \right] = (1-\gamma)\left(\left(1 - \mu G(\overline{\omega}_{t+1})\right) R_{t+1}^H q_t H_t^E - R_t^n \left(q_t H_t^E - X_t^E \right) \right) + w_{c,t}^E N_{c,t}^E + w_{H,t}^E N_{H,t}^E . \quad (14)$$

D. The Consumer Goods Sector: Investment Return and Real Wage

There are two firms in the consumer goods sector: a perfectly competitive intermediate goods producer (IGP) and a monopolistically competitive retailer. The IGP hires labor from the household and entrepreneurs, and it rents housing service from entrepreneurs to produce intermediate goods. Note that the housing service acquired by the household is not used for production. The retailer buys intermediary goods to produce final consumer goods. The retailer is a price setter such that the

[5] An alternative assumption is that there is perfect insurance among entrepreneurs, such that their net worth is ex post identical (e.g., Forlati and Lambertini, 2011). In this case, the bank is dealing with a representative entrepreneur in each period.

model can capture nominal price rigidity in a New Keynesian fashion. If Y_t^z is the total output of intermediate goods z, the production function is given by

$$Y_t^z = A_t {H_{t-1}^E}^{\alpha} N_t^{1-\alpha}, \tag{15}$$

where N_t is the quantity of labor provided by both the household and the entrepreneurs. Under the assumption of perfect competition, the rental payment for H_{t-1}^E is

$$P_t^z \frac{\alpha Y_t^z}{H_{t-1}^E},$$

where P_t^z is the price of the intermediate goods z. The aggregate return on entrepreneurs' house investments includes the rent and capital gain due to housing price fluctuation. Denoting the nominal house price by Q_t and the rate of depreciation by δ, we express the aggregate return on the house investment as

$$R_t^H = \frac{P_t^z \frac{\alpha Y_t^z}{H_{t-1}^E} + (1-\delta)Q_t}{Q_{t-1}}.$$

Buying Y_t^z from the IGP, the retailer turns intermediate goods into final consumer goods without using any other resources and sells them to the household and entrepreneurs with a markup M_t.

$$M_t = \frac{P_t}{P_t^z}.$$

The aggregate return can be rewritten in real terms as

$$R_t^H = \frac{\frac{1}{M_t}\frac{\alpha Y_t^z}{H_{t-1}^E} + (1-\delta)q_t}{q_{t-1}/(1+\pi_t)}. \tag{16}$$

In addition to rent, the IGP also needs to determine how much of the household and entrepreneurs' labor to employ. For technical simplicity, we assume that the composed labor supply N_t has a standard form as in the literature (e.g., BGG 1999).

$$N_t = {N_{c,t}^p}^{\varsigma} {N_{c,t}^E}^{1-\varsigma},$$

where $N_{c,t}^p$ is the household's labor for the consumer goods sector, and ζ measures its share. The total wage rate in a perfectly competitive industry equals the marginal product of labor, and the IGP's objective is to minimize labor cost, which gives the optimal demand for the household and entrepreneurs' labors. Hence, the inverse demand functions of the labors are given by

$$w_{c,t}^{p} = \frac{1}{M_t} \frac{\varsigma(1-\alpha)Y_t^z}{N_{c,t}^{p}} \text{ and} \tag{17}$$

$$w_{c,t}^{E} = \frac{1}{M_t} \frac{(1-\varsigma)(1-\alpha)Y_t^z}{N_{c,t}^{E}}. \tag{18}$$

E. The Housing Sector and Real Wage

A perfectly competitive developer hires labor from the household and entrepreneurs, to build new houses with the technology described by

$$H_t = A_{H,t} {N_{H,t}^{p}}^{\rho} {N_{H,t}^{E}}^{1-\rho}. \tag{19}$$

The marginal product of labor determines the wage rate in the housing sector.

$$w_{H,t}^{p} = q_t \frac{\rho H_t}{N_{H,t}^{p}} \text{ and} \tag{20}$$

$$w_{H,t}^{E} = q_t \frac{(1-\rho)H_t}{N_{H,t}^{E}}. \tag{21}$$

The developer provides housing units that are sufficient to meet the demand of the household and entrepreneurs *and* to make up for the loss in housing stock due to the depreciation and liquidation of collateral when default occurs. This implies the following condition for market clearing.

$$H_t = (1-\psi)\left[H_t^E - (1-\delta)H_{t-1}^E + \mu G(\overline{\omega}_t)H_{t-1}^E\right] + \psi\left(H_t^P - (1-\delta)H_{t-1}^p\right). \tag{22}$$

Note that the recovery of a house lost in liquidation is necessary for the existence of a steady-state equilibrium. It also avoids the house price appreciation due to the decrease of house supply as a result of house lost in case of default and depreciation.

F. The General Equilibrium

The rest of the building blocks of our model are standard, as in the New Keynesian literature. We briefly state the objective functions of households, introduce a nominal price rigidity here, and provide the details of the calculations in Appendix A.

The representative householder gains utility from consumption C_t^p and housing service H_t^p but disutility from supply of labor N_t^p. He/she maximizes his/her lifetime utility function as

$$U = \sum_{t=0}^{\infty} \beta^t \left[\ln C_t^p + \chi_H \ln H_t^p - \chi_N \frac{{N_t^p}^{1+1/\phi}}{1+1/\phi} \right] \text{ and}$$

$$N_t^p = \left[N_{c,t}^{p\ 1+\varepsilon} + N_{H,t}^{p\ 1+\varepsilon} \right]^{\frac{1}{1+\varepsilon}},$$

subject to the period budget constraint

$$\frac{R_{t-1}^n b_{t-1}}{1+\pi_t} + w_{c,t}^p N_{c,t}^p + w_{H,t}^p N_{H,t}^p + q_t (1-\delta) H_{t-1}^p + \Pi_t = C_t^p + q_t H_t^p + b_t,$$

where $N_{C,t}^p$ is the hours worked in the consumer goods sector, and $N_{H,t}^p$ is the hours worked in the housing sector. The left-hand side of the budget constraint is interest income from his/her savings in the last period b_{t-1}, wages earned in both sectors, revenue from selling the house he/she possessed in the last period $(1-\delta)H_{t-1}^p$ (δ is the depreciation rate), and dividend yield Π_t from owning the retailer. R^n_t is the risk-free interest rate set by the central bank. The items on the right-hand side are consumption, the purchase of a new house, and savings.

The retailer purchases intermediary goods Y_t^z at price P_t^z, composites them into final consumer goods Y_t with a constant elasticity of substitution (CES) technology, and sells them monopolistically to the household and entrepreneurs. The profit of the retailer is a rebated lump-sum to the household. Following Calvo (1983), we assume that in each period, the retailer is free to change the price with probability $1 - \theta$. This generates a familiar forward-looking Phillips curve

$$\pi_t = \beta \pi_{t+1} + \kappa \hat{M}_t,$$

where $\kappa = \frac{(1-\theta)(1-\theta\beta)}{\theta}$, and $\hat{M}_t$ is the log-deviation of M_t from its steady state.

The central bank follows the Taylor rule to set the monetary policy. Thus,

$$R_t^n = R_{t-1}^{n\ rr} \left(\pi_t^{1+r_\pi} (Y_t / Y)^{r_Y} \right)^{1-rr} e_{R,t}, \tag{23}$$

which is also standard in the literature. $e_{R,t}$ captures monetary policy shocks, that is, deviations from the policy rates subscribed by the Taylor rule.

The general equilibrium is defined as follows: Given state variables, including the last period's house price, households' and entrepreneurs' house stock, entrepreneurs' net worth, households' savings, and risk-free interest rate, denoted by $\{q_{t-1}, H_{t-1}^E, H_{t-1}^p, R_{t-1}^n, X_{t-1}^E, b_{t-1}^E\}$ respectively, the household chooses the current period's consumption, labor supply, savings, and house demand to maximize utility subjected to the budget constraint. With the same set of state variables, entrepreneurs decide on investment demand and labor supply. The commercial bank determines the interest rate and quantities of loans for entrepreneurs. The IGP hires labor and housing service to produce consumer goods. The developer employs labor to produce new houses. The central bank sets the policy rate according to the Taylor rule. All markets clear for every period.

The steady state and log-linearized system are presented in Appendix A.

G. Calibration of the Model

For the household's utility function, $\beta = 0.99$, which is standard in studies of the business cycle. For the Frisch elasticity of labor supply, we take a widely-accepted value of $\phi = 2$. χ_N is set to 3.8, to match the steady-state labor supply of 0.32 (total amount of labor available is fixed at 1, reflecting around 8 hours of work a day). χ_H is 0.6, so that the share of the house owned by the entrepreneurs is 19% in the steady state (Iacoviello 2005). The elasticity of labor substitution between the consumer goods and housing sector is 0.871, as estimated by Iacoviello and Neri (2010). The household accounts for 70% of the total population, that is, $\Psi = 0.7$.

On the production side, the measurement of price rigidity θ is set at 0.75, as in Angeloni et al. (2006). For the production function, $\alpha = 0.3$ to capture the steady-state share of rent in the total factor income. Similarly, $\rho = 0.7$ to measure the household's contribution to the output value of the housing sector. The labor composition of the household and entrepreneurs for producing consumer goods is set at $\zeta = 0.9$ to prevent entrepreneurs from rapidly accumulating wage income to such a level that their net worth is large enough to finance investment without borrowing.

The parameters for monetary policy are rr = 0.79, $r_\pi = 0.5$, and $r_Y = 0.5$, following Taylor's standard estimation (1993). For the idiosyncratic shock to investment return, we calibrate the distribution parameters so that the simulation results in a steady state match the actual data. For instance, when the variance is var(ω) = 0.11 and the verification cost in default is μ = 0.08, the simulated annual business failure rate is around 4%, and the interest rate spread between R_t^H and the risk-free rate R_t^n is about 200 basis points, both of which are close to real-world observations. For convenience of comparison, we list some of the simulated key rates and ratios in Table 1.

<Insert Table 1 here >

The model is driven by idiosyncratic return shocks and monetary policy. To see the effects of the policy rate on the housing market, we use the actual federal fund rates for the period 1998 to 2007 in our model simulations and report the results in the next section.

III. Model simulations

In this section, we simulate our baseline model to gauge the importance of monetary policy relative to financial innovations in creating asset bubbles. To clearly see the extent to which each set of factors affect house price, we mute all the other external shocks, including technological and preferential changes, in our model simulations. We first conduct experiments with monetary shocks, that is, deviations of the benchmark interest rate from the Taylor rule, but we do so without financial innovations. We then make the policy rates in line with the Taylor rule and introduce an "exotic" financial product, MBS, into the model. In this way, we are able to separate the effects of monetary policy from those of financial innovations and measure the degree of significance respectively.

A. Monetary Shocks

To understand the transmission mechanisms through which monetary policy affects house price, we run an impulse analysis of a transitory monetary policy shock, that is, an unexpected one-period deviation of the policy rate from the Taylor rule. The impulse responses of some key variables are illustrated in figure 1.

<Insert Figure 1 here>

Figure 1h shows that a 1% downward deviation of the policy rate from the Taylor rule can generate up to a 9% increase in house price. An elasticity of nine sounds extraordinary, but is not hard to comprehend. The interest rate affects decision making of all market players, and its accumulated impact could be much larger than commonly thought. We identify four effects of monetary policy in this paper, namely, the direct effect, substitution effect, financial accelerator effect, and risk taking effect.

The direct effect refers to an increase in the demand for housing investment by entrepreneurs (figure 1b) when the cost of bank credit falls with the policy rate (figure 1a and Proposition 1). The policy-induced increase in investment demand lifts housing prices. The substitution effect stems from a cross-sector labor substitution by both the household and the entrepreneurs. The household tends to consume more when the interest rate is lower (figure 1c). Greater demand drives the price of consumer goods higher. The IGP will hire more workers by offering better compensation in order to avail of business opportunities. Higher wages of the household translate to higher demand for and higher price of housing. As the household and entrepreneurs devote more of their time to the consumer goods sector (figures 1d and 1e), the developer must increase real wages (figure 1f) to compete for labor, resulting in a "cost-push inflation" of the house price.

The financial accelerator effect was introduced by Bernanke et al. (1999) as positive feedback from housing price to itself via net worth. Higher housing price increases the net worth of entrepreneurs (figure 1g), which enables them to borrow more (Equation 12). With more external resources available, entrepreneurs tend to buy more houses as investment, causing the house price to spiral upward. While recognizing the critical role of net worth, we should note another impetus of the financial accelerator, that is, enhanced investment return due to price inflation in a strengthening property market. A rise in the housing price represents a windfall gain in the aggregate return on investment, as can be seen from the following equation.

$$R_t^H = \frac{\frac{1}{M_t}\frac{\alpha Y_t^z}{H_{t-1}^E} + (1-\delta)q_t}{q_{t-1}/(1+\pi_t)},$$

where R_t^H increases with house price q_t. In anticipation of the enhanced return, entrepreneurs are inclined to leverage up (Proposition 1). Likewise, the bank lowers its lending standard and takes more risks by raising the LTV ratio (Proposition 2). In fact, the U.S. LTV ratio did climb in those easy money years (see the left-hand panel of figure 4).

Having shown impacts of transitory monetary shocks, we now study how asset price responds to a persistently low interest rate. We calculate actual deviations of the Federal Fund rates from the predictions of the Taylor rule for the period 1999 to 2008 (figure 2). We feed these deviations as monetary shocks into our model. We then compare the model-implied house price trajectory with the Freddie Mac House Price Index in figure 3.

<Insert Figure 2 here>

<Insert Figure 3 here>

The model-generated house prices tracked the real-world index fairly well. Persistently low interest rates *alone*, especially, without the assistance of financial innovations, can produce housing bubbles. This result does not require continuous cuts in the interest rate. So long as the benchmark interest rate stays low, house prices will keep rising because of the *self-sustained* positive feedback. In a strengthening property market, entrepreneurs are willing and able to expand investment. As the value of their net worth burgeons with house prices, they have more collateral to put up for loans from the bank. Moreover, improved return on investment due to house price inflation allows entrepreneurs to borrow disproportionally to the value of collateral. Consequently, the leverage (see the right-hand panel of figure 4) and the LTV ratio (see the left-hand panel of figure 4) move up steadily.

<Insert Figure 4 here>

The model-simulated LTV ratios closely follow the movement of the actual LTVs, and both reached the level of 95% toward the eve of the financial crisis in 2008. At the extreme, we prove in Appendix B that the LTV approaches 1 for a sufficiently low risk-free interest rate. Investments of entrepreneurs would be entirely financed by bank loans, or equivalently, zero down payments, a familiar feature of subprime mortgages in the precrisis U.S. economy. Thus, besides financial deregulation and excessive risk taking of financial intermediaries, monetary policy can also cause the lending standards of commercial banks to deteriorate. The impact of monetary policy on lending practice has been recognized by the Fed officials as well as academics. The Fed's own bulletin (2010) acknowledges that, "longtime low interest rate provided incentives for financial intermediaries to leverage up as if the risk of loaning out money had been banished." Krugman, in his New York Times blog (2001 to 2005), repeatedly warned that a flourishing housing market in a low interest rate environment led to a "complete abandonment" of mortgage lending standards (see also Hammond 2012). Krugman noted:

> "Millions of Americans have decided that low interest rates offer a good opportunity to refinance their homes or buy new ones" --- May 2, 2001,
> "The Fed's dramatic interest rate cuts helped keep housing strong" --- December 28, 2001,
> "Those 11 interest rate cuts in 2001 fueled a boom both in housing purchases and in mortgage refinancing" --- October 1, 2002, and
> "Low interest rates … have been crucial to America's housing boom." --- May 20, 2005.

Our model went a step further to illustrate how the reduction in the cost of funding (Dell' Ariccia and Marquez 2006) enhances return on housing investment and consequently encourages the bank to take more risks by raising the LTV ratio. This is by no means the only mechanism through which monetary policy affects the risk appetite of financial institutions. Angeloni, Faia, and Lo Duca (2013) argued that a low interest rate relieves the pressure of bank run, and banks become less prudent by increasing risk exposure in the credit market. Rajan (2005) proposed the hypothesis of "searching for yields," according to which, low interest rates drive banks to go for high return and hence high risk assets.

The policy implications of this finding are straightforward: Tighter market regulation is not sufficient to prevent asset bubbles from occurring again. In addition to various ongoing proposals and plans, regulation of the money supply should be discussed and included in any serious reform agenda. In this regard, fixed rules such as Friedman's *k*% rule (Friedman and Schwartz 1963) and the Taylor rule may offer ready, albeit imperfect, solutions. These rules might be far from being "optimal," but they can guarantee some degree of consistency and avoid human errors that could bring about unpredictable and disastrous consequences (see Taylor (2012) for more discussions).

B. The Effect of MBS

Massive use of MBS has been criticized as a major cause of the housing bubble in the U.S. (Gerardi et al. 2008; Dokko et al. 2009; Nadauld and Sherlund 2009). MBS, as a popular argument goes, enabled banks to share risks with financial investors and hence induced them to issue more exotic mortgages. Consequently, high risk borrowers obtained bank credit, which would have been declined under "normal" circumstances (Nadaul and Sherlund 2009). As the "latent" demand for mortgages was satisfied, funds flowed into the housing market and boosted prices (Gabriel and Rosenthal 2007; Mian and Sufi 2009). Furthermore, investors accepted this "unfair" deal and failed to price MBS accurately because of an informational asymmetry between originators, underwriters, and investors (Akerlof and Shiller 2009; Keys et al. 2009).

We notice that securitization of bank assets was a common practice long before the housing bubble of the 2000s, and the informational asymmetry had also been experienced before. A question arises naturally: Why did the issuance of MBS remain largely stable and pick up abruptly only in the early 2000s (see figure 5)? What were the triggers for the sharp upturn starting in the year 2001? The attempt to answer these questions leads us to speculate over a reversal of the above chain of reasoning. Persistently low policy rates might prompt banks to lend more aggressively, as stated by Proposition 2, and increased loan risk provides banks strong incentives to use MBS as a vehicle to share the risk. Ziadeh-Mikati (2013) provides empirical evidence to show that low interest rates between 2001 and 2006 indeed caused banks to shift toward riskier assets. Shiller (2009) argues that the strengthening housing price caused banks to lower the lending standard for home mortgages and caused rating agencies to misprice MBS. As the quality of their loan portfolios worsened, banks had strong incentive to replace illiquid assets with cash by selling MBS. Moreover, as Mattich (2012) argues, monetary policies could embolden financial innovations, either directly through the "search-for-yield" effect (Rajan 2005), or indirectly with the implicit guarantee of "Greenspan Put."

<Insert Figure 5 here>

Given the complexity of the issue and the simple structure of our model, we could only treat the effects of MBS toward improving the bank's liquidity so that it may extend more loans (Salmon 2010). Other popular financial products available at the time, such as CDS, also might have aroused banks' lending (Duca et al. 2010). However, the consequent credit expansion was not due to extra liquidity but changes in lending standards. In this subsection, we focus our discussion on the liquidity effect of financial innovations and leave the issue of risk preference to the next section.

Formally, the amount of liquidity gained from selling MBS is given exogenously in our model. By the credit market clearing condition, we have

$$(1-\psi)b_t^E = \psi b_t \tau_t, \qquad (24)$$

where ψ is the share of the household's population, b_t^E is entrepreneurs' demand for loans, and b_t denotes the household's savings. τ_t is the liquidity shock to capture the impact of MBS. It is equal to one plus the ratio of incremental liquidity by MBS over total savings. To calculate the ratio, we collect data of MBS issuance in the U.S. for the period 1997 to 2007 and divide it by the corresponding aggregate U.S. households' savings (figure 6). We assume that the additional liquidity comes entirely from outside the system, for example, from a "global saving glut" (Bernanke 2005). Under this assumption, the liquidity effect of MBS is overstated in the model. If domestic households subscribe to some of the MBS, their savings deposits at banks would decrease so as to offset the liquidity gain from selling MBS. Likewise, bank purchase of MBS, widely observed in reality before the crisis (see data in the Flow of Funds Accounts of the United States), would not at all improve liquidity for the banking industry as a whole.

<Insert Figure 6 here>

A positive liquidity shock increases the banks' loanable fund, which appears on the right-hand side of Equation (24). It will drive down the mortgage interest rate and stimulate entrepreneurs' demand for investment and external financing. As a result, the house price rises, starting the positive feedback process through the financial accelerator, as described before.

Assuming that the monetary policy follows the Taylor rule, we run model simulations under the MBS-channeled liquidity shocks. The effect of liquidity shocks on house price, depicted in figure 7, is significantly weaker than that of monetary shocks depicted in figure 3. Although the model does produce a bubble, its scale is far smaller than what is observed in reality. The model-generated house price is less than 40% of the observed price for most of the time during the bubble years. When we feed data of *net* issuance of MBS, that is, *gross* origination minus redemption, into the model (figure 8), the simulated housing bubble shrinks substantially in figure 9 as compared to that in figure 7.

<Insert Figure 7 here>

<Insert Figure 8 here>

<Insert Figure 9 here>

There are two reasons for the weakness of the effect of MBS-channeled liquidity shocks relative to that of monetary shocks. Though the increase in liquidity can help reduce the mortgage rate Z_t and hence boost borrowing, the cost of fund for the bank remains the same as before. In comparison, when the central bank cuts the benchmark interest rate, the cost of fund is lower and so is Z_t. Not only are entrepreneurs more willing to borrow but the bank also becomes more capable to lend. Paying less for the household's savings deposits, the bank can take more risks with a relaxed budget constraint (Dell'ariccia and Marquez 2006). The cost-of-fund effect for the bank does not exist under liquidity shocks. Secondly, the liquidity shock has no substitution effect as defined in Section II, whereas the policy rate cut will substitute consumption for saving and cause subsequent reallocation of labor. The so-increased demand for consumer goods and competition for labor drive up real wages and bring about a cost-push inflation of house prices.

From the above simulations and discussions, we arrive at the following general impression: The influence of the interest rate over the macro economy is perhaps broader than that of any other single parameter in the model. The interest rate affects the cost of fund for the bank, rate of intertemporal substitution of the household, and leverage of enterprises. It is far more important for policy makers to get the price of capital "right" than to get financial regulations "right." We shall return to this point later, in Section V.

So far, we have used models with embedded financial accelerator to study the effects of the monetary policy. There are other types of models in the literature addressing financial market frictions but without financial accelerators. Borrowing constraints are set exogenously in these models. As can be naturally expected, this class of models would underestimate impacts of monetary policy on housing price. However, one advantage of such models is their potential to provide a framework for the study of behavioral changes of banks due to either financial innovations or deregulations.

C. Exogenous Lending Constraint

When risk sharing financial instruments like MBS are available, banks become more accommodative to loan applications of less creditworthy clients, for example, subprime mortgage borrowers (Bies 2004; Nadauld and Sherlund 2009). One of the features of subprime mortgages is high LTV ratio (Duca et al. 2010). It could also be the case that deregulation allows banks to undertake more risks (Greenspan 2004; Bernanke 2010). These effects on banks' lending practices are not contradictory but complimentary to a major result of our baseline model in Section II, where the bank raises the LTV ratio when the central bank cuts the policy rate. In this subsection, we argue that deregulations or financial innovations increase the LTV ratio as a given and investigate how strong an increase in the LTV ratio impacts the house price. To do so, we substitute the lending contract in our baseline model by a borrowing constraint, where the LTV ratio is exogenous. Then, we feed the actual LTV ratio data into the new model and simulate the implied house price.

The new model is based on that of Neri and Iacoviello (2010) (hereafter, NI model; also see Kiyotaki and Moore 1997; Iacoviello 2005). There are no idiosyncratic shocks to investment return in the model. Therefore, the model degenerates into nearly a deterministic model except that it includes a white noise random shock to monetary policy (Equation 23). The amount of borrowing is bounded by a fixed fraction of the collateral value, that is, the LTV ratio. More specifically, in period t, the representative entrepreneur has a piece of collateral, the house he/she bought, with an expected present value: $q_{t+1}H_t^E\ (1+\pi_{t+1})/R_t^n$. The entrepreneur faces the following borrowing constraint:

$$b_t^E \le g_t E_t\left[\frac{q_{t+1}H_t^E(1+\pi_{t+1})}{R_t^n}\right], \tag{25}$$

where g_t represents the LTV ratio. Because there is no default, the interest rate on the loan is simply the risk-free rate. As in the baseline model, we assume that the entrepreneur discounts the future more heavily than the household to rule out the possibility of zero demand for bank credit. Appendix C provides a complete model with log-linearized and steady-state equations. The calibration of this model is, by and large, the same as that of the baseline model, except for the LTV ratio g_t. We plug the actual data of the U.S. LTV ratio into Equation (25) for g_t and run simulations to estimate the strength of LTV shocks vs. monetary shocks in terms of the impact on house price.

In the absence of monetary shocks, that is, the policy rate set according to the Taylor rule, the relaxation of lending constraints per se fails to generate any noticeable house price inflation (figure 10). This result is somewhat surprising, for the increases in LTV ratio are not trivial. The LTV ratio actually rises from 0.87 around the year 2000 to peak at 0.95 in 2007. The reasons for the minimal response of house price lie in the demand. The nominal cost of a bank loan is the risk-free interest rate; yet, the entrepreneur has to buy the house as collateral to obtain the loan. Since he/she can borrow only a fraction of the value of the house, that is, $g_t < 1$, the *effective* opportunity cost of the loan is $R_t^n./g_t$. When g_t increases, the effective cost of borrowing decreases, and therefore, entrepreneurs have incentives to increase investment demand and borrow more. However, they could be self-restrained from borrowing too much, for going deeper in debt today would reduce their net worth and hence their capacity of consumption and investment in the next period. The bottleneck in the credit market shifts from the supply side to the demand side. Meanwhile, the increasing LTV ratio has no impact on households' demand for houses, and thus, the competing demand for houses between households and entrepreneurs is missing.

<Insert Figure 10 here>

In contrast, if monetary shocks, as defined in the previous sections (e.g., figure 2), are introduced into the model, a substantial house price run-up is observed (the green line in figure 11). Under this circumstance, the cost of borrowing decreases and the entrepreneur's net worth increases because of the saving in interest payment. Thus, he/she proceeds with more ambitious investment and borrowing, which pushes house prices higher than under the LTV shocks. Increased house prices feed back to the enhanced value of collateral, and entrepreneurs can borrow even more. In addition to the stronger direct effect on house prices, lower interest rates also bring about a competing demand for houses between households and entrepreneurs; interest rate cuts boost household consumption and house purchases, while increase in the LTV ratio does not. Once again, we see that the interest rate has a more comprehensive influence on the economy than any single change in market conditions, and it plays a great role in creating asset bubbles.

<Insert Figure 11 here>

Though sizable, the housing bubble in the NI model is considerably smaller than the one generated by the baseline model with a financial accelerator. Without incorporating a financial market, the NI model underestimates the effects of the monetary policy. Although there is also positive feedback between house price and bank credit either in the NI model or in the BGG model, the strength of the feedback is weaker, because banks' risk taking behavior is missing here. Of course, the purpose of theoretical research is not so much to develop models that may closely track the movement of economic indicators in reality but to discover transmission mechanisms of monetary policy. In so doing, we can separate the effects of various factors and sort out policy priorities based on the relative importance of each set of factors. To this end, we prefer the BGG (1999) model as a potentially more powerful tool for policy analysis.

IV. Stylized Facts

In this section, we present stylized facts about monetary policy, financial innovations, and their relationship with house price. Drawing patterns from observations, we try to echo the central theme of this paper: Generally speaking, monetary policy has a broader and stronger influence on asset price than any other single factor, such as financial deregulation or innovation, in the financial market. The most challenging task of an empirical study on this subject is to separate the effect of monetary policy from all other effects. Given the limitations of data and econometric methods, we follow previous research to choose a sample in which the financial market can be considered to be in steady-state equilibrium.

Using data for a period *without* noticeable growth of new financial products, Ahrend et al. (2008) show that for Eurozone countries, changes in house price are positively correlated with the deviation of interest rates from the Taylor rule. When house price is replaced by the amount of home mortgages, the correlation rises from 0.35 to 0.67, and to 0.83 with property investment. We adopt the same methodology for 11 Asia-Pacific countries in the period 1990 to 1996 and obtain a similar result (figure 12). Like the case for the Eurozone, no widely spread financial innovations were reported in that period for the Asian economies. Of course, the identification of monetary policy as a cause of housing bubbles does not exempt financial innovations and deregulations from the list of suspects.

<Insert Figure 12 here>

For the precrisis period when both monetary policy and financial markets experienced drastic changes, we conduct event analysis, paying special attention to the timing of events. Irregularities of housing and financial indicators emerged around the year 2001, the beginning of a low interest rate era (also see Ahrend et al. 2008; Hofmann and Bogdanova 2012; Taylor 2012). For example, the affordability index of the U.S. (measured by real house price over real per capita disposable income) started rising (Figure 13a). The rise coincides with an off-trend growth of households' home mortgage originations (figure 13b).

<Insert Figure 13 here>

Some attributed the abnormality of house price to unconventional home mortgages (Dokko et al. 2009; Bernanke 2010) that poured large sums of funds into property markets. However, we note that the subprime share of total issuance of mortgages never exceeded 15% despite a surge in 2003 and the later years (figure 14a). The main home mortgages remained conventional. Even if subprime mortgages did serve as a major channel of excess liquidity, we would like to understand why they did not get popular until 2003. As argued by Dokko et al. (2009), one reason for commercial banks to shift toward riskier assets is the use of MBS, which allowed them to share risks with investors in financial markets. Indeed, the issuance of MBS rose sharply from 2001 onwards (figure 14b).

<Insert Figure 14 here>

While recognizing the role of MBS, we cannot ignore that the possible causation could be reversed. That is, increasing risk of mortgage loans might have prompted commercial banks to issue more MBS (Shiller 2009; Mattich 2012). We notice that the origination of MBS went hand-in-hand with that of home mortgages (figure 15). Furthermore, there was nearly a one-to-one correspondence between the market value of subprime MBS and subprime mortgages until 2007, when the MBS market suffered a major correction (figure 16).

<Insert Figure 15 here>

<Insert Figure 16 here>

Of course, correlation does not yield any helpful hint on causation. Fortunately, it is less important than thought to judge the direction of the cause–effect. Whether MBS induced the outburst of subprime mortgages or the reversal, the upward turning points and humps of both curves in figures 15 and 16 occur in the easy money years. This also shows one weakness of Dokko et al.'s (2009) argument. Given that MBS, as the risk sharing vehicle, provide banks incentive to take risk, the abnormity of MBS market and mortgage lending did not emerge before the persistently long interest rate cut since 2001. By contrast, historical data of interest rate and home mortgage origination show that low interest rate has been the driving force of mortgage lending (figure 17).

<Insert Figure 17 here>

There is yet another hypothesis about the sudden acceleration of MBS origination in the early 2000s, namely that financial deregulations rather than low interest rates are responsible for the flooding of financial innovations (Coffee 2008; Blinder 2009; Stiglitz 2009). Particularly, two pieces of legislations are considered relevant: the Gramm–Leach–Bliley (GLB) Act of 1999 and the Commodity Futures Modernization (CFM) Act of 2000.

By removing entry barriers, the GLB allows financial institutions to put commercial banking, securities brokerage, and insurance businesses under one umbrella. According to the critics, the GLB creates too-big-to-fail problems and encourages more risk taking. Surprisingly, little evidence can be found in the literature to support this assertion. Contrary to the popular view, banks actually increased lending to more creditworthy clients in the post-merger stage (Chionsini, Foglia, and Foglia 2003), and the consolidation of the banking sector made financial institutions more prudent (Dam, Escrihuela-Villar, and Sanchez-Pages 2005). Other forces at work might have offset the effects of moral hazards created by the too-big-to-fail policy. For example, when mergers reduced competition, and hence improved profitability, banks felt less pressure to raise yields by going for riskier assets (Hellmann, Murdock, and Stiglitz 2000; Repullo 2004).

The CFM of the year 2000 loosened the supervision of over-the-counter (OTC) derivative trading to such an extent that the market was said to be left "completely unregulated" (Sherman 2009). The existence of an active CDS market may encourage banks to take more risks by lowering lending standards, for example, by lowering monitor efforts or raising the LTV ratio. As shown before, higher LTV ratio per se only has limited impacts on house price. It is also worth noting that the volume of CDS purchased by America's commercial banks did not get an immediate boost by the CFM but started burgeoning three years later, in 2003 (figure 18). The time lag seems to suggest, again, a causality running from riskier assets of banks to the rise in their demand for financial derivatives. In addition, a survey by Weistroffer (2009) of the Deutsche Bank and Fitch Ratings shows that only 18% of the overall commercial banks' purchases of CDS before the crisis were done for hedging against risk and portfolio management (which provided them additional incentive to take risk in the first place). Most of the purchases, instead, were for speculative purposes. Therefore, the effect of CDS on commercial banks' risk taking was limited, and CDS did not provide these banks additional liquidity, as the data show that commercial banks purchased more CDS than they sold.

<Insert Figure 18 here>

We could draw a general pattern and sequence of events from the data: Monetary policy began to deviate from the Taylor rule in year 2000/2001. In response to the monetary easing, commercial banks expanded credit more aggressively, and a liquidity-driven housing bubble emerged. Investment banks soon caught up with the momentum in the friendlier regulatory environment of 2002/2003, to profit from increasing demand for risk diversifying products. The subsequent use of financial instruments, as well as seemingly ever-rising house price, made financial institutions underestimate risks and proceed with even more ambitious expansions of their balance sheets. Note that in sketching this picture, we do not mean to single out monetary policy as the most important contributing factor to the housing bubble; rather, we mean to describe its contribution as an initial push that caused many market irregularities.

V. Conclusions and Discussion

Following BGG (1999), we constructed a DSGE model with an embedded financial accelerator to gauge the impact of monetary policy on asset price as compared to the liquidity effect of MBS. Our model simulations show that monetary policy is more powerful in generating asset price inflation than the use of liquidity-enhancing financial products. When fed with actual Federal Fund rates, the model yielded a house price trajectory that traces the U.S. housing price index quite closely, while the use of MBS failed to do the same if monetary policy is set according to the Taylor rule. The contrast is impressive but not surprising, for monetary policy has a far broader influence on the real economy and property market. In the discussions following the model simulations, we identified multiple transmission mechanisms of monetary policy, namely substitution between consumption and saving, net worth, and banks' portfolios, among others.

These results bring us to the long-standing debate on the implementation of monetary policy, that is, rule-based vs. discretionary. The theoretical discussions and empirical evidence presented in this paper support the former and contest the latter. As Friedman and Schwartz (1963) show convincingly, a monetary contraction turned a market correction into a great depression in the 1930s. The monetary expansion from 2001 to 2006 might be regarded some day by economic historians as another case of inappropriately conducted policy. In the context of our model, the persistently low interest rates sent a distorted signal to the bank and entrepreneurs, resulting in overinvestment that eventually led to housing bubbles. From this point of view, we cannot agree more with Friedman's statement (1968): "The first and most important lesson that history teaches us about what monetary policy can do is that it can prevent money itself from being a major source of economic disturbance."

Policy rules, which are not necessarily "optimal," can keep central banks from making serious, and sometimes fatal, mistakes by actually removing them from the post of decision making. "Right" decisions require "reasonably good" forecast of the macro economy, including reactions of market players to the policy to be introduced. Unfortunately, our cognitive capacity is limited, and human errors are inevitable. If we do not believe that a government agency can set the correct prices for computers and wages for workers, why should we entrust the central bank with the job of getting interest rates right? The interest rate is nothing mysterious; it is but a price, the price of capital. Rules do not work magic but are automatic stabilizers. Imagine that when a demand shock hits the economy, house price goes up with output and product prices. With a windfall gain in their net worth, entrepreneurs in our model would increase their investment demand for house. However, the Taylor rule would render an interest rate hike to dampen investment. When the central bank sets monetary policy at its discretion, such a negative feedback mechanism is broken. With cheap credit available, entrepreneurs in our model overborrowed period after period to help finance the house purchase they would otherwise be unable to afford. There were no counteracting forces in the model to stop house price from rising through the accumulated net-worth effect, so long as the central bank kept the benchmark interest rate low.

A common critique to the rule-based monetary policy is its rigidity, which would restrict the central bank's capacity to cope with difficult situations like the financial crisis of 2008 (for more discussions, see Van Lear 2000; Stokey 2003). It is true that none of the rules are flexible enough to permit the central bank to do whatever is necessary to combat market panic and possible collapses. In fact, the existing rules, or any rules, are designed for the conduct of monetary policy under normal circumstances. They cannot and should not apply to emergency cases. During crises, all players constantly reassess market risks and change their strategy accordingly. If grasped by panic, their behavior, particularly, their reaction to policies, becomes highly unpredictable, or even indescribable. Under such circumstances, there is neither a theoretical nor an empirical foundation upon which policy rules can be drawn. To strike a balance between stability and flexibility, we suggest forging a "switch" in the hands of the Congress of Parliament. When the switch is turned off, the central bank follows a certain rule to set up monetary policy. When it is on, the central bank is authorized to have a certain degree of discretionary power. This idea is nothing new but an economic version of the alternation of governmental power between peace and war.

While we have discussed the role of monetary policy in creating asset bubbles, the issue of bubble bursting remains unaddressed in this paper. To analyze the ending of the game, a general equilibrium model would have to capture panic and contagion in the housing and financial markets. In such a model, the agents would change their preferences as well as their estimates of parameters and probabilities at the beginning of period $t + 1$, based on the equilibrium prices, output, and net worth of entrepreneurs in period t. This is a daunting task, if ever doable. It would be more fruitful and prudent to focus future research on how to prevent asset bubbles rather than how to deal with bubble bursting. For instance, if we can prove that financial innovation is a rational response of financial institutions to low interest rates, then regulation of monetary policy should be assigned a higher priority than regulation of markets on any reform agenda.

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Appendix A: General Equilibrium of the Baseline Model

The representative household's problem:

$$\max \qquad U=\sum_{t=0}^{\infty}\beta^t\left[\ln C_t^p+\chi_H\ln H_t^p-\chi_N\frac{N_t^{p\,1+1/\phi}}{1+1/\phi}\right]$$

$$s.t. \qquad N_t^p=\left[N_{c,t}^{p\ \ 1+\varepsilon}+N_{H,t}^{p\ \ 1+\varepsilon}\right]^{\frac{1}{1+\varepsilon}}$$

$$\frac{R_{t-1}^n b_{t-1}}{1+\pi_t}+w_{c,t}^p N_{c,t}^p+w_{H,t}^p N_{H,t}^p+q_t(1-\delta)H_{t-1}^p+\Pi_t=C_t^p+q_tH_t^p+b_t$$

The first order conditions are given by:

$$\frac{q_t}{C_t^p}=\chi_H\frac{1}{H_t^p}+E_t\left[\frac{\beta(1-\delta)q_{t+1}}{C_{t+1}^p}\right]$$

$$\chi_N\left(1+\left(\frac{w_{H,t}^p}{w_{c,t}^p}\right)^{\frac{1+\varepsilon}{\varepsilon}}\right)^{\frac{1/\phi-\varepsilon}{1+\varepsilon}}N_{c,t}^{p\ \ 1/\phi}=\frac{w_{c,t}^p}{C_t^p}$$

$$\left(\frac{N_{c,t}^p}{N_{H,t}^p}\right)^{\varepsilon}=\frac{w_{c,t}^p}{w_{H,t}^p}$$

$$1=E_t\left[\beta\frac{C_t^pR_t^n}{C_{t+1}^p(1+\pi_{t+1})}\right]$$

The representative and monopolistic competitive retailer's purchases the intermediary goods Y_t^z at the price P_t^z, differentiates it into goods Y_t^{ω}, and sells it to households with the composition technology:

$$Y_t=\left(\int_0^1 Y_t^{\omega\frac{\tilde{\varepsilon}-1}{\tilde{\varepsilon}}}d\omega\right)^{\frac{\tilde{\varepsilon}}{\tilde{\varepsilon}-1}}$$

where $\tilde{\varepsilon}$ is the elasticity of substitution among varieties. The retailer charges P_t^{ω} on each differentiated goods Y_t^{ω}. With this technology, the aggregate price index, or final consumer price index, is defined as:

$$P_t=\left(\int_0^1 P_t^{\omega 1-\tilde{\varepsilon}}d\omega\right)^{\frac{1}{1-\tilde{\varepsilon}}}$$

The demand of Y_t^{ω} is obtained by solving

$$\min \qquad \int_0^0 P_t^{\omega}Y_t^{\omega}d\omega$$

$$s.t. \qquad \left(\int_0^1 Y_t^{\omega\frac{\tilde{\varepsilon}-1}{\tilde{\varepsilon}}}d\omega\right)^{\frac{\tilde{\varepsilon}}{\tilde{\varepsilon}-1}}\geq Y_t$$

This gives

$$Y_t^{\omega} = \left(\frac{P_t^{\omega}}{P_t}\right)^{-\tilde{\varepsilon}} Y_t$$

Facing this demand function, the retailer determines the optimal price P_t^{ω} to charge. Following Calvo (1983), we assume that each period, the retailer has probability $1-\theta$ to alter the price, i.e., with probability θ, the price P_t^{ω} will be unable to change in period t+1. Therefore, the retailer takes this rigidity into account and maximizes the following life-time profit:

$$\max \quad E_t \sum_{i=0}^{\infty} \frac{\theta^i \left(P_t^{\omega} Y_{t+i}^{\omega} - P_{t+i}^{z} Y_{t+i}^{\omega}\right)}{\Delta_{t,t+i} P_{t+i}}$$

$$Y_{t+i}^{\omega} = \left(\frac{P_t^{\omega}}{P_{t+i}}\right)^{-\tilde{\varepsilon}} Y_{t+i}$$

where $\Delta_{t,t+i}$ is the discount factor between period *t+i* and *t*, which is applied by the households because the profit is rebated to them. Solving this problem gives the optimal price of P_t^{ω}:

$$P_t^{\omega^*} = \frac{\tilde{\varepsilon}}{\tilde{\varepsilon}-1} E_t \left[\frac{\sum_{i=0}^{\infty} \theta^i \Delta_{t,t+i} Y_{t+i} P_{t+i}^{z}}{\sum_{i=0}^{\infty} \theta^i \Delta_{t,t+i} Y_{t+i}} \right]$$

$$= \frac{\tilde{\varepsilon}}{\tilde{\varepsilon}-1} E_t \left[\sum_{i=0}^{\infty} \Psi_{t+i} \frac{P_{t+i}}{M_{t+i}} \right]$$

where

$$\Psi_{t+i} = E_t \left[\frac{\theta^i \Delta_{t,t+i} Y_{t+i}}{\sum_{i=0}^{\infty} \theta^i \Delta_{t,t+i} Y_{t+i}} \right]$$

This result shows that the optimal price set by the retailer is the markup times the weighted average of the future marginal cost.

Following this nominal price rigidity, the CPI can be re-written as:

$$P_t = \left[\theta P_{t-1}^{\;1-\varepsilon} + (1-\theta) P_t^{\omega^{*1-\varepsilon}} \right]^{\frac{1}{1-\varepsilon}}$$

Taking the above results into this equation, we get the familiar forward looking Phillips curve:

$$\pi_t = \beta \pi_{t+1} + \kappa \hat{M}_t$$

where

$$\kappa = \frac{(1-\theta)(1-\theta\beta)}{\theta}$$

The derivations of the rest components of the general equilibrium are already introduced in the paper.

The steady state equations are listed below:

$$\left[1-\beta(1-\delta)\right]\frac{q}{C^{p}}-\frac{\chi_{H}}{H^{p}}=0$$

$$\chi_{N}\left(1+\left(w_{H}^{p}/w_{c}^{p}\right)^{\frac{1+\varepsilon}{\varepsilon}}\right)^{\frac{1/\phi-\varepsilon}{1+\varepsilon}}N_{c}^{p\,1/\phi}-w_{c}^{p}/C^{p}=0$$

$$\left(N_{c}^{p}/N_{H}^{p}\right)^{\varepsilon}-w_{c}^{p}/w_{H}^{p}=0$$

$$\overline{\omega}R^{H}qH^{E}-(1+Z)b^{E}=0$$

$$\overline{\omega}=\lambda\left(R^{H}/R^{n}\right)$$

$$qH^{E}=s\left(R^{H}/R^{n}\right)X^{E}$$

$$b^{E}=qH^{E}-X^{E}$$

$$X^{E}=(1-\gamma)\left\{\left[1-\mu G(\overline{\omega})\right]R^{H}qH^{E}-R^{n}\left(qH^{E}-X^{E}\right)\right\}+w_{c}^{E}N_{c}^{E}+w_{H}^{E}N_{H}^{E}$$

$$\left[N_{c}^{E\,1+\varepsilon}+N_{H}^{E\,1+\varepsilon}\right]^{\frac{1}{1+\varepsilon}}=1$$

$$\left(N_{c}^{E}/N_{H}^{E}\right)^{\varepsilon}-w_{c}^{E}/w_{H}^{E}=0$$

$$Y-\overline{A}H^{E\,\alpha}N^{1-\alpha}=0$$

$$N-N_{c}^{p\,\varsigma}N_{c}^{E\,1-\varsigma}=0$$

$$R^{H}=\alpha Y/\left(MH^{E}q\right)+1-\delta$$

$$w_{c}^{p}-\varsigma(1-\alpha)Y/\left(MN_{c}^{p}\right)=0$$

$$w_{c}^{E}-(1-\varsigma)(1-\alpha)Y/\left(MN_{c}^{E}\right)=0$$

$$H-\overline{A}_{H}N_{H}^{p\,\rho}N_{H}^{E\,1-\rho}=0$$

$$w_{H}^{p}-\rho qH/N_{H}^{p}$$

$$w_{H}^{E}-(1-\rho)qH/N_{H}^{E}$$

$$H=(1-\psi)\left(\delta+\mu G(\overline{\omega})\right)H^{E}+\psi\delta H^{p}$$

$$Y=(1-\psi)C^{E}+\psi C^{p}$$

$$(1-\psi)b^{E}=\psi b$$

$$M=\frac{\tilde{\varepsilon}}{\tilde{\varepsilon}-1}$$

The log-linearized system of our baseline model is described by the following equations (where variable with a hat denotes the log deviation of the original variable from its steady state):

$$\hat{q}_{t}-\hat{c}_{t}^{p}+\left(1+\beta(1-\delta)\right)\hat{h}_{t}^{p}-\beta(1-\delta)\hat{q}_{t+1}+\beta(1-\delta)\hat{c}_{t+1}^{p}=0$$

$$\frac{1/\phi-\varepsilon}{\varepsilon}\frac{\left(w_{H}^{p}/w_{c}^{p}\right)^{(\varepsilon+1)/\varepsilon}}{1+\left(w_{H}^{p}/w_{c}^{p}\right)^{(\varepsilon+1)/\varepsilon}}\hat{w}_{H,t}^{p}-\left[1+\frac{1/\phi-\varepsilon}{\varepsilon}\frac{\left(w_{H}^{p}/w_{c}^{p}\right)^{(\varepsilon+1)/\varepsilon}}{1+\left(w_{H}^{p}/w_{c}^{p}\right)^{(\varepsilon+1)/\varepsilon}}\right]\hat{w}_{c,t}^{p}+\frac{1}{\phi}\hat{n}_{c,t}^{p}+\hat{c}_{t}^{p}=0$$

$$\varepsilon\hat{n}_{c,t}^{p}-\varepsilon\hat{n}_{H,t}^{p}-\hat{w}_{c,t}^{p}+\hat{w}_{H,t}^{p}=0$$

$$\hat{c}_{t}^{p}+\hat{R}_{t}^{n}-\hat{c}_{t+1}^{p}-\pi_{t+1}=0$$

$$\hat{\overline{\omega}}_{t+1} + \hat{R}^H_{t+1} + \hat{q}_t + \hat{h}^E_t - \hat{b}^E_t - \hat{z}_t = 0$$
$$\hat{\overline{\omega}}_{t+1} - \overline{\lambda}\hat{R}^H_{t+1} + \overline{\lambda}\hat{R}^n_t = 0$$
$$\hat{q}_t + \hat{h}^E_t - \hat{X}^E_t - \overline{s}\hat{R}^H_{t+1} + \overline{s}\hat{R}^n_t = 0$$
$$\hat{b}^E_t - \hat{X}^E_t - \left(\overline{s}/(\overline{s}-1)\right)\hat{R}^H_{t+1} + \left(\overline{s}/(\overline{s}-1)\right)\hat{R}^n_t = 0$$
$$- X^E\pi_{t+1} - X^E\hat{X}^E_{t+1} - \left(\mu R^H qH^E/\sqrt{2\pi}\sigma\right)\hat{\overline{\omega}}_{t+1} + \left(1-\mu G(\overline{\omega})\right)R^H qH^E\hat{R}^H_{t+1}$$
$$+ \left(\left(1-\mu G(\overline{\omega})\right)R^H - R^n\right)qH^E\hat{q}_t + \left(\left(1-\mu G(\overline{\omega})\right)R^H - R^n\right)qH^E\hat{h}^E_t - b^E R^n\hat{R}^n_t$$
$$+ R^n X^E\hat{X}^E_t + w^E_c N^E_c\left(\hat{w}^E_{c,t} + \hat{n}^E_{c,t}\right) + w^E_H N^E_H\left(\hat{w}^E_{H,t} + \hat{n}^E_{H,t}\right) - C^E\hat{c}^E_t = 0$$
$$-\left(C^E/\gamma\right)\hat{c}^E_t - \left(\mu R^H qH^E/\sqrt{2\pi}\sigma\right)\hat{\overline{\omega}}_{t+1} + \left(1-\mu G(\overline{\omega})\right)R^H qH^E\hat{R}^H_{t+1} + \left(\left(1-\mu G(\overline{\omega})\right)R^H - R^n\right)qH^E\hat{q}_t$$
$$+ \left(\left(1-\mu G(\overline{\omega})\right)R^H - R^n\right)qH^E\hat{h}^E_t - b^E R^n\hat{R}^n_t + R^n X^E\hat{X}^E_t = 0$$
$$\varepsilon\hat{n}^E_{c,t} - \varepsilon\hat{n}^E_{H,t} - \hat{w}^E_{c,t} + \hat{w}^E_{H,t} = 0$$
$$N_c^{E^{1+\varepsilon}}\hat{n}^E_{c,t} + N_H^{E^{1+\varepsilon}}\hat{n}^E_{H,t} = 0$$
$$-\hat{y}_t + \hat{a}_t + \alpha\hat{h}^E_{t-1} + (1-\alpha)\hat{n}_t = 0$$
$$-R^H\hat{R}^H_t + \left(R^H - 1 + \delta\right)\left(\hat{y}_t - \hat{M}_t - \hat{h}^E_{t-1}\right) + R^H\left(\pi_t - \hat{q}_{t-1}\right) + (1-\delta)q_t = 0$$
$$-\hat{n}_t + \varsigma\hat{n}^p_{c,t} + (1-\varsigma)\hat{n}^E_{c,t} = 0$$
$$-\hat{w}^p_{c,t} + \hat{y}_t - \hat{M}_t - \hat{n}^p_{c,t} = 0$$
$$-\hat{w}^E_{c,t} + \hat{y}_t - \hat{M}_t - \hat{n}^E_{c,t} = 0$$
$$-\pi_t + \beta\pi_{t+1} + \kappa\hat{M}_t = 0$$
$$-\hat{H}_t + \hat{a}_{H,t} + \rho\hat{n}^p_{H,t} + (1-\rho)\hat{n}^E_{H,t} = 0$$
$$-\hat{w}^p_{H,t} + \hat{q}_t + \hat{H}_t - \hat{n}^p_{H,t} = 0$$
$$-\hat{w}^E_{H,t} + \hat{q}_t + \hat{H}_t - \hat{n}^E_{H,t} = 0$$
$$-H\hat{H}_t + (1-\psi)H^E\hat{h}^E_t - (1-\psi)(1-\delta)\left(1-\mu G(\overline{\omega})\right)H^E\hat{h}^E_{t-1} + \left[(1-\psi)(1-\delta)H^E\mu/\left(\sqrt{2\pi}\sigma\right)\right]\hat{\overline{\omega}}_t$$
$$+ \psi H^p\hat{h}^p_t - \psi(1-\delta)H^p\hat{h}^p_{t-1} = 0$$
$$-Y\hat{y}_t + (1-\psi)C^E\hat{c}^E_t + \psi C^p\hat{c}^p_t = 0$$
$$\hat{b}^E_t = \hat{b}_t + \hat{\tau}_t$$
$$\hat{R}^n_t = rr\hat{R}^n_{t-1} + (1-rr)(1+r_\pi)\pi_t + (1-rr)r_Y\hat{y}_t + \tilde{e}_{r,t}$$

Note that $\hat{\tau}_t$ and $\tilde{e}_{r,t}$ are liquidity shock and monetary policy shock respectively.

Appendix B: Properties of the financial contract

For the notational simplicity, we drop the subscript i that represents the identity of entrepreneur in the financial contract. Then the optimal contract is characterized by the following two equations:

$$\frac{\Gamma'(\overline{\omega})}{(1-\Gamma(\overline{\omega}))(\Gamma'(\overline{\omega})-\mu G'(\overline{\omega}))+(\Gamma(\overline{\omega})-\mu G(\overline{\omega}))\Gamma'(\overline{\omega})}=\frac{R^H}{R^n} \tag{B1}$$

$$H^E=\frac{X^E}{\left[1-(\Gamma(\overline{\omega})-\mu G(\overline{\omega}))\frac{R^H}{R^n}\right]q} \tag{B2}$$

where

$$\Gamma(\overline{\omega})\equiv\int_0^{\overline{\omega}}\omega dF(\omega)+\overline{\omega}[1-F(\overline{\omega})] \text{ and } G(\overline{\omega})\equiv\int_0^{\overline{\omega}}\omega dF(\omega)$$

and note that

$$\Gamma'(\overline{\omega})=1-F(\overline{\omega}),\ \Gamma''(\overline{\omega})=-f(\overline{\omega}),\text{ and } G'(\overline{\omega})=\overline{\omega}f(\overline{\omega})$$

Also notice that the lending contract specifies that the share of investment return on housing that goes to the lenders is:

$$U^L(\overline{\omega})=\Gamma(\overline{\omega})-\mu G(\overline{\omega})$$

And that goes to the entrepreneur is:

$$U^E(\overline{\omega})=1-\Gamma(\overline{\omega})$$

Using definitions, we have

$$U^L(\overline{\omega})>0 \text{ for } \overline{\omega}\in(0,\infty),\text{ and } \lim_{\overline{\omega}\to 0}U^L(\overline{\omega})=0,\ \lim_{\overline{\omega}\to\infty}U^L(\overline{\omega})=1-\mu$$

$$\frac{dU^L(\overline{\omega})}{d\overline{\omega}}=(1-F(\overline{\omega}))(1-\mu\overline{\omega}h(\overline{\omega})),\text{ where } h(\overline{\omega})=\frac{f(\overline{\omega})}{1-F(\overline{\omega})}$$

Our assumption about the property of the hazard rate $h(\overline{\omega})$ in footnote 3 (that $\overline{\omega}h(\overline{\omega})$ is increasing in $\overline{\omega}$) implies that there exists an $\overline{\omega}^*$ such that:

$$\frac{dU_L(\overline{\omega})}{d\overline{\omega}}>0 \text{ if } 0<\overline{\omega}<\overline{\omega}^*$$

$$\frac{dU_L(\overline{\omega})}{d\overline{\omega}}=0 \text{ if } \overline{\omega}=\overline{\omega}^*$$

$$\frac{dU_L(\overline{\omega})}{d\overline{\omega}}<0 \text{ if } \overline{\omega}>\overline{\omega}^*$$

This is, the share of investment return that goes to the lenders reaches a global maximum when $\overline{\omega}=\overline{\omega}^*$. Thus the lenders will never choose a cutoff value of the shock that is larger than $\overline{\omega}^*$.

Define $\Theta(\overline{\omega})=\frac{\Gamma'(\overline{\omega})}{\Gamma'(\overline{\omega})-\mu G'(\overline{\omega})}$, we have:

$$\frac{d\Theta(\overline{\omega})}{d\overline{\omega}}=\frac{\mu[\Gamma'(\overline{\omega})G''(\overline{\omega})-\Gamma''(\overline{\omega})G'(\overline{\omega})]}{[\Gamma'(\overline{\omega})-\mu G'(\overline{\omega})]^2}>0,\text{ for } \overline{\omega}\in(0,\overline{\omega}^*)$$

$$\lim_{\overline{\omega}\to 0}\Theta(\overline{\omega})=1,\ \lim_{\overline{\omega}\to\overline{\omega}^*}\Theta(\overline{\omega})=+\infty$$

Then equation B1 can be re-written as:

$$\frac{R^H}{R^n}=\frac{\Theta(\overline{\omega})}{1-\Gamma(\overline{\omega})+(\Gamma(\overline{\omega})-\mu G(\overline{\omega}))\Theta(\overline{\omega})}\equiv\Xi(\overline{\omega})$$

Taking derivatives, we obtain:

$$\begin{aligned}\frac{d\Xi(\overline{\omega})}{d\overline{\omega}}&=\frac{\Theta'(\overline{\omega})[1-\Gamma(\overline{\omega})+(\Gamma(\overline{\omega})-\mu G(\overline{\omega}))\Theta(\overline{\omega})]}{[1-\Gamma(\overline{\omega})+(\Gamma(\overline{\omega})-\mu G(\overline{\omega}))\Theta(\overline{\omega})]^2}\\&\quad-\frac{\Theta(\overline{\omega})[-\Gamma'(\overline{\omega})+\Theta'(\overline{\omega})(\Gamma(\overline{\omega})-\mu G(\overline{\omega}))+\Theta(\overline{\omega})(\Gamma'(\overline{\omega})-\mu G'(\overline{\omega}))]}{[1-\Gamma(\overline{\omega})+(\Gamma(\overline{\omega})-\mu G(\overline{\omega}))\Theta(\overline{\omega})]^2}\\&=\frac{\Theta'(\overline{\omega})[1-\Gamma(\overline{\omega})+(\Gamma(\overline{\omega})-\mu G(\overline{\omega}))\Theta(\overline{\omega})]}{[1-\Gamma(\overline{\omega})+(\Gamma(\overline{\omega})-\mu G(\overline{\omega}))\Theta(\overline{\omega})]^2}-\frac{\Theta(\overline{\omega})[\Theta'(\overline{\omega})(\Gamma(\overline{\omega})-\mu G(\overline{\omega}))]}{[1-\Gamma(\overline{\omega})+(\Gamma(\overline{\omega})-\mu G(\overline{\omega}))\Theta(\overline{\omega})]^2}\\&=\Theta'(\overline{\omega})\frac{1-\Gamma(\overline{\omega})}{[1-\Gamma(\overline{\omega})+(\Gamma(\overline{\omega})-\mu G(\overline{\omega}))\Theta(\overline{\omega})]^2}>0\text{, for }\overline{\omega}\in(0,\overline{\omega}^*)\end{aligned}$$

As $\Xi(\overline{\omega})$ is increasing in $\overline{\omega}$, the equation (4) in our paper has the property that:

$$\overline{\omega}=\lambda\left(\frac{R^H}{R^n}\right)\text{, with }\lambda'>0\text{, where }\lambda(\cdot)=\Xi^{-1}(\cdot)$$

Meanwhile, equation B2 can be re-written as:

$$\frac{qH^E}{X^E}=\frac{1}{1-[\Gamma(\overline{\omega})-\mu G(\overline{\omega})]\Xi(\overline{\omega})}\equiv\Omega(\overline{\omega})$$

Again, taking derivatives, we obtain:

$$\frac{d\Omega(\overline{\omega})}{d\overline{\omega}}=\frac{[\Gamma'(\overline{\omega})-\mu G'(\overline{\omega})]\Xi(\overline{\omega})+[\Gamma(\overline{\omega})-\mu G(\overline{\omega})]\Xi'(\overline{\omega})}{[1-[\Gamma(\overline{\omega})-\mu G(\overline{\omega})]\Xi(\overline{\omega})]^2}>0\text{ for }\overline{\omega}\in(0,\overline{\omega}^*)$$

Thus, as $\frac{qH^E}{X^E}=\Omega(\overline{\omega})=\Omega\left(\lambda\left(\frac{R^H}{R^n}\right)\right)=\Omega\left(\Xi^{-1}\left(\frac{R^H}{R^n}\right)\right)\equiv s\left(\frac{R^H}{R^n}\right)$ (equation 5 of our paper), we have:

$$s'(\cdot)>0$$

In addition, using the properties of $\Theta(\overline{\omega})$ and $U^L(\overline{\omega})$, we have

$$\lim_{\overline{\omega}\to 0}\Xi(\overline{\omega})=1\text{, and }\lim_{\overline{\omega}\to\overline{\omega}^*}\Xi(\overline{\omega})=\frac{1}{\Gamma(\overline{\omega}^*)-\mu G(\overline{\omega}^*)}\equiv A^*$$

Thus $\Omega(\overline{\omega})$ has the boundary of

$$\lim_{\overline{\omega}\to 0}\Omega(\overline{\omega})=1\text{, and }\lim_{\overline{\omega}\to\overline{\omega}^*}\Omega(\overline{\omega})=+\infty$$

Since $s(\cdot)=\Omega(\Xi^{-1}(\cdot))$, and $\frac{R^H}{R^n}\in(1,A^*)$, we have:

$$\lim_{\frac{R^H}{R^n}\to 1}s\left(\frac{R^H}{R^n}\right)=1\text{, and }\lim_{\frac{R^H}{R^n}\to A^*}s\left(\frac{R^H}{R^n}\right)=+\infty$$

This property shows that, if the investment return rate approaches to the risk free rate, the investment demand approaches to the net worth, i.e., entrepreneurs will not borrow from banks, and all the housing investment is financed by their own net worth; on the other hand, if the investment return rate approaches to A^*R^n, the entrepreneurs are willing to borrow un-limited amount from banks.

The loan-to-value ratio, defined by

$$LTV = \frac{qH^E - X^E}{qH^E} = 1 - \frac{1}{s(\cdot)}$$

and it has the property that:

$$\lim_{\frac{R^H}{R^n} \to 1} LTV = 0 \text{, and } \lim_{\frac{R^H}{R^n} \to A^*} LTV = 1$$

This says that when risk free interest rate is sufficiently lower than the investment return rate, the loan-to-value ratio approaches to 1.

Appendix C: complete model of exogenous borrowing constraint

The model of exogenous borrowing constraint follows Iacoviello (2005) closely. Patient households maximize lifetime utility function:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t [\ln C_t^P + \chi_H \ln H_t^p - \chi_N \frac{N_t^{1+1/\phi}}{1+1/\phi}]$$

subject to the budget constraint:

$$\frac{R_{t-1}^n b_{t-1}^P}{1+\pi_t} + w_t N_t + q_t H_{t-1}^P + \Pi_t = C_t + q_t H_t^P + b_t^P$$

where π_t is the inflation rate, w_t is the real wage. Solving this problem yields the following first order conditions:

$$\frac{q_t}{C_t^P} = \chi_H \frac{1}{H_t^P} + E_t\left[\frac{\beta q_{t+1}}{C_{t+1}^P}\right] \tag{C1}$$

$$\chi_L L_t^{1/\phi} = \frac{w_t}{C_t^P} \tag{C2}$$

$$\frac{1}{C_t^P} = E_t\left[\frac{\beta R_t^n}{C_{t+1}^P(1+\pi_{t+1})}\right] \tag{C3}$$

Note that in this problem, we assume no depreciation of the house. The model of exogenous borrowing constraint features no default by entrepreneurs either. By assuming away the depreciation of the house, we no longer need a house developer to produce house. Instead, we assume to total housing supply is fixed by a constant *H*. Thus, households do not need to allocate their labor between goods sector and housing sector, and N_t denotes the labor supply to the intermediary goods sector.

The representative entrepreneur maximizes his lifetime utility function

$$U^E = E_0 \sum_{t=0}^{\infty} \gamma^t \ln C_t^E$$

and produces intermediary goods Y_t^z using labor and house via a constant return to scale technology (where A_t is the productivity):

$$Y_t^z = A_t H_{t-1}^{E\ \alpha} N_t^{1-\alpha} \tag{C4}$$

The perfect competitive entrepreneur sells Y_t^z to monopolistic competitive retailer at price P_t^z. Thus the entrepreneur's problem is to maximize U^E by choosing housing investment level and labor demand, subject to C4 and following budget constraint and borrowing constraint (where again, $M_t=P_t/P_t^z$):

$$\frac{Y_t}{M_t} + q_t H_{t-1}^E + b_t^E = C_t^E + q_t H_t^E + \frac{R_{t-1}^n b_{t-1}^E}{1+\pi_t} + w_t N_t \tag{C5}$$

$$b_t^E \le g_t E_t\left[\frac{q_{t+1} H_t^E (1+\pi_{t+1})}{R_t^n}\right] \tag{C6}$$

The first order conditions are given by:

$$\frac{q_t}{C_t^E} = E_t\left[\frac{\gamma\alpha Y_{t+1}}{C_{t+1}^E M_{t+1} H_t^E}\right] + gE_t\left[\frac{1+\pi_{t+1}}{R_t^n}\frac{q_{t+1}}{C_t^E}\right] + \gamma(1-g)E_t\left[\frac{q_{t+1}}{C_{t+1}^E}\right] \tag{C7}$$

$$\frac{(1-\alpha)Y_t}{M_t N_t} = w_t \tag{C8}$$

The retailer purchases the intermediary goods Y_t^z and composites them into final goods via constant elasticity of substitution technology as in appendix A. This gives the forward looking Phillips curve that is the same as the one in appendix A.

The steady state equations of this model are given as follows:

$$\chi_H \frac{1}{H^P} = (1-\beta)\frac{q}{C^P}$$

$$\chi_L N^{\frac{1}{\phi}} = \frac{w}{C^P}$$

$$R^n = \frac{1}{\beta}$$

$$Y = AH^{E^{\alpha}} N^{1-\alpha}$$

$$\frac{\gamma\alpha Y}{MH^E} = [1-g\beta-\gamma(1-g)]q$$

$$\frac{(1-\alpha)Y}{ML} = w$$

$$b = g\beta q H^E$$

$$\frac{Y}{X} + (1-R^n)b - C^E - wN = 0$$

$$\frac{1}{M}\frac{\varepsilon}{\varepsilon-1} = 1$$ (this is the markup charged by retailers in steady state)

$$H^P + H^E = H$$ (housing market clears)

$$C^E + C^P = Y$$

The log-linearized version of this model is given by:

$$\hat{h}_t^P + \frac{1}{1-\beta}\left(\hat{q}_t - \hat{c}_t^P\right) - \frac{\beta}{1-\beta}\left(\hat{q}_{t+1} - \hat{c}_{t+1}^P\right) = 0$$

$$\frac{1}{\phi}\hat{n}_t - \hat{w}_t + \hat{c}_t^P = 0$$

$$\hat{c}_t^P - \hat{c}_{t+1}^P + \hat{R}_t^n - \pi_{t+1} = 0$$

$$\hat{y}_t - \hat{a}_t - \alpha\hat{h}_{t-1}^E - (1-\alpha)\hat{n}_t = 0$$

$$-\hat{q}_t + (1-\beta g)\hat{c}_t^E - \gamma_m\hat{h}_t^E - \gamma_m\hat{M}_{t+1} - (1-\beta g)\hat{c}_{t+1}^E + (\beta-\gamma)g\hat{g}_t + \beta g\pi_{t+1} - \beta g\hat{R}_t^n + (1-\gamma_m)\hat{q}_{t+1} = 0$$

$$\hat{y}_t - \hat{M}_t - \hat{n}_t - \hat{w}_t = 0$$

$$\hat{b}_t - \hat{g}_t - \hat{q}_{t+1} - \hat{h}_t^E + \hat{R}_t^n - \pi_{t+1} = 0$$

$$\frac{Y}{M}\left(\hat{y}_t - \hat{M}_t\right) + qH^E\left(\hat{h}_{t-1}^E - \hat{h}_t^E\right) + b\hat{b}_t - C^E\hat{c}_t^E - \frac{b}{\beta}\left(\hat{R}_{t-1}^n + \hat{b}_{t-1} - \pi_t\right) - wN\left(\hat{w}_t + \hat{n}_t\right) = 0$$

$$\pi_t - \beta\pi_{t+1} + \frac{(1-\theta)(1-\theta\beta)}{\theta}\hat{M}_t = 0$$

$$\hat{h}_t^P + \frac{H^E}{H^P}\hat{h}_t^E = 0$$

$$\frac{C^P}{Y}\hat{c}_t^P + \frac{C^E}{Y}\hat{c}_t^E - \hat{y}_t = 0$$

$$\hat{R}_t^n - r_R\hat{R}_{t-1}^n - (1-r_R)(1+r_\pi)\pi_t - (1-r_R)r_Y\hat{y}_t - \varepsilon_{R,t} = 0$$

$$\hat{g}_t - \rho_g\hat{g}_{t-1} - \varepsilon_{g,t} = 0$$

Tables and Figures

TABLE 1

STEADY-STATE VALUES UNDER BENCHMARK CALIBRATION

Variables	
Loan interest rate minus risk-free rate (%)	6
Annualized failure rate (%)	3.01
Entrepreneur house demand (% of all demand)	18.9
Leverage ratio (net borrowing over net worth)	4.08
Loan-to-value ratio (%)	80.3
Household's hours worked (share of total hours; %)	31.7

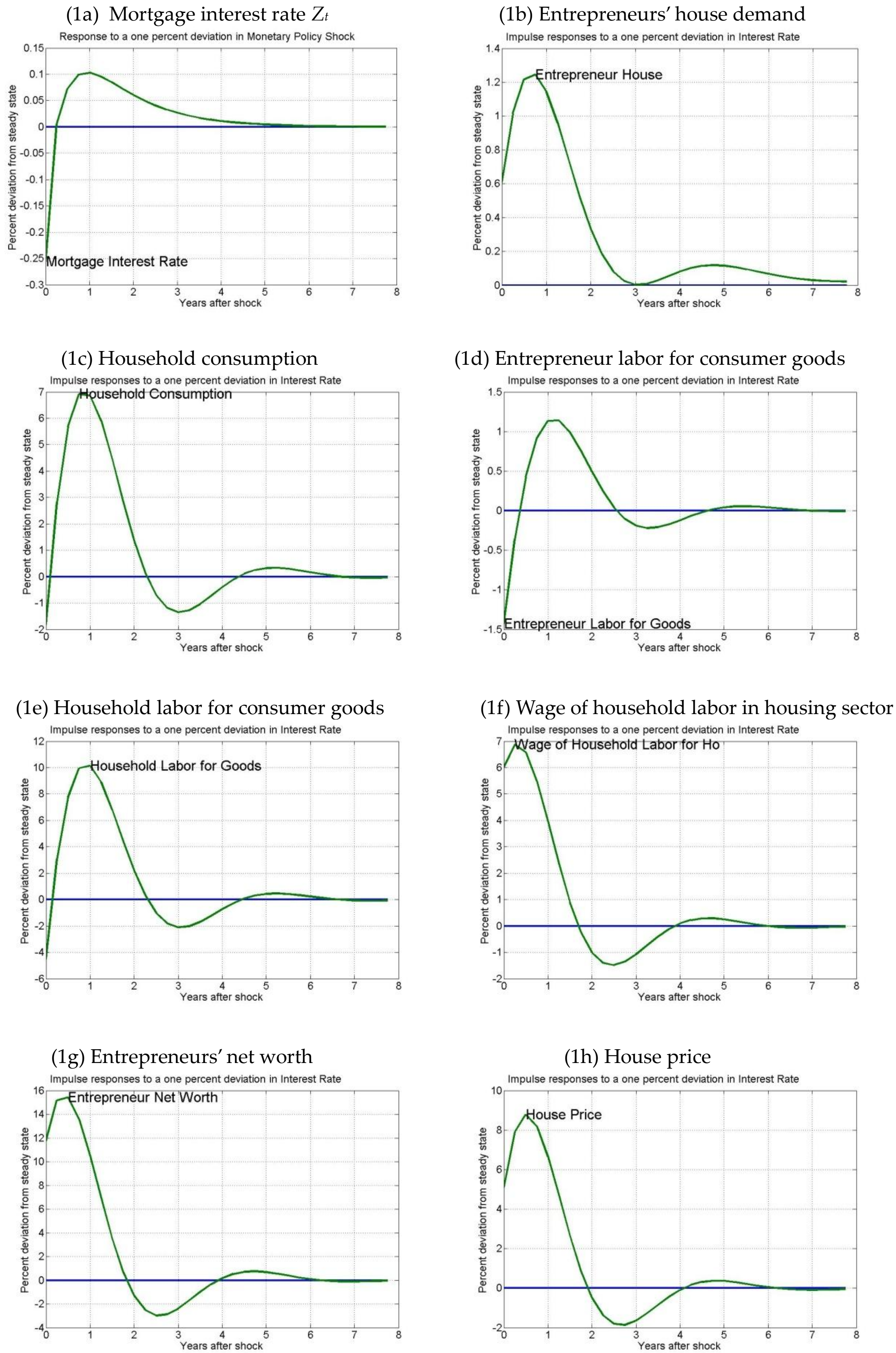

FIG. 1.—Impulse responses to a one-percent negative monetary policy shock.

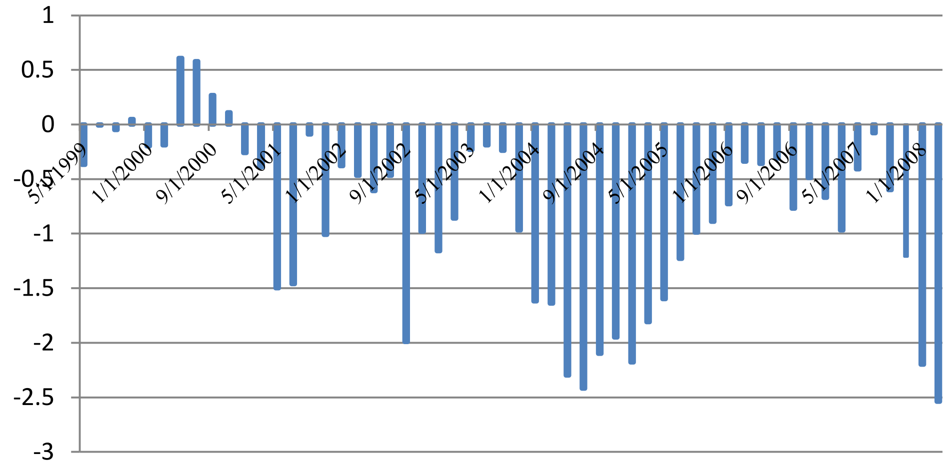

FIG. 2.—Deviation of actual Fed's policy rates from the Taylor rule's rates in the U.S. (1999 to 2008).
Source: CEIC and authors' calculation.

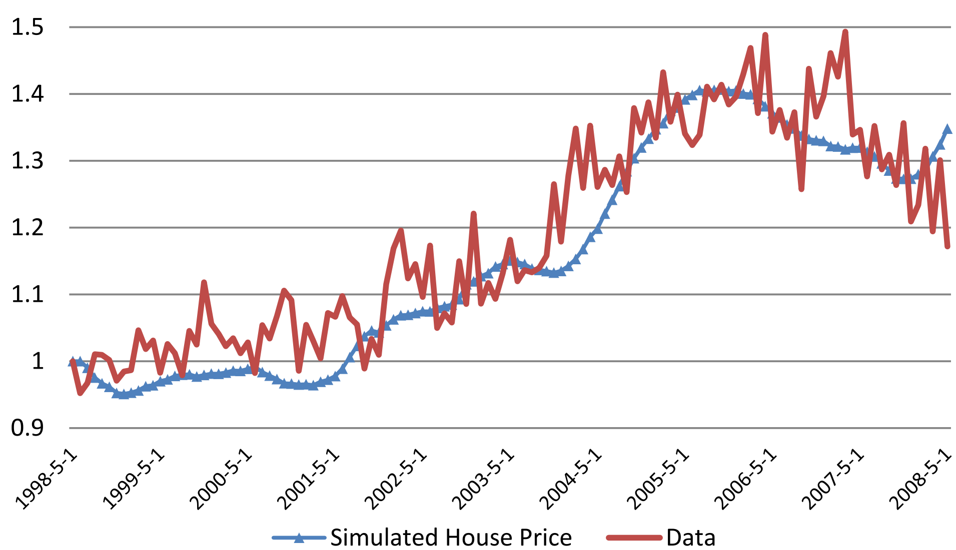

Fig. 3.—Simulated house prices with actual Fed's policy rates inputted into the model and comparison with the actual data.
Source: House price data from Freddie Mac House Price Index, adjusted by CPI inflation, and authors' own calculation.

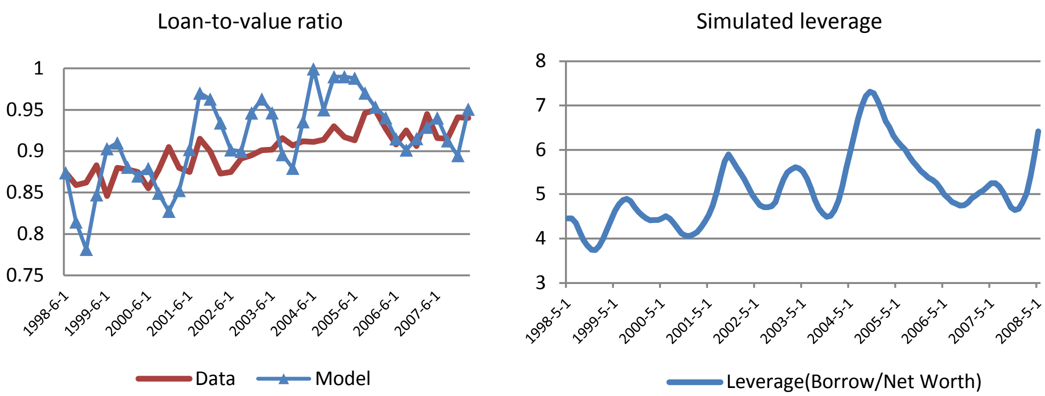

FIG. 4.—Left: Simulated LTV ratios and comparison to actual data. Right: Simulated leverage of entrepreneurs.
Source: American Housing Survey and authors' calculation.

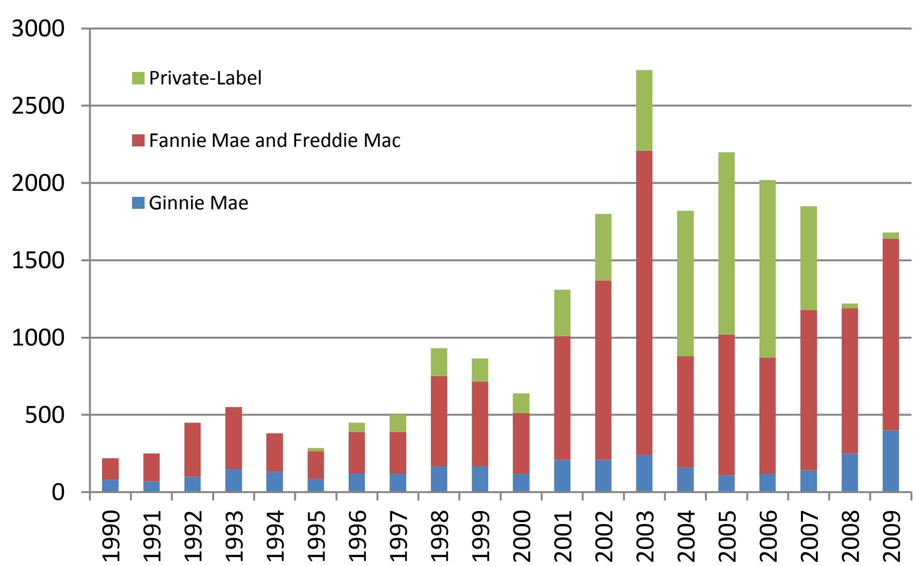

FIG. 5.—Mortgage-backed securities issuance in the U.S. (billions of dollars).
Source: www.sifma.org report.

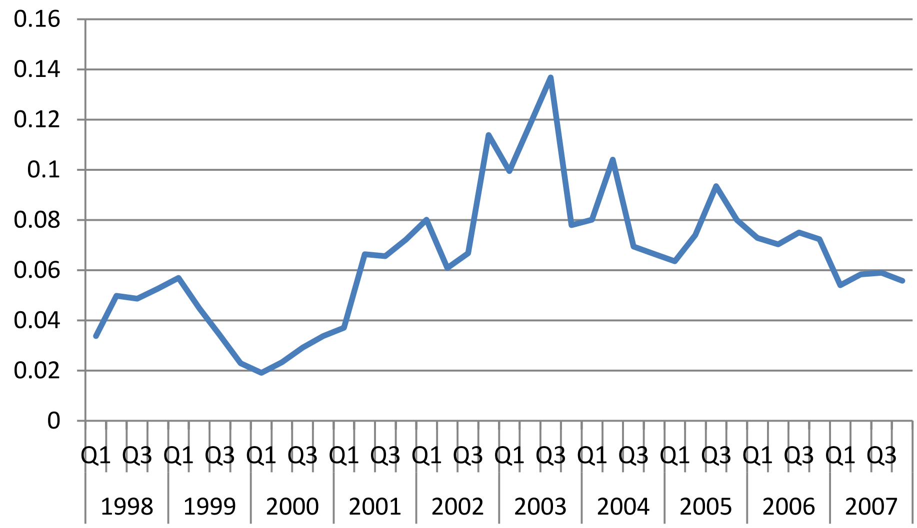

FIG. 6.—Ratio of MBS issuance over aggregate household saving.
Source: sifma.org report.

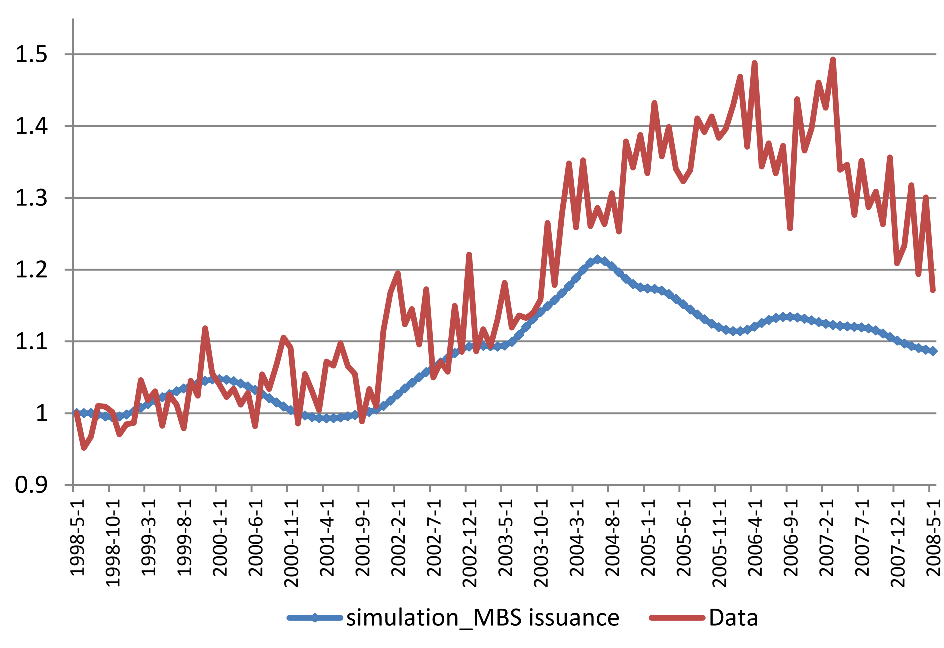

FIG. 7.—Implied house price trajectory achieved by feeding MBS-issuance shock into our model.

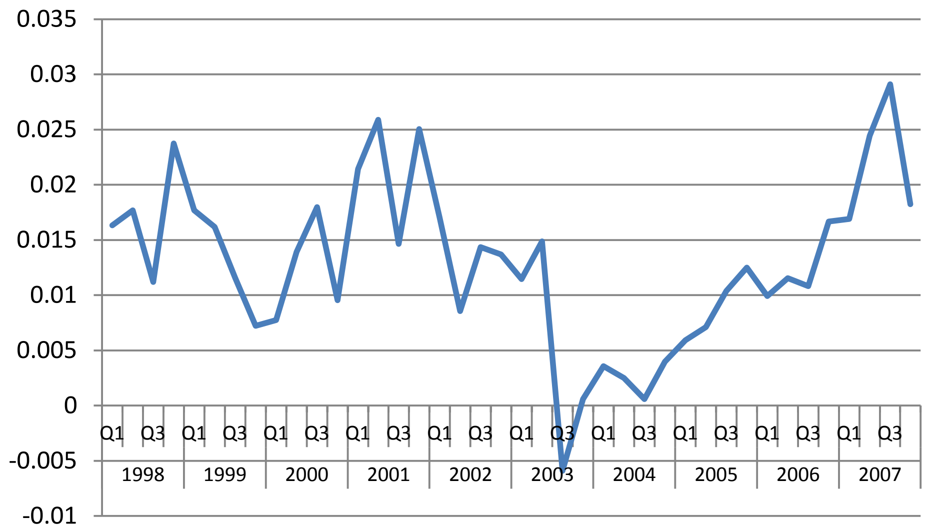

FIG. 8.—Ratio of net increase of MBS over aggregate household saving. Source: sifma.org report.

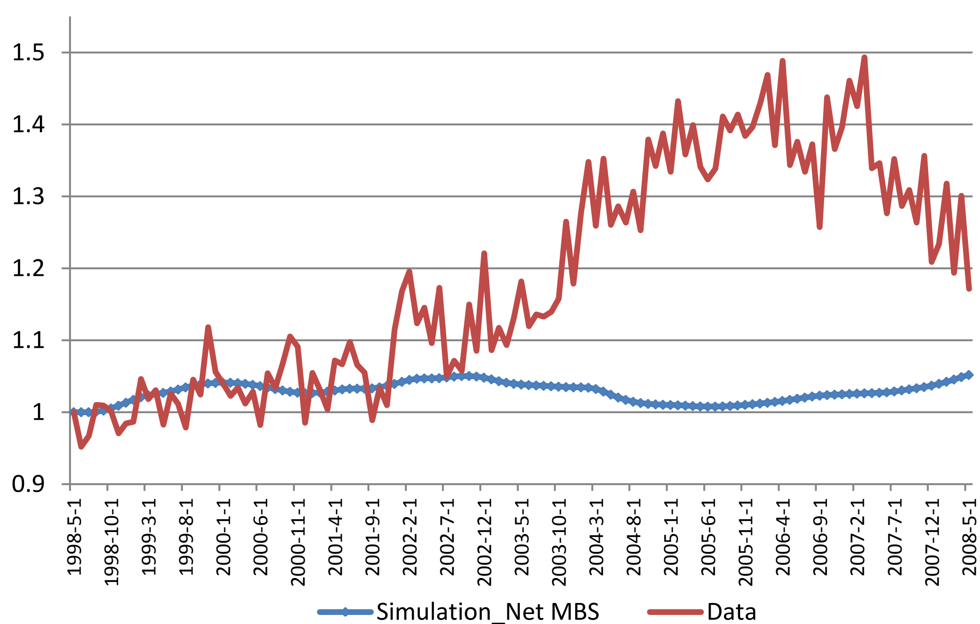

FIG. 9.—Implied house price trajectory achieved by feeding net increase of MBS shock into our model.

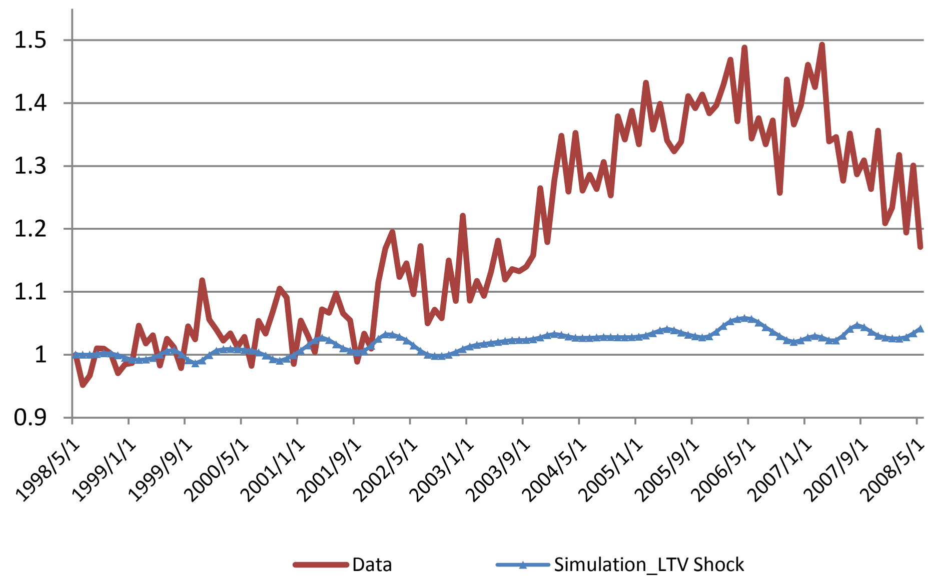

FIG. 10.—Simulated house price path under an LTV ratio shock only.

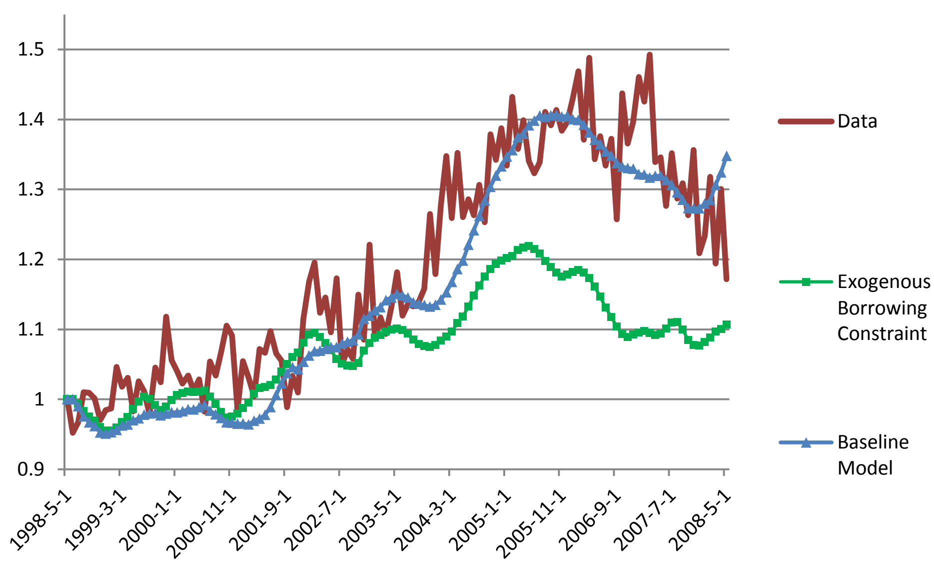

FIG. 11.—Simulated house price for the exogenous borrowing constraint model (new/NI model), baseline model, and data.

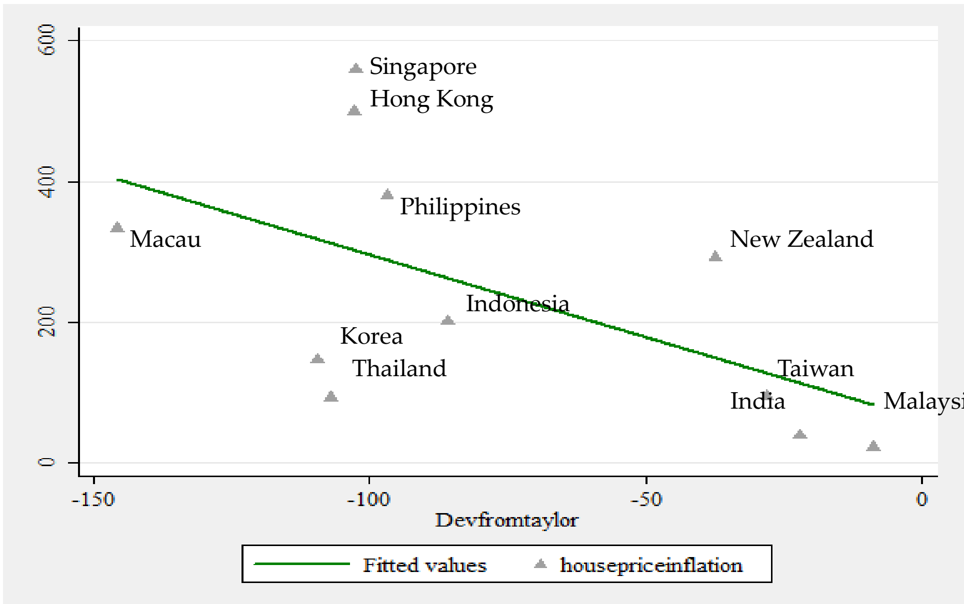

FIG. 12.—House price inflation versus deviation from the Taylor rule: $y = -2.335x + 62.59$, $P > |t| = 0.068$, $R^2 = 0.324$.

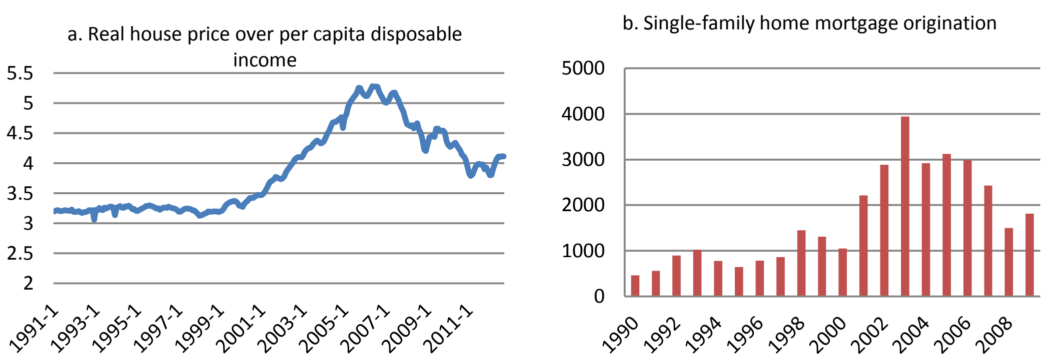

FIG. 13.—Real house price divided by real per capita disposable income (chart a) and household sector's single-family home mortgage originations (billions of dollars) in the U.S. (chart b).
Sources: U.S. Flow of Funds Accounts, CEIC data base, and the Federal Housing Finance Agency (FHFA) report.

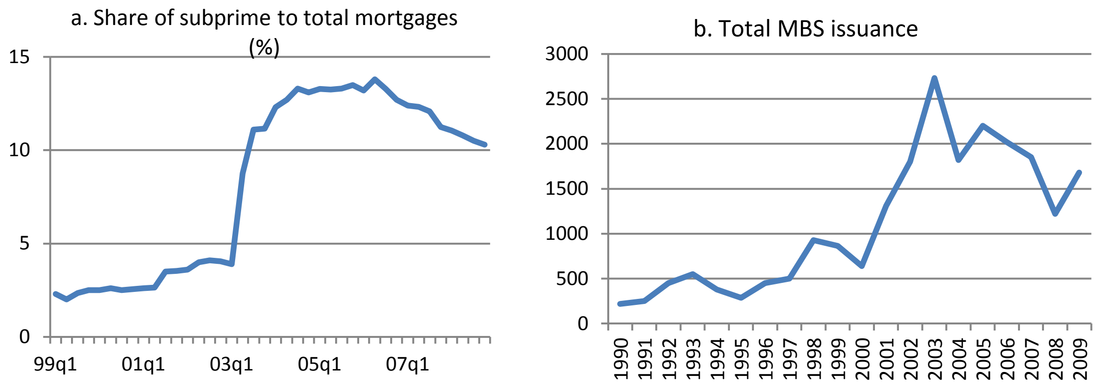

FIG. 14.—Share of subprime to total mortgages (%, chart a) and total U.S. MBS issuance (billions of dollars, chart b).
Sources: Federal Reserve Bank of San Francisco and sifma.org report.

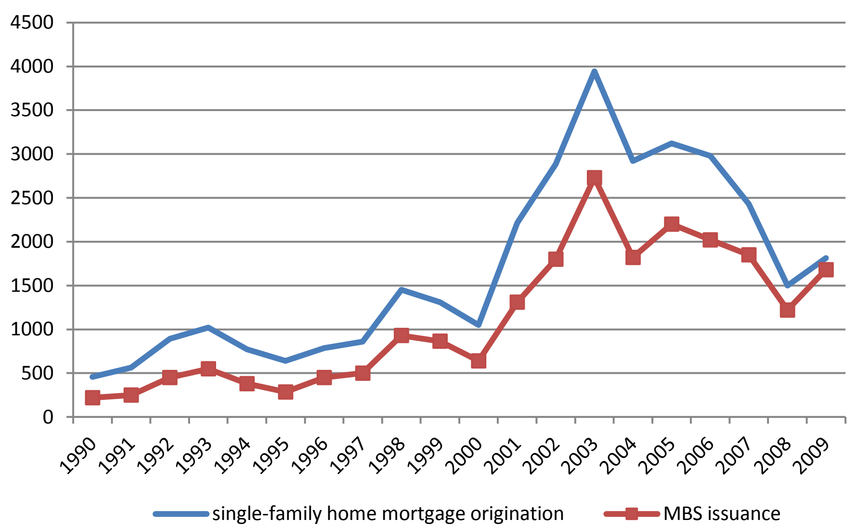

FIG. 15.—MBS issuance seems to follow the pattern of home mortgage origination in the U.S. (y-axis: billions of dollars).
Sources: Federal Housing Finance Agency (FHFA) and sifma.org report.

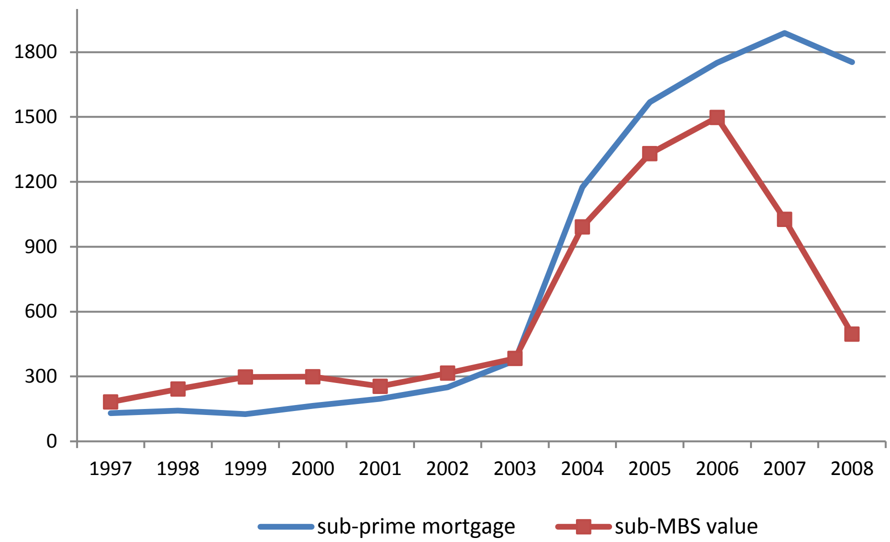

FIG. 16.—Outstanding subprime mortgages and subprime MBS (y-axis: billions of dollars).
Sources: Freddie Mac, the U.S. Flow of Funds Accounts, Cato Institute, and Mark Calabria (2011).

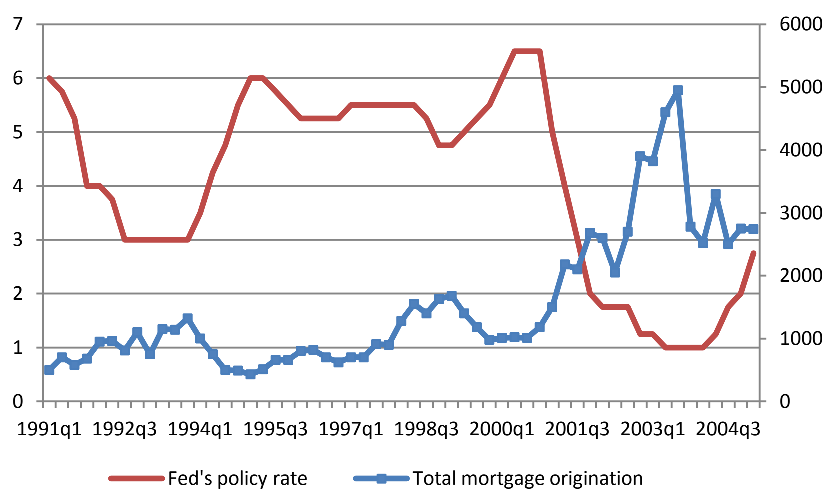

FIG. 17.—Total regular mortgage origination (right axis, billions of dollars) and Federal policy rate (left axis, %).
Sources: Greenspan and Kennedy (2005) and Freddie Mac investors' presentation (2014).

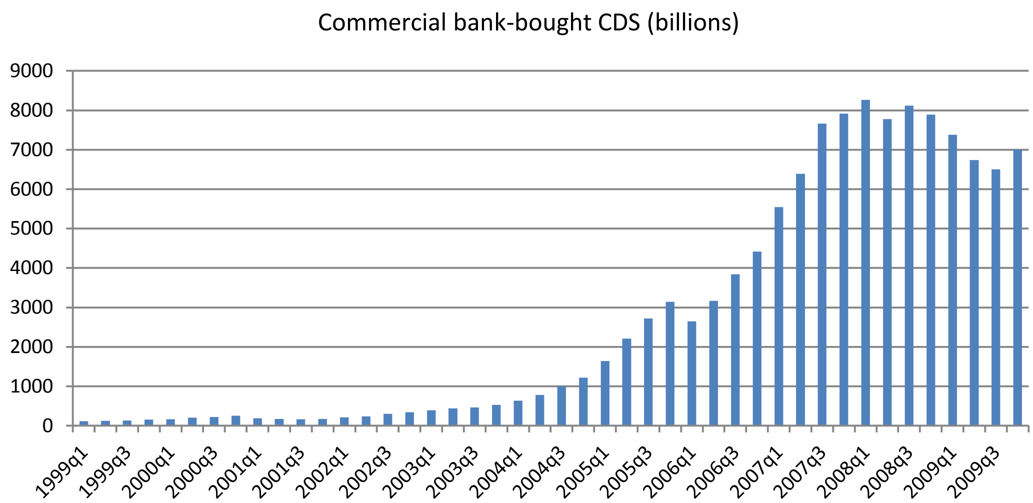

FIG. 18.—Credit default swaps purchased by U.S. commercial banks (billions of dollars). Sources: Office of the Comptroller of the Currency and the U.S. Department of the Treasury.