MONASH University
Business and Economics

DEPARTMENT OF ECONOMICS

ISSN 1441-5429

DISCUSSION PAPER 13/11

Asset Prices, Monetary Policy, and Aggregate Fluctuations: An Empirical Investigation

Lichao Cheng* **Yi Jin**† **and Zhixiong Zeng**‡

Abstract:
This paper studies empirically the dynamic interactions between asset prices, monetary policy, and aggregate fluctuations during the Volcker-Greenspan period. Using a simple structural vector autoregression framework, we investigate the effects of monetary policy on output, inflation and asset prices, the interactions of asset prices with the aggregate economy, as well as the relationship between stock price and house price. Several robust findings emerge. The systematic response of monetary policy to output and inflation is also found to play an important role in stabilizing the aggregate economy. In addition, the results call for special attention to be paid to house price when studying the dynamic relationships between asset prices and macroeconomic fluctuations.

JEL Classifcation Codes: E31, E32, E44, E52.
Keywords: House prices; stock prices; systematic monetary policy; structural vector autoregressions.

* China Center for Economic Research, Peking University, Beijing 100871, China. Phone: +86-10-62742076, Fax: +86-10-62751474, Email: lichaocheng@pku.edu.cn.
† Department of Economics, Monash University, 900 Dandenong Road, Caulfield East, VIC 3145, Australia. Phone: +61-3-99032042, Fax: +61-3-99031128, Email: yi.jin@monash.edu Homepage: http://users.monash.edu.au/~yij/.
‡ Corresponding author. Department of Economics, Monash University, 900 Dandenong Road, Caulfield East, VIC 3145, Australia. Phone: +61-3-99034045, Fax: +61-3-99031128, Email: zhix-iong.zeng@monash.edu

1 Introduction

This paper investigates the dynamic interactions between asset prices, monetary policy, and aggregate fluctuations during the Volcker-Greenspan period. We employ a simple structural vector autoregression (SVAR) framework to answer three broad sets of important questions, namely: (1) What are the effects of monetary policy on output, inflation, and asset prices? Furthermore, what are the different roles played by monetary policy shock versus systematic monetary policy? (2) How do asset prices interact with the aggregate economy? (3) What is the dynamic relationship between stock price and house price—the two asset prices considered in this paper? To this end we consider four specifications based on short-run recursiveness identification schemes, along the line of Christiano, Eichenbaum, and Evans (1999, CEE henceforth), Iacoviello (2005), and Sims and Zha (2006), among others. Our benchmark specification extends the CEE framework to incorporate asset prices. Under this "extended CEE" specification, monetary policy reacts contemporaneously to output and inflation innovations but reacts to asset price movements only with a lag. In contrast, under the "flexible monetary policy" specification, monetary policy is allowed to change in response to all non-policy shocks, while under the "sluggish monetary policy" and "extended Iacoviello" specifications, monetary policy respond to all non-policy shocks with a lag. Extended Iacoviello differs from sluggish monetary policy in whether output is ordered in front of or behind inflation and asset prices.

In terms of dynamic responses to shocks, the following robust findings emerge: (1) A positive shock to the federal funds rate, the monetary policy instrument in our SVARs, broadly leads to persistent declines in (real) house price, in addition to the fall in output and inflation, across the four specifications. (2) A positive shock to stock price generates a boom in output, while a positive house price shock leads to an initial increase (up to 7 quarters) and subsequent decline in output. Both asset price shocks generate persistent increases in inflation. On the other hand, house price responds negatively to output shocks. (3) There are positive comovements between the two asset prices. That is, a positive house price shock leads to an increase in stock price and vice versa.

Our variance decomposition results indicate that more than 60% of the variations in the federal funds rate reflect systematic responses of monetary policy to changes in the state of the economy. Hence it is important to evaluate the roles played by the non-policy variables in the setting of the monetary policy instrument, as well as the role played by the systematic component of monetary policy in shaping the dynamic behavior of output, inflation and asset prices. Regarding the monetary policy reaction function, we find that the federal funds rate increases in response to positive inflation shocks under all specifications. It responds positively to output shocks under extended CEE/flexible monetary policy but shows no significant reaction under sluggish monetary/extended Iacoviello. Moreover, the Fed does not appear to take asset price movements into direct account when setting the federal funds rate. Nevertheless, asset price movements exert an indirect influence on policy setting through its effect on inflation. In fact, the responses of the federal funds rate to asset price shocks mimic the responses of inflation to these shocks in a robust fashion.

To assess the role played by systematic monetary policy in the fluctuations in the aggregate economy and in asset prices, we follow Bernanke, Gertler and Watson (1997) and Sims and Zha (2006) to compare the impulse responses under the benchmark SVAR and a counterfactual, which assumes that monetary policy does not respond to any of the non-policy shocks. In general, the responses of output and inflation to the structural disturbances are smaller under the original SVAR, meaning that systematic monetary policy does help smooth output and inflation. Interestingly, systematic monetary policy turns out to help stabilize house price, despite that the policy does not directly react to house price movements. In fact, reacting only to output and inflation movements allows monetary policy to actually reduce house price fluctuations to a large extent. In contrast, the systematic monetary policy does not help stabilize stock price by much. Another striking result is that the estimated systematic monetary policy succeeds in mitigating the effects on output, inflation and house price of unpredictable shifts in monetary policy, i.e., innovations to the federal funds rate. This implies that to the extent that disturbances to monetary policy making are unavoidable, having a policy rule that dictates systematic reactions of the policy instrument to output and inflation movements actually helps avoid some of the economy's fluctuations that would otherwise result from those disturbances.

An innovative aspect of our study is that it incorporates both stock price and house price into an identified VAR framework that characterizes the dynamic interactions between asset prices, monetary policy and aggregate fluctuations. The paper is related to the empirical literature on the relationship between monetary policy, the business cycle, and stock price/returns. Fama and French (1989) study the relationship between the expected returns on stocks and bonds and the business cycle. Built on Fama and French (1989), Patelis (1997) finds that monetary policy stances help forecasting stock returns considerably. Thorbecke (1997) employs VARs and the method of event study and finds that expansionary monetary policy leads to rises in stock returns. DeStefano (2004) analyzes the relationship between stock prices and the business cycle, using dummy variables to represent different phases of the business cycle. He finds that stock prices are leading indicators of the business cycle. Bernanke and Kuttner (2005) investigate the relationship between monetary policy and stock prices. They find that a 25-basis point decline in the federal funds rate leads to about 1 percentage point increase in stock price indexes, and that the effects of unanticipated monetary policy actions on expected excess stock returns account for the largest part of the response of stock prices. Bordo, Dueker, and Wheelock (2007) study the relationship between monetary policy and stock market booms and busts for post World War II U.S., U.K., and Germany by introducing qualitative variables into VARs. They find that stock market booms are associated with episodes of high economic growth and low inflation, which are subsequently brought to an end by rises in inflation and tightening of monetary policy. They suggest that monetary policy that minimizes inflation volatility helps to stabilize financial markets.

There has been recently a growing interest in studying the dynamic interaction of the housing market and the aggregate economy. Of particularly relevance to our study are papers that involve both monetary policy and house price within VAR frameworks. For example, Del Negro and Otrok (2007) use a VAR to investigate the extent to which expansionary monetary policy is responsible for the increase in house prices in the U.S. for the period 2001-2005. They find that the impact of policy shocks on house prices to be small in comparison with the magnitude of the change in house prices in that period.

Iacoviello and Minetti (2003) use VARs to study the role of monetary policy shocks in house price fluctuations in Finland, Sweden, and U.K.. They find that the response of house prices to interest rate surprises is bigger and more persistent in periods characterized by more liberalized financial markets. VARs are also employed by Iacoviello and Minetti (2008) in their investigation of the credit channel of monetary policy in the housing markets of Finland, Germany, Norway, and the U.K. These papers, however, do not involve stock price. Incorporating both house price and stock price allows us to study their dynamic relationship. Even if one is mainly interested in studying the interaction of house price with monetary policy and aggregate fluctuations, it might still be desirable to consider stock price as well in the system in light of the mutual influence between these two asset prices and their respective interactions with monetary policy and the aggregate economy.

Our results suggest that special attention should be paid to house price in macroeconomic analyses. Asset price shocks, especially house price shock, figure prominently in generating inflation volatility. They are in fact *the most important* sources of inflation fluctuations other than the shock to inflation itself. House price shock is also the largest source of stock price volatility other than the shock to stock price itself. In addition, there appear to be a number of robust patterns found in the dynamic interactions between house price and the aggregate economy, more so than in the interactions between stock price and the aggregate economy. That is, house price appears to have more "connect" with the macroeconomy than stock price does. Recently there have been a growing number of works studying the role of house price in business cycle fluctuations and the transmission mechanisms of monetary policy, such as Jin and Zeng (2004), Iacoviello (2005), Chen and Leung

(2007), Jaccard (2009) and those surveyed in Leung (2004). Our results have implications for the directions of future research along this line.

The rest of the paper is organized as follows. Section 2 describes the specifications and the data. Section 3 presents the main results and robustness checks. The role of systematic monetary policy is examined in Section 4. The last section concludes.

2 Specifications

Our benchmark VAR consists of five quarterly endogenous variables, grouped in the vector $Z_t = [Y_t, \pi_t, R_t, q_{Ht}, q_{St}]'$, where Y_t represents log real GDP, π_t inflation, R_t the federal funds rate, q_{Ht} log real house price, and q_{St} log real stock price. Following common practice in the literature, the federal funds rate is regarded as the policy instrument of the Federal Reserve, as in Christiano, Eichenbaum, and Evans (1996, 1999), Bernanke and Mihov (1998), Romer and Romer (2004), and Sims and Zha (2006), among many others. The inflation rate π_t is the log difference of the GDP deflator between time t and time $t-4$, following Kontonikas and Montagnoli (2004). Both π_t and R_t are expressed in percent per annum. Following Iacoviello (2005), we take the Conventional Mortgage Home Price Index (CMHPI) to be the measure of house price. Using the GDP deflator to divide CMHPI yields the real house price q_{Ht} used in our model. We use the Standard & Poor's 500 index (S&P500) as the measure of stock price in our benchmark specification, and use the GDP deflator to convert it into the real stock price q_{St}. All the variables are stationarized by H-P filtering with the smoothing parameter set to be 1600.[1] The behavior of these five

[1] In Iacoviello (2005), the series are also filtered before running VARs.

variables is meant to represent in a concise manner the broad picture of monetary policy setting, macroeconomic performance, and the financial aspects of the economy.[2]

We also add two types of exogenous variables to the model. The first type includes the first and fourth lags of the log difference of the CRB/BLS Spot Price Index (see also Iacoviello, 2005). A common perception in the literature is that the spot price index is a leading indicator of the general price level. Adding the lagged values of this index as an exogenous variable to the VAR system helps to resolve the so called "price puzzle".[3] The second type of exogenous variable is a dummy variable that is assigned the value 1 for the time period 2001Q1-2003Q1 and 0 otherwise. This dummy is added to capture the exceedingly large effects on stock price of abrupt events like the burst of the dot com bubble and the 911 event.

We adopt a variant of CEE's short-run recursiveness identification scheme as our benchmark specification, whereby an innovation to a variable in the vector Z_t is restricted to have no contemporaneous impact on the variables ordered in front of it. Building on CEE, we introduce asset prices to an SVAR system to study the interaction between monetary policy, asset prices, and the aggregate economy. In particular, the vector Z_t contains three blocks: the k_1 variables, X_{1t}, whose contemporaneous values as well as lagged values appear in the time-t information set of the monetary authority, denoted by Ω_t, the k_2

[2]The data sources are as follows. The federal funds rate is from the Board of Governors of the Federal Reserve System: http://www.federalreserve.gov/econresdata/releases/statisticsdata.htm. The Conventional Mortgage Home Price Index is from Freddie Mac: http://www.freddiemac.com/finance/cmhpi/. The Stock price index is from "Online Data Robert Shiller": http://www.econ.yale.edu/~shiller/data.htm. Real GDP and GDP deflator are from the Bureau of Economics Analysis: http://www.bea.gov.

[3]Without such a variable the general price level would rise, rather than fall, persistently after a monetary contraction. Adding this variable allows the monetary authority to react quickly to changes in this leading indicator of the business cycle and avoids the counter-intuitive responses of the price level to monetary policy shocks. See Sims (1992).

variables, X_{2t}, which only appear with lags in Ω_t, and finally, the monetary policy instrument S_t itself. That is, $Z_t = \left[\begin{array}{ccc} X'_{1t} & S'_t & X'_{2t} \end{array} \right]'$.[4] In our baseline specification, $S_t = R_t$, $X_{1t} = [Y_t, \pi_t]'$, and $X_{2t} = [q_{Ht}, q_{St}]'$. The setting of monetary policy is thus represented by the equation corresponding to R_t in the SVAR system. This implies that monetary policy can equivalently be characterized by $S_t = f(\Omega_t) + \varepsilon_t^s$, where f—the feedback rule—is a linear function that relates S_t to the monetary authority's time-t information set Ω_t, which contains the current and lagged values of X_{1t}, the lagged values of X_{2t}, as well as the exogenous variables described above. The i.i.d. random variable, ε_t^s, is interpreted a monetary policy shock. The part $f(\Omega_t)$ is regarded as the systematic component of monetary policy.

The major difference of our model from CEE is that ours takes into consideration of asset prices. Ordering asset prices $[q_{Ht}, q_{St}]'$ to the bottom of Z_t reflects the notion that these prices should be allowed to react contemporaneously to a monetary policy shock. Asset prices, especially stock price, presumably adjust more quickly than other variables. In fact, locating asset prices at the bottom of the system also allows them to react contemporaneously to all other non-asset price shocks in the system. Furthermore, placing q_{Ht} in front of q_{St} captures the idea that stock price is more flexible than house price. In particular, stock price reacts contemporaneously to all sorts of shocks to the economy, while house price reacts contemporaneously to all shocks except the shock to stock price. There is thus a lag for stock price innovations to affect house price. In

[4] This ordering reflects the assumption that the policy maker does not see X_{2t} when S_t is set, and that the monetary policy shock is orthogonal to the elements in X_{1t} as the shock is assumed to have no contemporaneous effect on each element in X_{1t}.

effect, stock price is treated as the most responsive variable in the system, while output and inflation are treated as the most sluggish, which reflects the common perception that changing the quantities and prices of most goods and services is subject to various sorts of adjustment costs.

In the monetary policy equation, i.e., the equation corresponding to the variable R_t, the federal funds rate depends on current and lagged values of output Y_t and inflation π_t. In addition, there is potential dependence of R_t on (lagged) values of house price q_{Ht} and stock price q_{St}. That is, we allow in principle for the possibility that monetary policy reacts to perceived development in asset markets. If any of the coefficients on asset prices in the monetary policy equation turns out to be significantly different from zero, then we say that historically the Fed did take into account asset prices in policy making. Otherwise the Fed is regarded as having ignored asset price movements when setting the federal funds rate target. Section 4.1 is devoted to this issue.

An immediate question under the short-run recursiveness assumption is the robustness of the results under different ordering of variables. To answer this question, we also consider three alternative short-run recursiveness based identification schemes. Hence in total we consider the following four specifications:

1. Extended CEE (baseline specification): $Z_t = [Y_t, \pi_t, R_t, q_{Ht}, q_{St}]'$.
2. Flexible monetary policy: $Z_t = [Y_t, \pi_t, q_{Ht}, q_{St}, R_t]'$.
3. Sluggish monetary policy: $Z_t = [R_t, Y_t, \pi_t, q_{Ht}, q_{St}]'$.
4. Extended Iacoviello: $Z_t = [R_t, \pi_t, q_{Ht}, q_{St}, Y_t]'$.

Under flexible monetary policy, the federal funds rate is permitted contemporaneous responses to all sorts of shocks. This specification is useful to look at for the following reason. We find under extended CEE that systematic monetary policy in the U.S. did not historically take asset price movements into account. We want to make sure that this finding does not rely on ruling out contemporaneous responses of the federal funds rate to asset price movements as in extended CEE. Such contemporaneous responses are allowed for under flexible monetary policy, where the federal funds rate is ordered last in the vector Z_t. Nevertheless, we fail to find significant responses of monetary policy to asset price movements even under flexible monetary policy, and are led to conclude that historically the federal funds rate did not respond directly to asset price movements.

In the CEE scheme output and inflation are assumed to be unresponsive to current-period monetary policy shocks, but are allowed to exert contemporaneous influences on the setting of the monetary policy instrument. Several authors, such as Sims and Zha (2006) and Iacoviello (2005), have proposed the opposite view that monetary policy does not respond contemporaneously to disturbances in inflation or real GDP. The argument for this view is based on the absence of contemporary data on these variables at the time policy decisions have to be made. Under the third and four specifications, namely sluggish monetary policy and extended Iacoviello, the federal funds rate occupies the first place in the vector Z_t. Hence under these specifications the funds rate cannot respond to current-period innovations to all the other variables. In Extended Iacoviello, output is moved to the last position in Z_t. This specification is, as its name suggests, an extended version of the SVAR system considered in Iacoviello (2005), where R_t, π_t, q_{Ht}, and Y_t, but not q_{St}, are included. The specification considered here differs from his in that we incorporate both house price and stock price. This allows us to analyze the dynamic relationship between house price and stock price. Even if one is mainly interested in studying the dynamic interaction of house price with monetary policy and aggregate fluctuations, it might still be desirable to consider stock price as well in light of the mutual influence between these two asset prices and their respective interactions with monetary policy and the aggregate economy.

We use the following notations throughout the paper. The matrices $A_1, ..., A_p$ refer to the coefficient matrices on $Z_{t-1}, ..., Z_{t-p}$ in the implied reduced-form VAR. Σ denotes the variance-covariance matrix of the vector of reduced-form residuals. The lower-triangular matrix A_0 captures the contemporaneous interactions among the endogenous variables in the SVAR. Finally, Λ is used to denote the variance-covariance matrix of the vector of structural disturbances.

Our sample period covers 1979Q3-2006Q1, which is chosen based on the following considerations. Clarida, Gali, and Gertler (CGG, 2000) find that the Fed policy from 1960s onward can be divided into two periods—the pre-Volcker period and the Volcker-Greenspan period. According to CGG, the pre-Volcker period, which ended in August 1979 when Volcker took office, was characterized by "accommodative" monetary policy whereby the nominal interest rate is raised by less than one-for-one with inflation, giving rise to self-fulfilling inflation expectations. In contrast, the Volcker-Greenspan period[5] was characterized by "aggressive" monetary policy whereby the nominal interest rate is raised by more than one-for-one with inflation, so that both inflation and output are better

[5] Volcker from August 1979 to August 1987, and Greenspan from September 1987 to January 2006.

stabilized. Since we want to look at a historical period where monetary policy is conducted in a relatively consistent manner, i.e., without major structural breaks in the way policy is conducted, we choose to work with the Volcker-Greenspan period. The same consideration leads us to defer to future research investigation of the recent Global Financial Crisis. During the Crisis monetary policy appeared to be "unconventional." (See Cecchetti, 2009, and Reis, forthcoming, among others.) Investigating the interactions between asset prices, the unconventional monetary policy, and aggregate economic fluctuations is undoubtedly a topic of immense importance. We nevertheless opt to focus the present paper on a historical period with a more or less consistent policy rule. The analysis in this paper is thus more about the normal time of business of monetary policy making.

Table 1 summaries the second moments of the variables in our SVARs. It is apparent that real house price is modestly more volatile than real GDP, while real stock price is much more volatile than any other variable. The standard deviation of real stock price is more than 6 times the standard deviation of real house price. Moreover, output, inflation, real stock price, real house price, and the federal funds rate are all positively correlated, except for that the correlation between inflation and real stock price is nearly zero.

[Insert Table 1 about here.]

It is typical in the VAR literature to select the number of lags according to Akaike information criterion (AIC) or Schwarz information criterion (SIC). For our model AIC suggests the number of lags to be 3 while SIC suggests 1. As a compromise we take the number of lags to be 2 for the benchmark. We do check the robustness of our results against the number of lags.

3 Results

The results presented in this section are organized into three broad categories, namely, (1) the effects of monetary policy shocks on output, inflation, and asset prices (2) the interaction of asset prices with the aggregate economy, and (3) the dynamic relationship between stock price and house price. Since our results are broadly robust across the four specifications, the presentation below focuses on the benchmark specification, i.e., extended CEE. The results under this specification are described in Sections 3.1-3. The similarities and differences under the other three specifications will be discussed in Section 3.4.

3.1 The Effects of Monetary Policy Shock

As mentioned earlier, the setting of the monetary policy instrument can be thought of comprising two parts: the anticipated component and the shock component. The anticipated part corresponds to $f(\Omega_t)$ and reflects the federal funds rate's systematic response to changes in the variables contained in the monetary authority's information set, Ω_t, which includes the current and lagged values of output and inflation and the lagged values of asset prices, as well as the exogenous variables. The policy shock is simply the random disturbance ε_t^s. The systematic and shock components of monetary policy play very different roles. Here we look at the effects of the monetary policy shock. The discussion of the role played by systematic monetary policy is deferred to Section 4.

Figure 1 displays the impulse responses with 90% confidence intervals.[6] The third column displays the impulse responses to a one standard deviation (78 basis points) shock to the federal funds rate. In response to such a contractionary monetary policy shock, there is widespread contraction in the economy: output, inflation, stock price, and house price all decline. Output initially changes little and reaches a peak decline of 0.24 percent three quarters after the shock. The output contraction persists for about two years. The decline in inflation appears to be slow and modest, with the maximum decline being 0.06 percentage point. The behavior of output and inflation responses to a monetary policy shock is in line with CEE, suggesting that their results are robust against the introduction of asset prices.

The effects of the monetary policy shock on stock price and house price are both negative, with noticeable differences. First, stock price declines by a much greater extent. The peak decline of house price is 0.24 percent, a magnitude equal to the peak decline in real GDP, while the peak decline of stock price is as large as 1.29 percent. Second, the decline of house price is more persistent than stock price. The peak decline of stock price occurs at the same period of the monetary policy shock, while the largest decline of house price occurs two quarters after the shock. In fact, the decline in house price shares the *hump-shaped* pattern with the decline in real GDP. Third, although the decline in house price is much smaller, its impulse responses are more precisely estimated than those of stock price.

[6] The confidence intervals for the impulse responses are computed by the Monte Carlo method. See Davidson and McKinnon (2004).

[Insert Figure 1 about here.]

The contributions of monetary policy shock to the volatilities of output, inflation, and asset prices can be quantitatively gauged using forecast error variance decomposition. The results are displayed in Table 2. As the forecast horizons tend to infinity, the results correspond to unconditional variance decomposition. It is apparent that after the 4-quarter forecast horizon monetary policy shock accounts for around 17% of the volatility of real GDP, and for around 10% of inflation volatility. Therefore monetary policy shock seems to play important roles in output and inflation fluctuations, consistent with CEE. In addition, the contribution of monetary policy shock to the forecast error variance of house price stays around 17% among the contribution from all shocks after the 4-quarter forecast horizon, while its contribution to the forecast error variance of stock price remains around 8% . These results indicate that monetary policy shock is an important source of house price volatility, and that its contribution to house price volatility is much larger than its contribution to stock price volatility.

[Insert Table 2 about here.]

3.2 Asset Prices and Aggregate Fluctuations

Figure 1 also reveals important interactions between asset price movements and aggregate economic fluctuations. A one-standard deviation shock to stock price (resp. house price) produces a maximum output increase of 0.25 (resp. 0.09) percentage point. It would be tempting to conclude that stock price movements exert larger impacts on output than house price movements. Yet it should be noticed that the standard deviation of stock price shock (5.94 percent) is far greater than that of house price (0.55 percent). If the shocks to these two asset prices were of the same magnitude, say 1 percent, then the influence of the house price shock on output would be far greater than the influence of the stock price shock. We also see from the figure that both asset price shocks stimulate inflation. The peak inflation response to a one standard deviation shock to house price (resp. stock price) is 0.10 (resp. 0.07) percentage point. The responses are quite persistent. In the other direction, both output and inflation shocks produce a decline in house price. In contrast, there is no discernible response of stock price to output shock, while stock price responds positively to inflation shock.

The mutual influences between asset price movements and macroeconomic fluctuations can again be quantitatively gauged by forecast error variance decomposition. Table 2 indicates that the contributions of output shock to the volatilities of both house price and stock price are very limited, with a maximum of 5.56% for house price and a maximum of 3.36% for stock price in the infinite horizon. However, the contributions of inflation shock to asset price volatilities are considerably larger, with 13.04% for house price and 9.19% for stock price in the unconditional variance decompositions.

In contrast to the small contributions of output shock to asset price volatilities, shocks to asset prices turn out to be important sources of output fluctuations. Although house price shock accounts for small portions of the forecast error variance for output at short horizons, its contribution to overall output volatility is above 13% in long horizons. The contribution of stock price shock to output forecast error variance ranges between 15% and 20% ever since the 4-quarter horizon. Furthermore, asset price shocks, especially house price shock, figure prominently in generating inflation volatility. They are in fact *the most important* sources of inflation fluctuations other than the shock to inflation itself. In the unconditional variance decomposition, house price shock and stock price shock contribute 21.92% and 12.93% respectively to inflation volatility, while monetary policy shock and output shock accounts for only 11.43% and 4.36% respectively.

3.3 The Comovement between House Price and Stock Price

Another important message from the impulse responses displayed in Figure 1a is that asset prices exhibit positive comovement, i.e., a positive shock to stock price drives house price up and vice versa. In particular, a one standard deviation shock to house price leads to a maximum increase in stock price by close to 2 percent, while the maximum response of house price to a one standard deviation shock to stock price is about 0.20 percent. There are various reasons for the positive comovement between house price and stock price. First, an increase in the price of one asset raises the wealth of households and firms, thereby pushing up the demand and hence the price for the other asset through a direct wealth effect. Second, the increase in the price of any asset raises the net worth of households and firms and hence strengthens their balance sheets. This allows them to borrow more at lower costs, which stimulates investment and bids up asset prices. Third, an increase in stock price might trigger the expectation that house price will also increase, and vice versa, leading to expectation-driven movements in asset prices.

The variance decomposition in Table 2 shows that more than 50% of forecast error variance of asset price, be it house price or stock price, is attributable to the shock to that asset price itself, which leaves relatively little to be explained by other shocks. Still, house price and stock price exhibit interesting interaction with each other. In the unconditional variance decomposition for house price, the contribution from stock price shock is 11.68%, larger than the contribution from output shock and only slightly smaller than the contribution from inflation shock. In the unconditional variance decomposition for stock price, the contribution from house price shock is 14.31%. In fact, house price shock is the largest source of stock price volatility other than the shock to stock price itself. The contribution of house price shock to stock price volatility is considerably larger than the contribution from monetary policy, inflation, or output shock. Note that house price shock is more important in explaining stock price volatility than the other way round. For house price, monetary policy shock is the largest source of fluctuations other than the shock to house price itself.

3.4 Robustness

In the previous subsections we have taken the CEE scheme extended to include asset prices as the baseline identification scheme, which is based on the notion of short-run recursiveness. For short-run recursiveness identification schemes the inference results depend to various extents on the ordering of the variables included in the SVAR. Hence it is important to assess the robustness of our results against different ordering of variables.

Regarding the effects of monetary policy shocks, a positive federal funds rate shock broadly leads to output contraction and decline in inflation across all the four specifications. However, there are initial increases in output and inflation when monetary policy is sluggish (sluggish monetary policy and extended Iacoviello). These initial increases are absent under extended CEE and flexible monetary policy. Under all the four specifications house price declines in response to contractionary monetary policy shocks. Stock price declines under extended CEE and extended Iacoviello. It is almost unresponsive under flexible monetary policy and even increases under sluggish monetary policy. Thus the decline in house price appears to be a more robust feature than the decline in stock price. Moreover, the response of stock prices are less precisely estimated.

The effects of asset price shocks on output and inflation are quite robust across the specifications. A positive house price shock leads to an initial increase (up to 7 quarters) and subsequent decline in output. The (positive) output effects generated by stock price shocks appear to be stronger. Both asset price shocks generate persistent increases in inflation.

Looking at the effects of output and inflation shocks on asset prices, house price responds negatively to output shocks under all specifications. Stock price is almost unresponsive to output shock under extended CEE and flexible monetary policy, as well as in extended Iacoviello. It shows an imprecisely estimated decline in response to output shock under sluggish monetary policy. As for the effects of inflation shocks, house price responds negatively to such shocks under extended CEE and flexible monetary policy. Its responses are less clear-cut under sluggish monetary policy and extended Iacoviello: It increases after a short, small initial declines under these two specifications. On the other hand, stock price increases in response to inflation shock under extended CEE, flexible monetary policy, and extended Iacoviello. It shows little response under sluggish monetary policy.

Turning to the comovement of asset prices, a positive shock to house price stimulates increases in stock price, and vice versa across all specifications. Thus the positive comovement between house price and asset price turns out to be robust.

The variance decomposition results are broadly robust across the specifications.[7] For the forecast error variances of output, the results are quite similar between extended CEE and flexible monetary, as well as between sluggish monetary policy and extended Iacoviello. Extended CEE/flexible monetary policy differs from sluggish monetary policy and extended Iacoviello at short-forecast horizons (the first two quarters). Under sluggish monetary policy/extended Iacoviello, the federal funds rate shock accounts for some (about 15%) of the forecast error variance of real GDP over short horizons, whereas the funds rate shock accounts for virtually nothing of the forecast error variance of output over the same horizons under extended CEE/flexible monetary policy. The gain in the contribution of federal funds rate shock when we switch from sluggish monetary policy/extended Iacoviello to extended CEE/flexible monetary policy obtains at the expense of the contribution of the shock to output itself. Similar comparison of results obtains for the forecast error variances of inflation.

The results for the variance decomposition for the forecast error variances of house price are similar among extended CEE, sluggish monetary policy, and extended Iacoviello. Compared to these three specifications, the contribution of monetary policy shock to the

[7] To save space, the variance decomposition results for flexible monetary, sluggish monetary policy and extended Iacoviello are not shown. They are available from the authors upon request.

forecast error variance of house price is much smaller under flexible monetary policy at all forecast horizons. The same thing can be said for the forecast error variances of stock price.

Within the extended CEE scheme, we have defended ordering stock price q_{St} behind house price q_{Ht} on the basis that the former is more flexible than the latter. Although we regard this assumption as quite plausible, we nevertheless verify the robustness of our results against rearranging the relative ordering of these two asset prices in the SVAR system. We find that the impulse responses when house price is ordered behind stock price are similar to those under the baseline specification. The major difference is that under the perturbed ordering stock price does not react contemporaneously to house price shock by restriction, while house price changes in the period when the stock price shock occurs.

The other robustness checks we have conducted include: (1) changing the number of lags from 2 to 3 (as AIC indicates), (2) using the consumer price index (CPI) instead of GDP deflator to deflate nominal asset prices, and (3) using the American Stock Exchange's AMEX index to replace the S&P500 index as the measure of stock price. Broadly speaking, the results remain robust against these changes.

4 Systematic Monetary Policy

4.1 The Reaction Function and the Funds Rate Volatility

The SVAR with short-run recursiveness assumption implies a rule for monetary policy setting represented by an equation of the form:

$$R_t = e_R \left(A_1 Z_{t-1} + \cdots + A_p Z_{t-p} + C W_t + A_0 \varepsilon_t \right),$$

where e_R is the $1 \times n$ unit vector with one on the place corresponding to R_t and zero otherwise (multiplying e_R with a particular coefficient matrix gives the the row in that matrix that corresponds to the position of R_t in the vector Z_t). Table 3 lists the A matrices under the four specifications.

[Insert Table 3 about here.]

The A_1 and A_2 matrices in the reduced form VARs are the same under all specifications, up to permutation of the rows and columns in accordance with the ordering of variables. Looking at the monetary policy equation, although none of the coefficients on lagged non-policy variables is statistically significant at the 90% level of confidence, the point estimates and t-statistics for the coefficients on lagged output and inflation far exceed the point estimates and t-statistics for the coefficients on lagged house price and stock price. The coefficients on lagged asset prices are all close to zero, while the coefficient on output is quite large for the first lag and the coefficient on inflation is large even for the second lag. The first lag of inflation takes the largest coefficient within the rows of A_1 and A_2 matrices that correspond to R_t.

The contemporaneous reactions of monetary policy to changes in non-policy variables are captured in the rows of the A_0 matrices that correspond to R_t. Under extended CEE, both output and inflation have positive contemporaneous impacts on the federal funds rate that are statistically significant at the 95% level of confidence. On the other hand, the identification assumption of extended CEE implies that the federal funds rate does not react contemporaneously to movements in asset prices (q_{Ht} and q_{St}). Given that the lagged values of asset prices do not exert significant impact on the federal funds rate (as shown in the A_1 and A_2 matrices), we are lead to the conclusion that monetary policy does not respond systematically to asset price movements, though they do react to output and inflation movements in a systematic fashion.

It is possible that the above conclusion hinges on the assumption of extended CEE that permits contemporaneous reactions of monetary policy to output and inflation movements but deprives the federal funds of reactions to asset price movements at the same time. To verify whether this is the case we look at the last row in the A_0 matrix under flexible monetary policy, when contemporaneous reactions of monetary policy to all non-policy variables are allowed. It is clear that output and inflation again have significantly positive coefficients. Furthermore, the values of these coefficients are almost identical to those under extended CEE. A one-percent increase in real GDP leads to an increase in the federal funds rate by about 0.32 percentage point, while a one percentage point increase in inflation results in an increase in the federal funds rate by about 0.19 percentage point. On the other hand, the coefficients on current asset prices seem to have the “wrong” sign. They are negative for both house price and stock price. However, the negative coefficient on current house price appears to be insignificant at the 90% level of confidence. The negative coefficient on stock price is significant at 90% confidence but insignificant at the 95% level, whereas the positive coefficients on output and inflation are both significant at 95% level of confidence.

The sluggish monetary policy and extended Iacoviello specifications by assumption rule out any contemporaneous reactions of monetary policy to movements in asset prices. Hence we are led to the conclusion, after examining the results under the four specifications, that monetary policy does not react systematically to asset price movements during the Volcker-Greenspan period. Note that under sluggish monetary policy and extended Iacoviello neither output nor inflation, current or lagged, has statistically significant impact on monetary policy setting. In contrast, significant impacts of output and inflation on the federal funds rate are well captured by extended CEE (and flexible monetary policy as well). These results suggest that restricting monetary policy to respond only sluggishly to all non-policy variables results fails to deliver a policy reaction function in a statistically significant fashion. Although Sims and Zha (2006) motivates their restriction on monetary policy response to contemporaneous disturbances to output and the price level, they acknowledge the fact that policy makers obviously have other sources of information about the economy than the published data, and might have a strong interest in using it to get accurate assessments of the state of the economy. Hence monetary policy is not likely to be entirely sluggish.

Looking at the impulse responses (Figures 1a-d), the federal funds rate increases in response to positive inflation shocks under all specifications. There are sizable increases in the federal funds rate in response to a positive output shock under extended CEE and flexible monetary policy. Under sluggish monetary policy and extended Iacoviello the federal funds rate has only modest increases in response to a positive output shock. Under the latter two specifications, the federal funds rate is denied contemporaneous responses to this shock, and its subsequent responses do not appear to be strong.

Interestingly, the responses of the federal funds rate to asset price shocks mimic the responses of inflation to these shocks in a robust fashion. Under extended CEE, sluggish monetary policy, and extended Iacoviello, the federal funds rate by assumption has no contemporaneous reaction to asset price shocks but increases persistently after the shock period. Under flexible monetary policy, where contemporaneous reactions of the federal funds rate to asset price shocks are allowed for, there are negative, yet insignificant initial responses of the federal funds rate to positive asset price shocks. After that, the federal funds rate again is persistently above the pre-shock level.

The last block of Table 2 shows the forecast error variance decomposition for the federal funds rate under the benchmark specification, i.e., extended CEE. For short forecast horizons, monetary policy shock is the dominant source of federal funds rate variability. Output and inflation shocks have significant influences on the federal funds rate, while asset price movements only have negligible influences. Over time inflation shock gains importance. And house price and stock price shocks exert significant impacts on federal funds rate variability over long forecast horizons. In the unconditional variance decomposition, monetary policy shock accounts for about 38% of federal funds rate volatility, inflation shock accounts for about 23%, output shock, house price shock and stock price shock each accounts for something in between 12% and 14%. These results indicate that unpredictable shifts in monetary policy account for less than 40% of variations in the value assumed by the monetary policy instrument, and that the bulk of monetary policy actions have historically been systematic reactions to the state of the economy, rather than unpredictable changes. Although asset price shocks have little influence on the federal funds rate in the short run, over time they exert more and more influences on the policy rate through their influences on output and inflation. Hence despite the lack of direct response of monetary policy to asset price movements, these movements are not to be neglected when accounting for the volatility of the federal funds rate. In fact, each of the two asset price shocks is as important as output shock in the long run.

The variance decomposition results for the forecast error variances of the federal funds rate are similar between extended CEE and flexible monetary, as well as between sluggish monetary policy and extended Iacoviello. Extended CEE/flexible monetary policy differs from sluggish monetary policy/extended Iacoviello in that the contributions of output and inflation shocks to federal funds rate volatility is considerably higher under extended CEE/flexible monetary policy at all forecast horizons. This is especially true for output shock and for shorter forecast horizons.

4.2 Has Monetary Policy Helped Stabilize the Aggregate Economy and Asset Prices?

Given that the bulk of monetary policy actions have historically been systematic reactions to the state of the economy, rather than unpredictable changes, assessment of the overall effects of monetary policy, as opposed to merely the effects of unpredictable changes in policy, must therefore consider what would happen if the systematic component of monetary policy were different. This is done by analyzing the impulse responses for a system in which the model's estimated monetary policy reaction function is replaced by one in which the monetary policy instrument is completely unresponsive to other variables in the system, that is, the monetary authority holds the monetary policy instrument such as the federal funds rate fixed in face of non-policy disturbances.

The idea of the counterfactual experiment is that we take the estimated benchmark recursive SVAR as the "true" model. That is, we take the estimated $A_0, A_1, ..., A_p$, and $\Lambda \equiv E(\varepsilon_t \varepsilon_t')$ as true parameters. We then perform a thought experiment on the true system, in the spirit of "*ceteris paribus*". In particular, we keep intact Λ and the non-monetary-policy rows of $A_0, A_1, ..., A_p$. We then change the monetary-policy rows of $A_0, A_1, ..., A_p$ by setting the coefficients on the current and lagged values of all variables other than the federal funds rate to be zero. The coefficients on lagged federal funds rate are kept unchanged. In doing so we take the structure of the economy, which is represented by Λ and the non-monetary-policy rows of the A matrices, as given, but change the nature of the monetary policy. Similar counterfactual experiments have been performed by Bernanke, Gertler, and Watson (1997) and Sims and Zha (2006), in contexts that do not involve asset prices.

Holding all equations of the system other than the monetary policy equation fixed means that we are ignoring changes in the dynamics of the private sector that would occur if private agents modified the way they forecast the economy under the new policy rule. That is, we are not thinking of the change in agents' belief in the policy rule and its impact on their behavior, as the Lucas critique emphasizes, as being important for our purpose. Sims and Zha (2006) argue that this is nonetheless an interesting exercise, for practical purposes even more interesting than an exercise that "takes account of" the Lucas critique via the "unreasonable" assumption that the policy change is immediately and fully understood and that the public believe that the change is permanent. Our counterfactual exercise therefore rests on the assumption that policy changes, but private agents are surprised by the change, even though it is in a systematic fashion. Relatedly, Leeper and Zha (2003) argue that if policy interventions are "modest" then they will not shift agents' beliefs about policy regime and will not induce changes in agents' behavioral rule, so that policy impacts can be reliably predicted by an identified VAR model.

We now investigate the effects of the systematic component of monetary policy. By comparing the impulse responses under the original SVAR and the counterfactual one, we are able to gauge the importance of systematic monetary policy in smoothing aggregate fluctuations induced by various sources of shocks in the economy. These impulse responses are displayed in Figure 2. Under the original SVAR, the federal funds rate is raised in response to positive shocks to output, inflation, and asset prices, whereas the rate is unresponsive to the shocks in the counterfactual SVAR. In general, the responses of output and inflation to the structural disturbances are smaller under the original SVAR, meaning that systematic monetary policy does help smooth output and inflation.

[Insert Figure 2 about here.]

To evaluate quantitatively the difference made by shutting the responses of monetary policy to non-monetary shocks, Table 4 lists the cumulative values of impulse responses over the first 20 quarters under the two SVARs. First look at the effects of the non-policy shocks. As indicated in the table, the cumulative output response to output shock (the most important source of output fluctuations) under the benchmark SVAR is only 62% as large as that under the counterfactual. The output response to stock price shock under the benchmark is only 27% of the response under the counterfactual. When moving from the counterfactual to the benchmark, the cumulative responses of output to inflation and house price shocks turn positive to negative and become larger in absolute value. However, the latter two shocks are the least important sources of output fluctuations. The stabilizing effect of the systematic monetary policy is even more pronounced when it comes to inflation. The cumulative responses of inflation to all the four non-policy shocks are all smaller under the benchmark as compared to the counterfactual. The cumulative inflation response to inflation shock under the benchmark is only half of the response under the counterfactual. Although the estimated systematic monetary policy does not appear to respond directly to asset price movements, the responses of inflation to the two asset prices shocks are substantially smaller under the benchmark SVAR, where systematic monetary policy applies.

[Insert Table 4 about here.]

Now turn to the effects of the monetary policy shock. It is striking that the estimated systematic monetary policy succeeds in mitigating the effects of unpredictable shifts in monetary policy, i.e., innovations to the federal funds rate. Switching from the counterfactual to the benchmark, the cumulative first 20-quarter decline of output in response to a contractionary funds rate shock reduces from 1.42 percent to only 0.33 percent, while the corresponding decline of inflation reduces from 1.01 to 0.56 percentage point. This implies that to the extent that disturbances to monetary policy making are unavoidable, having a policy rule that dictates systematic reactions of the policy instrument to output and inflation movements actually helps avoid some of the economy's fluctuations that would otherwise result from those disturbances.

Another surprising effect of the estimated monetary policy is that it turns out to help buffer house price from monetary policy shock as well as the non-policy shocks, despite that the policy does not directly react to house price movements. In fact, reacting only to output and inflation movements allows systematic monetary policy to actually stabilize house price to a large extent. The systematic policy reduces the cumulative house price response to house price shock by 40% and the response to stock price shock by 65%. In addition, it almost completely eliminates the impact of output shock on house price, though it turns the cumulative response of house price to inflation shock from positive to a negative number larger in absolute value. Finally, the systematic policy reduces the cumulative first 20-quarter decline of house price in response to a contractionary monetary policy shock by half. In sharp contrast, the systematic monetary policy does not help stabilize stock price by much.[8] Hence the role of the systematic monetary policy on asset price fluctuations is quite asymmetric. Its has a substantial stabilizing effect on house

[8]Although the cumulative decline of stock price in response to a contractionary monetary policy shock also decreases under the benchmark relative to the counterfactual, it results from the cancellation of some of the negative responses within the first 11 quarters by the positive responses after 11 quarters, the cancellation only present under the benchmark.

price but not on stock price.

5 Conclusions

In this paper we have investigated empirically the dynamic interactions between asset prices, monetary policy, and aggregate fluctuations during the Volcker-Greenspan period. Several robust findings emerge out of four different specifications of SVARs falling within the short-run recursiveness scheme. The systematic response of monetary policy to output and inflation is found to play an important role in stabilizing the aggregate economy. Our results call for special attention to be paid to house price when studying the dynamic relationships between asset prices and the macroeconomy. In future research other identification strategies, such as long-run restrictions (Blanchard and Quah, 1989) and sign restrictions (Faust, 1998; Canova and Nicolo, 2002; Uhlig, 2005), can be explored. The different identification schemes can also be combined using Bayesian techniques as in Lastrapes (1998). Simple as it is, the framework adopted in the present paper have appeared to deliver a rich set of important results. On another front, the focus on a historical period where monetary policy is conducted in a relatively consistent manner has led us to work with the Volcker-Greenspan period. It is an important task in future research to study the interactions between asset prices, macroeconomic performance, and the "unconventional" monetary policy.

References

[1] Akram, Q. Farooq, Gunnar Bardsen, and Øyvind Eitrheim (2006), "Monetary Policy and Asset Prices: To Respond or Not?" *International Journal of Finance and Economics*, **11**(2): 279–292.

[2] Bernanke, Ben S., and Mark Gertler (1999), "Monetary Policy and Asset Price Volatility." *Economic Review*, Federal Reserve Bank of Kansas City, Fourth Quarter, 17–51.

[3] Bernanke, Ben S., and Mark Gertler (2001), "Should Central Banks Respond to Movements in Asset Prices?" *American Economic Review*, **91**(2), 253–257.

[4] Bernanke, Ben S., Mark Gertler, and Mark Watson (1997), "Systematic Monetary Policy and the Effects of Oil Price Shocks." *Brookings Papers on Economic Activity*, **1**, 91–142.

[5] Bernanke, Ben S., and Kenneth N. Kuttner (2005), "What Explains the Stock Market's Reaction to Federal Reserve Policy." *Journal of Finance*, **60**(3): 1221–57.

[6] Blanchard, Olivier Jean, and Danny Quah (1989), "The Dynamic Effects of Aggregate Demand and Supply Disturbances," *American Economic Review*, **79**(4): 655–673.

[7] Bordo, Michael D., Michael J. Dueker, and David C. Wheelock (2007), "Monetary Policy and Stock Market Booms and Busts in the 20th Century." Federal Reserve Bank of St. Louis Working Paper.

[8] Canova, Fabio, and Gianni De Nicolo (2002), "Monetary Disturbances Matter for Business Cycle Fluctuations in the G-7," *Journal of Monetary Economics*, **49**: 1131–1159.

[9] Cecchetti, Stephen, Hans Genberg, John Lipsky, and Sushil Wadhwani (2000), "Asset Prices and Central Bank Policy." *Geneva Reports on the World Economy*, vol. 2. Geneva: International Center for Monetary and Banking Studies; London: Centre for Economic Policy Research.

[10] Cecchetti, Stephen (2009), "Crisis and Responses: The Federal Reserve in the Early Stages of the Financial Crisis," *Journal of Economic Perspectives*, **23**, 51–75.

[11] Chen, Nan-Kuang, and Charles Ka Yui Leung (2007), "Asset Price Spillover, Collateral and Crises: with an Application to Property Market Policy," *Journal of Real Estate Finance and Economics*, **37**: 351–385.

[12] Christiano, Lawrence J., Martin Eichenbaum, and Charles Evans (1999), "Monetary Policy Shocks: What Have We Learned and to What End?" in John Taylor and Michael Woodford (ed.), *Handbook of Macroeconomics*, Vol. 1, Elsevier.

[13] Davidson, Russell, and James G. MacKinnon (2004), *Econometric Theory and Methods*, New York: Oxford University Press.

[14] Del Negro, Marco, and Christopher Otrok (2007), "99 Luftballons: Monetary Policy and the House Price Boom across U.S. States," *Journal of Monetary Economics*, **54**, 1962–1985.

[15] DeStefano, Michael (2004), "Stock Returns and the Business Cycle." *The Financial Review*, **39**(4): 527–547.

[16] Fama, Eugene F., and Kenneth R. French (1989), "Business Conditions and Expected Returns on Stocks and Bonds." *Journal of Financial Economics*, **25**(1): 23–49.

[17] Faust, Jon (1998), "The Robustness of Identified VAR Conclusions about Money," *Carnegie-Rochester Conference Series on Public Policy*, **49**: 207–244.

[18] Iacoviello, Matteo (2005), "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle." *American Economic Review*, **95**(3): 739–764.

[19] Iacoviello, Matteo, and Raoul Minetti (2003), "Financial Liberalisation and the Sensitivity of House Prices to Monetary Policy: Theory and evidence," *The Manchester School*, **71**(1), 20–34.

[20] Iacoviello, Matteo, and Raoul Minetti (2008), "The Credit Channel of Monetary Policy: Evidence from the Housing Market." *Journal of Macroeconomics*, **30**(1): 69–96.

[21] Jaccard, Ivan (2009), "Asset Pricing, Housing Markets and the Business Cycle: a Macro-Finance Approach," Working paper, European Central Bank.

[22] Jin, Yi, and Zhixiong Zeng (2004), "Residential Investment and House Prices in a Multi-Sector Monetary Business Cycle Model," *Journal of Housing Economics*, **13**: 268–286.

[23] Kontonikas, Alexandros, and Alberto Montagnoli (2004), "Has Monetary Policy Reacted to Asset Price Movements? Evidence from the UK." *Ekonomia*, **7**(1), 18–33.

[24] Lastrapes, William D. (1998), "The Dynamic Effects of Money: Combining Short-Run and Long-Run Identifying Restrictions using Bayesian Techniques," *Review of Economics and Statistics*, **80**(4): 588–599.

[25] Leeper, Eric M., and Tao Zha (2003), "Modest Policy Interventions," *Journal of Monetary Economics*, **50**, 1673–1700.

[26] Leung, Charles Ka Yui (2004), "Macroeconomics and Housing: A Review of the Literature," *Journal of Housing Economics*, **13**, 249–267.

[27] Patelis, A. (1997), "Stock Return Predictability and the Role of Monetary Policy." *Journal of Finance*, **52**(4): 1951–1972.

[28] Reis, Ricardo (forthcoming), "Interpreting the Unconventional U.S. Monetary Policy of 2007-09," *Brookings Papers on Economic Activity*.

[29] Semmler, Willi, and Wenlang Zhang (2007), "Asset Price Volatility and Monetary Policy Rules: A Dynamic Model and Empirical Evidence." *Economic Modelling*, **24**(3): 411–430.

[30] Sims, Christopher A. (1992), "Interpreting the Macroeconomic Time Series Facts: the Effects of Monetary Policy," *European Economic Review*, **36**(5), 975–1000.

[31] Sims, Christopher A., and Tao Zha (2006), "Does monetary policy generate recessions?" *Macroeconomic Dynamics*, 10(2), 231–272.

[32] Thorbecke, Willem (1997), "On Stock Market Returns and Monetary Policy." *Journal of Finance*, **52**(2): 635–654.

[33] Uhlig, Harald (2005), "What Are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure," *Journal of Monetary Economics*, **52**: 381–419.

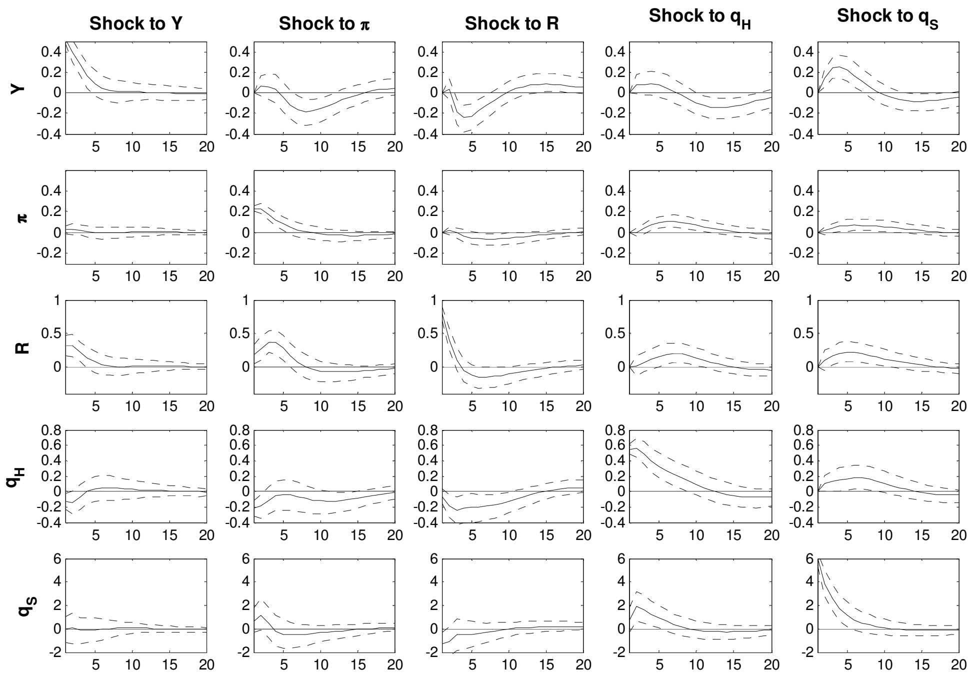

Figure 1a. Impulse Responses under extended CEE

Note: The dashed lines represent 90% confidence intervals for the impulse responses.

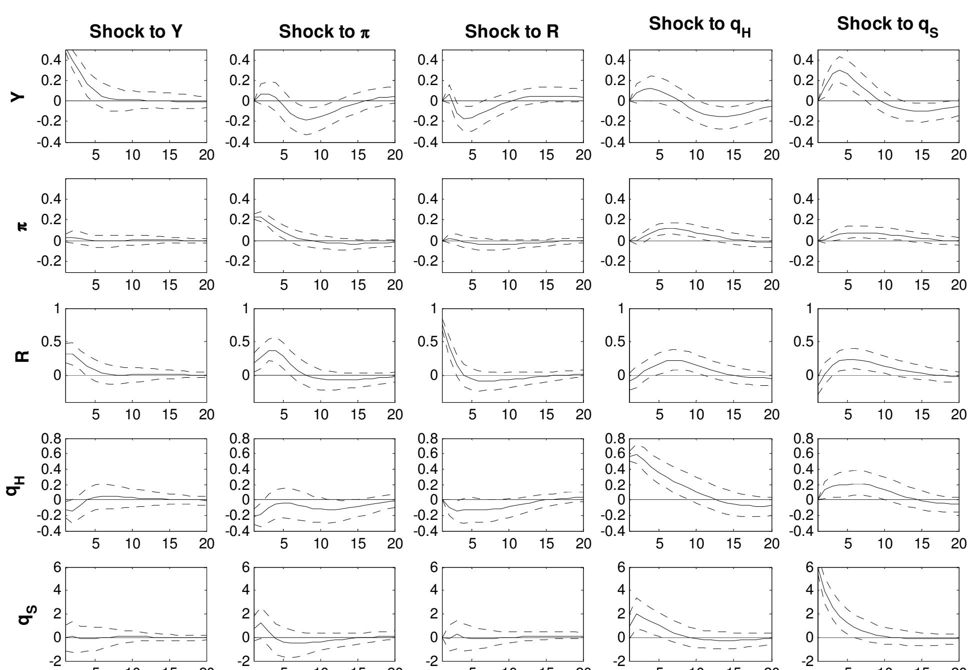

Figure 1b. Impulse Responses under Flexible Monetary Policy

Note: The dashed lines represent 90% confidence intervals for the impulse responses.

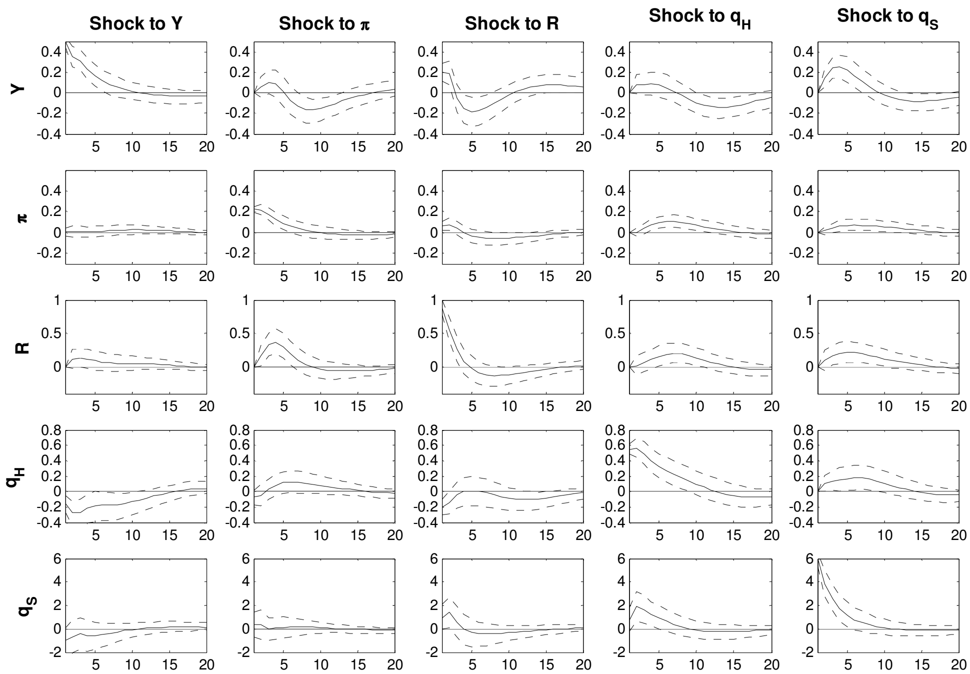

Figure 1c. Impulse Responses under Sluggish Monetary Policy

Note: The dashed lines represent 90% confidence intervals for the impulse responses.

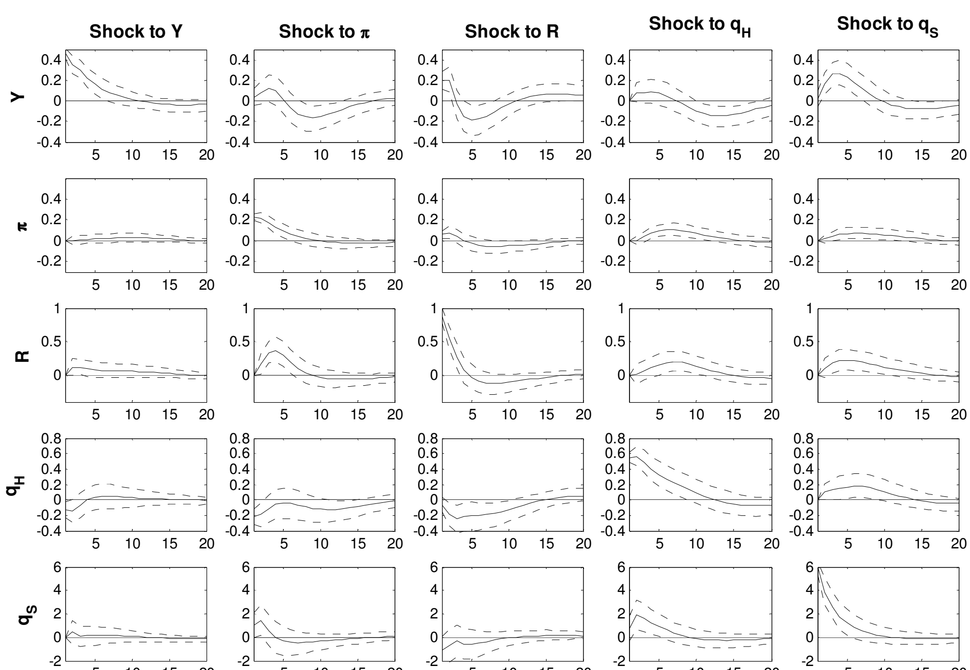

Figure 1d. Impulse Responses under Extended Iacoviello

Note: The dashed lines represent 90% confidence intervals for the impulse responses.

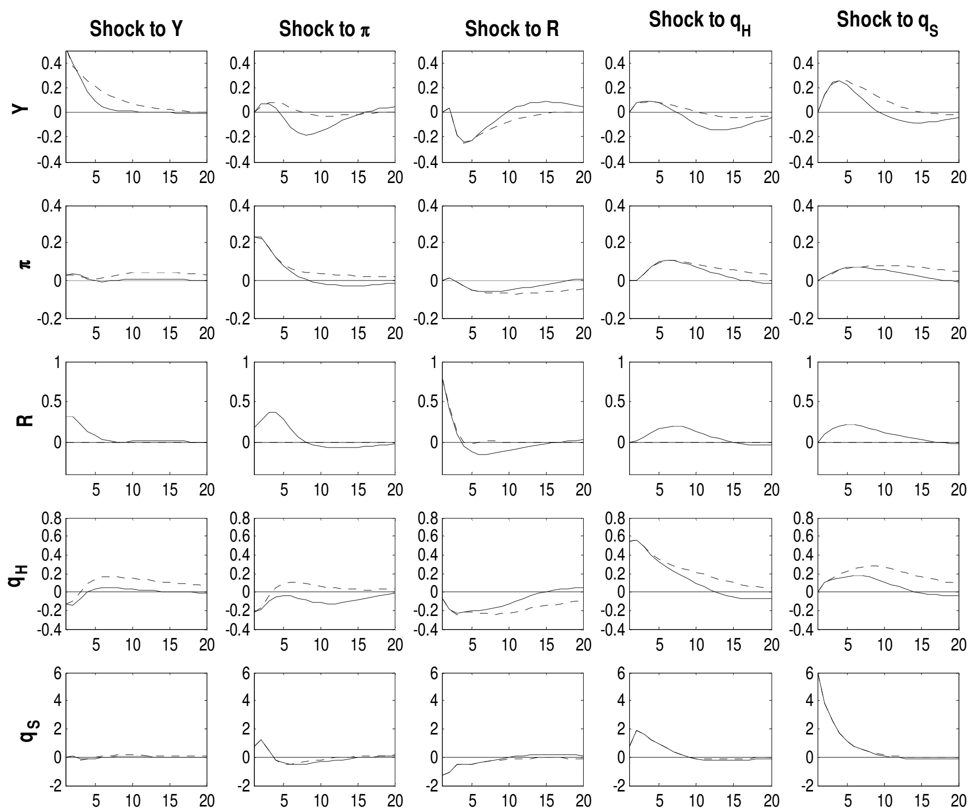

Figure 2. Impulse Responses under Benchmark vs. Counterfactual

Solid lines: benchmark, dashed lines: counterfactual

Table 1. Second Moment Properties

a. Volatilities

	Standard deviation
Real GDP	0.013
Inflation	0.006
Federal funds rate	0.016
House price	0.016
Stock price	0.100

b. Correlations

	Real GDP	Inflation	Funds rate	House price	Stock price
Real GDP	1.00				
Inflation	0.26	1.00			
Funds rate	0.42	0.76	1.00		
House price	0.43	0.49	0.37	1.00	
Stock price	0.34	0.03	0.05	0.25	1.00

Table 2. Variance Decomposition: Extended CEE

Quarters	Y					π				
	Y shock	π shock	q_H shock	q_S shock	R shock	Y shock	π shock	q_H shock	q_S shock	R shock
1	100.00	0.00	0.00	0.00	0.00	2.36	97.64	0.00	0.00	0.00
	[100, 100]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.00]	[0.01, 7.89]	[92.11, 99.99]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.00]
2	91.12	1.57	1.91	4.47	0.93	3.24	94.71	0.54	0.77	0.74
	[83.36, 97.11]	[0.01, 5.41]	[0.02, 5.97]	[0.57, 10.24]	[0.00, 3.52]	[0.08, 10.02]	[87.53, 98.97]	[0.00, 2.09]	[0.00, 2.95]	[0.00, 2.78]
4	64.16	2.74	3.70	16.87	12.52	3.54	84.64	5.28	4.19	2.34
	[48.23, 79.40]	[0.16, 8.92]	[0.17, 10.81]	[6.52, 29.29]	[3.36, 25.00]	[0.25, 10.61]	[72.50, 94.15]	[0.78, 13.48]	[0.28, 11.42]	[0.20, 7.04]
8	47.18	10.08	4.68	20.05	18.01	3.81	59.53	18.80	9.98	7.88
	[31.31, 65.00]	[2.23, 21.76]	[0.52, 12.50]	[7.15, 35.76]	[4.91, 34.10]	[0.47, 10.64]	[40.52, 78.58]	[5.26, 35.18]	[1.46, 22.75]	[0.95, 19.93]
12	41.43	14.83	8.26	18.73	16.75	4.09	52.06	21.34	12.11	10.39
	[26.53, 58.45]	[4.12, 29.17]	[1.95, 17.47]	[7.01, 33.68]	[5.03, 31.57]	[0.64, 10.90]	[31.94, 72.73]	[6.88, 39.02]	[2.29, 26.73]	[1.45, 24.68]
20	36.13	14.28	13.02	19.11	17.46	4.31	50.48	21.45	12.68	11.08
	[21.36, 52.94]	[4.25, 27.77]	[4.06, 25.28]	[7.55, 34.12]	[5.45, 32.50]	[0.71, 11.15]	[29.78, 71.37]	[6.88, 39.02]	[2.56, 28.24]	[1.68, 25.66]
∞	34.75	14.83	13.75	19.10	17.57	4.36	49.35	21.92	12.93	11.43
	[20.07, 51.62]	[4.41, 28.82]	[4.25, 26.98]	[7.41, 34.34]	[5.40, 32.67]	[0.70, 11.35]	[27.89, 71.08]	[7.02, 39.62]	[2.60, 28.81]	[1.70, 26.79]

Table 2 (con't). Variance Decomposition: Extended CEE

Quarters	q_H					q_S				
	Y shock	π shock	q_H shock	q_S shock	R shock	Y shock	π shock	q_H shock	q_S shock	R shock
1	5.26	13.38	79.30	0.00	2.04	1.12	3.46	2.38	89.16	5.08
	[0.23, 13.44]	[3.89, 24.49]	[66.99, 90.81]	[0.00, 0.00]	[0.01, 6.65]	[0.00, 4.29]	[0.06, 10.25]	[0.02, 7.86]	[79.18, 97.09]	[0.22, 12.96]
2	5.89	11.53	74.63	1.80	6.15	1.63	6.18	7.91	79.95	5.99
	[0.40, 15.01]	[2.52, 23.24]	[60.48, 87.77]	[0.03, 5.09]	[0.49, 15.16]	[0.07, 5.29	[0.46, 15.91]	[1.02, 17.94]	[66.96, 91.48]	[0.52, 14.90]
4	4.88	9.15	69.23	4.82	11.92	2.28	6.73	11.85	74.00	6.65
	[0.75, 12.64]	[2.07, 20.92]	[52.31, 84.36]	[0.28, 12.55]	[1.37, 26.59]	[0.21, 6.72]	[0.98, 16.80]	[1.82, 25.54]	[58.23, 87.53]	[0.96, 16.68]
8	5.38	9.15	59.50	9.70	16.27	3.09	8.26	12.94	68.98	7.56
	[0.93, 12.79]	[2.18, 22.21]	[40.66, 77.23]	[0.89, 23.77]	[2.29, 35.66]	[0.37, 8.74]	[1.60, 18.94]	[2.54, 27.47]	[51.28, 84.34]	[1.30, 18.75]
12	5.58	11.46	53.45	10.94	17.12	3.25	8.82	13.36	67.36	7.80
	[1.00, 13.32]	[2.95, 26.70]	[34.34, 72.46]	[1.14, 27.55]	[2.65, 37.34]	[0.42, 8.94]	[1.76, 19.87]	[2.93, 27.71]	[49.09, 83.12]	[1.46, 19.01]
20	5.55	12.79	52.69	11.33	16.88	3.31	8.97	14.05	65.95	8.19
	[1.08, 13.31]	[3.70, 28.37]	[32.61, 72.10]	[1.55, 28.04]	[2.73, 36.53]	[0.46, 9.05]	[1.85, 20.09]	[3.33, 28.46]	[46.58, 82.34]	[1.62, 19.86]
∞	5.56	13.04	53.86	11.68	17.03	3.36	9.19	14.31	65.18	8.39
	[1.07, 13.34]	[3.75, 28.90]	[32.66, 75.14]	[1.63, 28.42]	[2.79, 36.76]	[0.47, 9.10]	[1.95, 20.62]	[3.46, 28.97]	[44.65, 82.09]	[1.68, 20.14]

Table 2 (con't). Variance Decomposition: Extended CEE

Quarters	*R*				
	Y shock	π shock	q_H shock	q_S shock	*R* shock
1	14.11	5.45	0.00	0.00	80.44
	[4.30, 26.09]	[0.42, 13.32]	[0.00, 0.00]	[0.00, 0.00]	[68.31, 91.42]
2	18.42	10.53	0.78	1.48	68.79
	[6.64, 32.22]	[2.16, 21.76]	[0.00, 3.00]	[0.01, 5.01]	[54.57, 82.34]
4	17.61	24.03	2.52	5.93	49.91
	[6.48, 31.19]	[9.92, 39.66]	[0.16, 7.64]	[0.73, 13.88]	[36.00, 64.97]
8	14.43	23.62	8.88	11.81	41.26
	[5.30, 26.33]	[10.06, 39.61]	[1.39, 20.25]	[2.94, 24.11]	[27.01, 55.76]
12	13.63	22.92	10.93	13.11	39.41
	[5.20, 25.18]	[9.85, 38.37]	[1.99, 23.73]	[3.92, 26.02]	[25.00, 54.05]
20	13.32	23.38	11.62	13.34	38.35
	[5.19, 24.58]	[10.22, 38.90]	[2.54, 24.83]	[4.19, 26.60]	[23.84, 53.11]
∞	13.12	23.27	12.20	13.52	37.90
	[4.98, 24.33]	[10.10, 38.74]	[2.66, 26.08]	[4.30, 26.83]	[23.21, 52.83]

Note: The entries are percentage contributions of the shocks to the forecast error variances. The numbers in parentheses denote 90% confidence intervals.

Table 3. The Estimated *A* Matrices

A_0: Extended CEE

1	0	0	0	0
0.026 (0.024)	1	0	0	0
0.316 (0.091)**	0.188 (0.086)**	1	0	0
-0.127 (0.064)**	-0.218 (0.061)**	-0.067 (0.058)	1	0
-0.041 (0.676)	0.710 (0.678)	-1.269 (0.632)**	0.749 (0.620)	1

A_0: Flexible Monetary Policy

1	0	0	0	0
0.026 (0.025)	1	0	0	0
-0.130 (0.066)**	-0.220 (0.061)**	1	0	0
-0.063 (0.667)	0.738 (0.670)	0.910 (0.658)	1	0
0.318 (0.088)**	0.187 (0.085)**	-0.096 (0.081)	-0.150 (0.080)*	1

A_0: Sluggish Monetary Policy

1	0	0	0	0
0.194 (0.053)**	1	0	0	0
0.059 (0.024)**	0.005 (0.024)	1	0	0
-0.156 (0.065)**	-0.077 (0.063)	-0.198 (0.059)**	1	0
-1.051 (0.673)	0.353 (0.644)	0.984 (0.631)	0.743 (0.606)	1

A_0: Extended Iacoviello

1	0	0	0	0
0.060 (0.024)**	1	0	0	0
-0.158 (0.064)**	-0.200 (0.061)**	1	0	0
-1.040 (0.651)	1.024 (0.657)	0.729 (0.636)	1	0
0.196 (0.056)**	0.009 (0.052)	-0.063 (0.052)	0.032 (0.049)	1

Table 3 (con't)

A_1: Extended CEE

0.709 (0.099)**	0.239 (0.255)	0.092 (0.070)	0.110 (0.097)	0.023 (0.009)**
0.004 (0.043)	0.966 (0.111)**	0.024 (0.031)	-0.001 (0.042)	0.003 (0.004)
0.225 (0.163)	0.668 (0.418)	0.547 (0.116)**	0.011 (0.160)	0.016 (0.014)
0.035 (0.115)	0.166 (0.295)	-0.128 (0.082)	1.003 (0.113)**	0.018 (0.010)*
0.569 (1.175)	5.644 (3.020)*	-0.102 (0.834)	2.551 (1.153)**	0.644 (0.103)**

A_2: Extended CEE

0.065 (0.095)	-0.241 (0.265)	-0.266 (0.068)**	-0.153 (0.094)	0.005 (0.009)
0.003 (0.041)	-0.183 (0.115)	-0.029 (0.030)	0.052 (0.041)	0.002 (0.004)
-0.047 (0.156)	0.304 (0.434)	-0.157 (0.111)	0.005 (0.154)	0.001 (0.015)
0.131 (0.110)	0.086 (0.307)	-0.003 (0.079)	-0.215 (0.109)**	-0.005 (0.010)
-0.845 (1.126)	-6.984 (3.137)**	0.574 (0.804)	-1.933 (1.114)	-0.066 (0.106)

Note: (1) The numbers in parentheses are standard errors. * denotes statistical significance at 90% level, ** at 95% level. (2) The A_1 and A_2 matrices are the same under all the four specifications, up to permutation of the rows and columns according to the ordering of variables. (3) The shaded lines correspond to the monetary policy equations.

Table 4. Comparison of Impulse Responses: Benchmark vs. Counterfactual

	Output response		Inflation response		House price response		Stock price response	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Output shock	1.53	2.47	0.14	0.64	-0.05	1.84	-0.23	1.00
Inflation shock	-0.91	0.12	0.64	1.29	-1.80	0.45	-1.40	0.20
Funds rate shock	-0.33	-1.42	-0.56	-1.01	-1.81	-3.62	-3.49	-6.08
House price shock	-0.88	0.20	0.80	1.22	2.79	4.67	5.35	6.63
Stock price shock	0.49	1.79	0.68	1.22	1.28	3.65	16.07	17.37

Note: Column (1): Cumulative impulse responses in the first twenty periods after the shocks under the *benchmark* SVAR. Column (2): Cumulative impulse responses in the first twenty periods after the shocks under the *counterfactual* SVAR.