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Sources of Housing Price Fluctuations: An Analysis Using Sign-restricted VAR*

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This article investigates the role of potential disturbances behind the housing market fluctuations in Korea using a VAR model with sign-restriction. Specifically, we identify four structural shocks, namely, i) monetary policy shock, ii) lending shock, iii) housing market shock, and iv) expectations shock, and estimate their effects on housing price and other macro variables.

The overall results from impulse responses and forecast error variance decomposition indicate that development in housing sectors is closely interrelated to other macro variables/factors, including monetary policy. When we decompose the historical contribution of each shock for the actual time series movements in housing price, non-monetary policy shocks, such as lending shock and housing market shock, seem to be mainly accountable for since 2000. In this time period, loose monetary policy also partly contributed, whose role seems to be relatively minor however.

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1. INTRODUCTION

The recent boom in house prices and residential investment in many advanced economies, as well as the sharp correction that has followed in some of them, have reignited the debate over the link between housing and the business cycle and over how (monetary) policy makers should respond to developments in the housing sector.

The Korean housing market has also undergone dramatic changes in the last decade and, in the course of these changes, housing prices have rapidly soared along with a few episodes of huge spikes.[1)] Although it is not followed by subsequent drops and the collapse of real sector as in the US and some EU countries, this rapid growth of housing price in Korea has sparked a debate over whether the housing sector is properly priced and is in accordance with the overall macroeconomic conditions. In addition, it has raised concern about the rapidly increasing household debt in the course of the housing price surge.

The experiences of Korea and other countries' housing sector raise several questions. What is the nature of the shocks hitting the housing market? How much of the housing price changes is attributable to monetary policy and own housing market development? What role does bubble/speculation, if any, play quantitatively and qualitatively? In turn, what are the consequences of the housing market boom for the aggregate economy? How big are the spillovers from the housing market, for example, the consumption wealth effect?

Answers to these questions have important implications both for the better understanding of the housing market and for the design and implementation of related macroeconomic and housing market policies. Particularly, given the relatively short history of the housing finance channel and its recent rapid expansion in Korea, they will serve as pivotal guidance in financial sector surveillance.

[1)] Housing prices at the national level and in Seoul have increased by more than 80% and 110%, respectively, during the years of 2000 to 2010.

In fact, with the occurrence of the recent (and ongoing) Great Recession in the US and in some EU countries, it is now widely believed that macroeconomic factors in general (and monetary policy in particular) were an important factor behind the variations in housing price.[2] Despite the general agreement that developments in the housing sector have important implications for the level of aggregate economic activity, whether there is consensus on why this is the case remains unclear.

Empirical studies on housing market cycles in foreign economies and their relation with other macro variables are usually conducted using VAR models with various types of identification schemes (see, e.g., Sutton, 2002; Iacoviello, 2002; Meen, 2002; Tsatsaronis and Zhu, 2004; and International Monetary Fund, 2008). Overall results suggest that monetary policy and variables associated with housing finance seem to matter in housing price variations. Moreover, additional factors, such as other asset prices and housing demand, seem to play a non-negligible role. However, there are large quantitative differences between individual countries in these results, and the results tend to be country specific. To some extent, this finding is caused by the various institutional differences, the degree of mortgage market development, and related regulations.[3]

There are also several studies on Korean housing market fluctuations from a macroeconomic perspective, and this line of research has focused on the empirical evaluation of the effect of monetary policy on housing sector, typically using VAR models. The role of monetary policy however seems to be mixed or unclear at best. For example, Lee (2008) uses a structural VAR with short-run restrictions to determine that monetary policy shocks, identified with the change in money supply and interest rate, and money

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[2] In particular, some of the overall consensus is as follows. First, the developments in the housing sector are not only a passive reflection of macroeconomic activity and may themselves be one of the driving forces of business cycles. Second, housing and housing finance played a central role in precipitating the 2008 crisis (Bernanke, 2008) and may could a boom-bust cycle (Burnside, Eichenbaum, and Rebelo, 2011).

[3] Regarding the issue, a recent report by IMF (2008) argues that (i) countries with a more flexible system of housing finance tend to experience stronger spillovers from the housing sector and that (ii) countries with more advanced innovation in housing finance systems are more exposed to shocks originating from the housing sector.

demand shock together account for a significant part of housing price variations. Chung (2006), using a dynamic equilibrium error-correction time series model, investigates the link between asset prices and liquidity rather than interest rate, and argues that housing price and liquidity have mutually positive effects on each other and that their interrelationship has strengthened recently. On the other hand, Son (2010), based on a VAR model with DAG (Directed Acyclic Graph) algorithm, finds that since 2000 the fluctuations in real housing prices have been more strongly affected by the shocks in real economic variables, such as income, housing investment, and households loans, rather than a monetary policy shock, which is associated with changes in call rate.[4)]

Another interesting line of studying housing market cycles is investigating the presence of bubble and its size in housing prices (Kim, 2004; Lee, 2006; and Lee and Song, 2007). The common approach is to use the time series models with appropriate long-run restrictions reflecting the property that housing prices and fundamental variables comove in the long-run. The overall results show that bubble in housing price may indeed exist, although the size is small.[5)]

This paper attempts to identify several potential sources of housing price variations of Korea using a VAR model, examine how some key macro variables as well as housing prices are affected by these disturbances, and (historically) quantify their contribution. Although it is a popular and common practice to employ standard restrictions (such as short-run and long-run restrictions) in VAR literature, these identification strategies are argued to suffer usually from the validity of identifying restrictions, and the robustness of results still remains a potential concern.[6)] In addition, as the mixed result on the role of monetary policy in Korean housing price

4) Readers may refer to Song (2008a) and the references therein for more discussions on the determinants of housing prices.

5) Aside from these popular time series models, Lee and Song (2007), based on some theoretical asset pricing models, also show that recent house prices are overall higher than the equilibrium prices, suggesting the possible case of a bubble, which may account for up to 8% of actual housing prices.

6) Section 2 discusses this issue in detail.

movements mentioned previously seems to be largely due to the difference in identification strategy adopted, noting this issue and properly addressing it are critical.

To avoid these potential issues in identification schemes used in conventional VAR methodology, we employ a VAR model with sign restrictions, a strategy proposed by Canova and Nicolo (2002) and Uhlig (2005). The key idea of this approach is to identify a shock whose impulse response is consistent with some sign restriction; that is, following the shock, variables in the model respond in a certain direction for a specified period. Using this strategy, we identify the following four structural shocks: i) monetary policy shock, ii) lending/liquidity shock, iii) (fundamental) housing market shock, and iv) expectations/bubble shock, which are commonly mentioned as potential sources of housing price fluctuations. Having identified these shocks, we then investigate their dynamic effects and the (historical) contribution of each shock to other macro variables as well as to housing prices.

The main finding of this paper is as follows. The overall results from impulse responses and forecast error variance decomposition indicate that monetary policy shocks have a significant effect on housing price, and developments in the housing sector in turn are associated with real and financial variables, at least in the short-run. Conversely, the effects of the other two shocks, lending and expectations, on real variables are largely limited.

The historical decomposition exercise shows that two housing market booms in the last decade are largely attributed to own housing market developments. Moreover, the housing market boom in 2002 is partly triggered by a lending shock, starting housing price-lending spirals. Given the increased price in housing that serves as a collateral for a loan, another spike in household lending in 2006 follows. However, this lending boom seems to matter relatively less to housing price increase around the time, when housing market shocks are mainly attributable. In the course of these episodes, loose monetary policy also partly contributes, whose role seems to be relatively minor however.

The rest of paper is organized as follows. Section 2 outlines the baseline model and the technical elements. Section 3 provides an overview of the results, such as impulse responses, forecast variance decomposition, and historical decomposition. Section 4 explores several issues related to robustness of the results and some extensions. Finally, section 5 presents the concluding remarks.

2. A BASELINE VAR MODEL

Consider the following VAR model for an $m\times 1$ vector of endogenous variables, Y_t :

$$Y_t = B_0 + \sum_{i=1}^{p} B_i Y_{t-i} + u_i, \tag{1}$$

where B_0 is an $m\times 1$ vector of constants, and B_i is an $m\times m$ matrix of autoregressive coefficients. In each period, the variables are hit by exogenous disturbances, u_t with $E[u_t]=0$ and $E[u_t u_t{}']=\sum$. These disturbances are in general correlated and are difficult to interpret. Suppose instead there are m fundamental or structural (normalized) shocks, ε_t with $\varepsilon_t \sim N(0,\ I_m)$; and we want to recover them through the following structural representation of VAR:

$$AY_t = AB_0 + A\sum_{i=1}^{p} B_i Y_{t-1} + \varepsilon_i, \tag{2}$$

where A is an $m\times m$ matrix and the relationship between ε_t and u_t is given by $\varepsilon_t = Au_t$.

A typical scheme to translate the reduced-from disturbances into structural shocks in the literature is to impose either short-run (or contemporaneous) or long-run restrictions or both. A short-run restriction involves, based on some economic theory, imposing some structural relation on the individual elements in matrix A so that one can identify up to $m(m+1)/2$ structural parameters from the estimate of the covariance matrix of reduced-form shocks.[7)] However, this type of restrictions tends to be dependent on a particular class of theory and is thus often subject to controversy. In avoiding under-identification, identifying assumptions are also occasionally set to be overly restrictive. In addition, short-run restrictions sometimes result in some puzzling results. For example, in identifying monetary policy shocks and estimating their effect, it is not unusual that, after a contractionary shock, even with interest rates going up and money supply going down, inflation goes up rather than down (referred to as price puzzle in the literature). Moreover, when identifying expansionary shocks as a surprise increase in money, interest rates tend to go up, not down (known as liquidity puzzle).

The other approach, long-run restriction, attempts to identify a certain class of shocks by assuming that their long run effects are zero.[8)] An example is identifying aggregate demand shocks, such as IS or monetary shocks, imposing their long-run effect on real variables is zero (Blanchard and Quah, 1989; Gali, 1992). However, it is often hard to find appropriate long-run restrictions, especially with large-scale VARs. In addition, identification at frequency zero is based on in finite sums of VAR coefficients, which are biased in finite samples. Thus, the resulting identification and estimation are likely to be significantly distorted.[9)]

To overcome these potentially controversial issues, this paper adopts an identification strategy through the sign restrictions proposed by Canova and

7) A simple example is to use a lower triangular matrix through Cholesky factorization, in which the variables are treated with different degrees of exogeneity.

8) Assuming invertibility and writing (1) compactly as $B(L)Y_t = u_t$, the vector moving average (VMA) representation corresponding to (2) is $Y_t = \tilde{C}(L)\varepsilon_t$; where $\tilde{C}(L) = B(L)^{-1}A$. Noting that this VMA representation is an impulse response function, a long-run restriction amounts to set $\sum_{i=0}^{\infty}\tilde{C}_k(1) = 0$ for k'th shock.

9) Further, it is argued that VARs with long run restrictions also leave a large share of variations in variables of interest unexplained at business cycle frequencies. Such an example is total factor productivity shock (Barsky and Sims, 2011). And Hur (2011) discusses additional issue of possible correlatedness among structural shocks in Blanchard and Quah (1989) type long-run restriction.

Nicolo (2002) and Uhlig (2005). The identification scheme imposes sign restrictions on the response of some of the variables to a shock for a certain period while leaving the response of the main variable of interest open.[10)] This idea can be easily extended to identify multiple orthogonal structural shocks (Mountford and Uhlig, 2009; Peersman, 2011). This strategy can be considered a partial identification of structural innovations in that we identify shocks whose number can be smaller than that of variables in the system.

Specifying the VAR, we set up a six-variable quarterly VAR model. The endogenous variables included are residential investment (ri_t), real GDP (y_t), consumer price index (CPI) (p_t), short-term nominal interest rate (call rate) (r_t), household loans (l_t) and housing prices (hp_t).[11)] The housing price index is obtained from Kookmin bank and all the other data are from the Bank of Korea. All variables except for interest rate are seasonally adjusted when needed. The sample runs from 1991:I to 2010:IV.

We estimate the VAR model in log levels, except for interest rate, with five lags.[12)] The choice of lag order is made a priori and reflects the frequent use of a lag length in VARs equal to one year plus a lag. However, VARs, as non-parsimonious models, usually perform poorly, as the number of unknown coefficients is large relative to the amount of information in

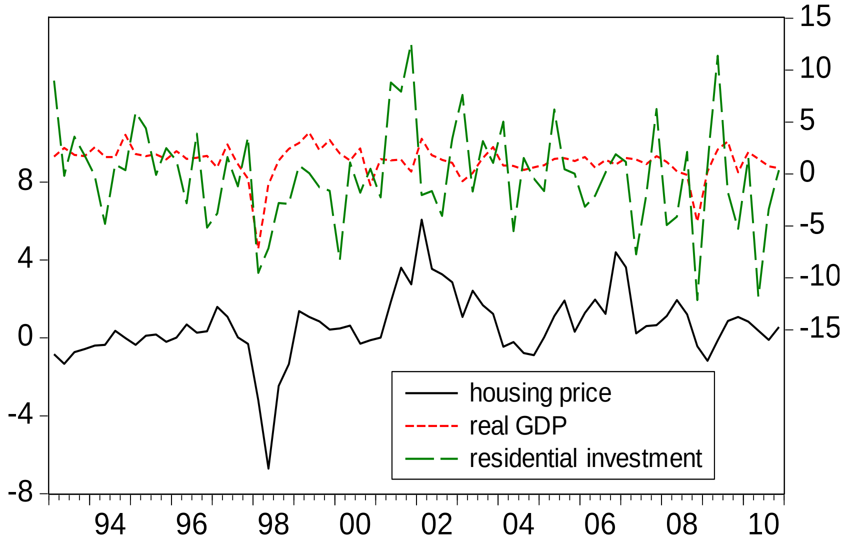
10) Take an example from Uhlig (2005), a contractionary monetary policy shock can be identified as such it does not lead to an increase in prices, non-borrowed reserves and, decreases in interest rate for a number of periods after the shock. Appendix provides a brief description of identification algorithm.

11) The selection of variables is largely based on the related literature discussed in section 1 and the actual time series of behavior of data. Figure 1 presents the time series of housing market variables and other macro variables that are potentially related housing market developments. It can be seen that housing market cycles are not tightly associated business cycles; there are several episodes in which housing prices do not comove with either GDP or residential investment. Instead, the changes in housing prices are more closely associated with household loans, and this feature is more noticeable after the foreign exchange rate crisis. Finally, it is also notable that the lending booms in 2002 and 2006 are not tightly linked to the change in interest rate.

12) Estimation of a VAR in levels will produce consistent estimates of the VAR impulse responses and is robust to cointegration of unknown form (Sims, Stock, and Watson, 1990). In fact, when there is uncertainty concerning the nature of common trends in the data, estimating the VAR in levels is the conservative approach (Hamilton, 1994).

Figure 1 Housing Market Cycles

(a) housing price and real variables



(b) housing price and financial variables

Note: The variables except for interest rate are percentage growth rates.

typical macro data. Thus, without prior information or some restrictions, it is hard to obtain precise estimates of many coefficients and analyses of impulse responses and forecasts tend to be imprecisely done. One proposed solution is to reduce the parameter uncertainty by placing restrictions on the coefficients in the form of Bayesian prior information. Hence, we first set our prior and posterior for the coefficients and covariance so that they belong to the Normal-Wishart family; the prior distributions on the lags of the endogenous variables are specified to be independent Normal with zero mean, while the first lag of the dependent variable in each equation has a prior mean of one.[13)]

In the VAR, we identify four types of underlying disturbances: i) monetary policy shock, ii) lending shock, iii) housing market shock, and iv) expectations shock. These shocks are commonly considered the potential driving forces behind the housing market fluctuations in the literature, as discussed in section 1. In the following, we discuss the identification of each shock.

First, an expansionary monetary policy shock is identified as a shock which has a negative effect on interest rate and a positive effect on household loans and prices. This assumption is a commonly shared view on the monetary policy; price puzzle and liquidity puzzle are ruled out by construction.[14)]

Second, a positive lending shock is assumed to be associated with increases in both interest rate and households loans. That is, this shock aims to capture the increase in lending not related to the decrease in interest rate.[15)] The recent surge in household lending in Korea is believed to be largely due to financial regulatory easing and structural changes in funding demand (i.e., switch in bank lending from corporate sector to households).

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13) This strategy largely follows Doan, Litterman, and Sims (1984), Litterman (1986), and Sims and Zha (1998). In addition, to tighten the prior with increasing lags, standard deviation decays with increasing lags at the harmonic function: The hyperparameters to control the priors on the Bayesian VAR are taken from Robertson and Tallman (2001).

14) Note that no restriction is imposed on the response of output, as the issue remains controversial. Later, we will revisit this issue as part of a robustness check.

15) A similar identification strategy is adopted by Peersman (2011) to capture the increase in credit supplied by commercial banks, independently of a shift in monetary policy.

In particular, in light of this paper's analysis, the self-perpetuating nature of mortgage lending is also notable and is likely to be responsible for the sharp increases in household loan and housing prices as well as the spiral between the two; as residential property prices rise, loan limits expand based on the collateral from a given mortgage, which in turn spurs housing demand (possibly including speculative demand).[16)]

Third, in identifying housing market shocks, we choose to be as least restrictive as possible and assume that a positive housing market shock is identified with an increase in housing price, while there is no restriction imposed on other variables in the system. It could reflect in the system, for example, either supply shock due to more housing construction or demand shock associated with increased income in the business cycle boom.

Finally, an expectations shock intends to capture a shock that pulls up the housing price without any direct link to actual development in the rest of the economy. Hence, this shock is identified with non-decrease in housing price, while the response of all the other variables in the system is zero on impact.[17)] Although various interpretations are possible in principle, this shock can be naturally considered an increase in price due to the speculation or bubble; it represents further change in housing price after it is allowed to respond freely to the changes in potential fundamentals as well as to other factors, such as monetary policy and increased availability in credit.

It is worth emphasizing two points in shock identification. First, we are least restrictive on the housing price movements and try to impose no direct link between housing price and other variables, except for the identification of expectations shock. Second, all of the shocks listed above are orthogonal to each other; i.e., we identify four independent sources of changes in housing price. The response horizon is set to four quarters. All sign restrictions are summarized as follows:

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16) See Seoh (2011) for a more comprehensive discussion on the causes of recent spikes in household lending.

17) This largely follows Beaudry and Portier (2006) and Beaudry, Nam, and Wang (2011) who introduce "news shocks" or "optimism shocks" by identifying a positive shock to stock price, contemporaneously orthogonal to current TFP (and other variables).

Table 1 Identification of Housing Price Disturbances

	ri_t	y_t	p_t	r_t	l_t	hp_t
Monetary Policy Shock	–	–	≥ 0	≤ 0	≥ 0	–
Housing Market Shock	–	–	–	–	–	≥ 0
Lending Shock	–	–	–	≥ 0	≥ 0	–
Expectations Shock	x –	x –	x –	x –	x –	≥ 0

Note: Small x's in the last row indicate no responses on impact.

3. EMPIRICAL RESULTS

This section presents the main results from the estimated model, using standard techniques in VAR methodology, such as impulse responses, forecast error variance decomposition, and historical decomposition. Below we discuss these one by one.

3.1. Impulse Responses

The dynamic responses of the variables to four types of shocks are presented in figure 2. A typical expansionary monetary policy shock is identified as an initial drop of 40 basis points in interest rate and an increase in price level and household loan of 0.15% and 0.3%, respectively.[18] Output also increases, exhibiting a hump-shaped pattern, and its response is the largest after one and a half years. Observe that the response is very persistent and remains significant beyond short-run horizons; so does that of CPI. On the other hand, residential investment increases in a rather sluggish manner, reaching the peak around two and a half years later, before gradually dying out over longer horizons. Housing price, the key variable of interest, increases in the short-run with its maximal response about two years later; the response is significant over medium horizons, that is, 10 to 15 quarters.[19]

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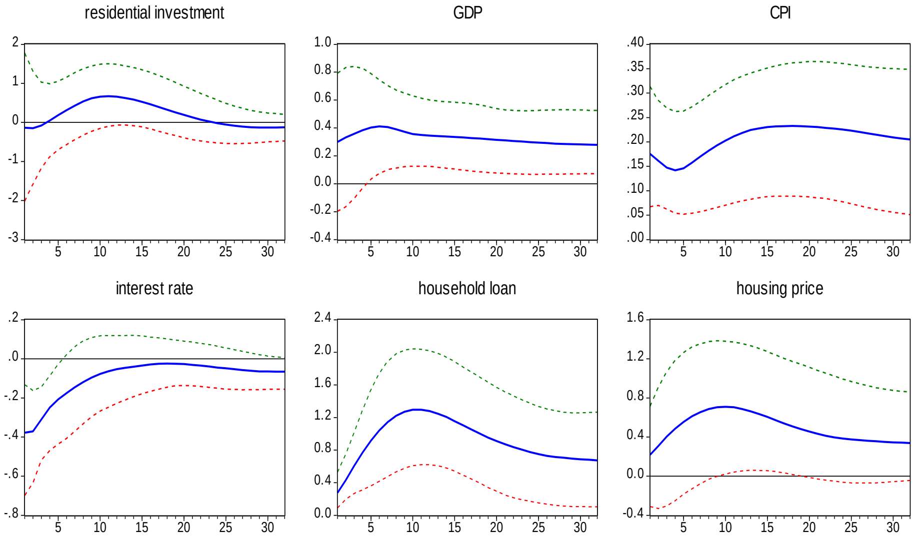
[18] Recall that price puzzle and liquidity puzzle are ruled out from the restriction.

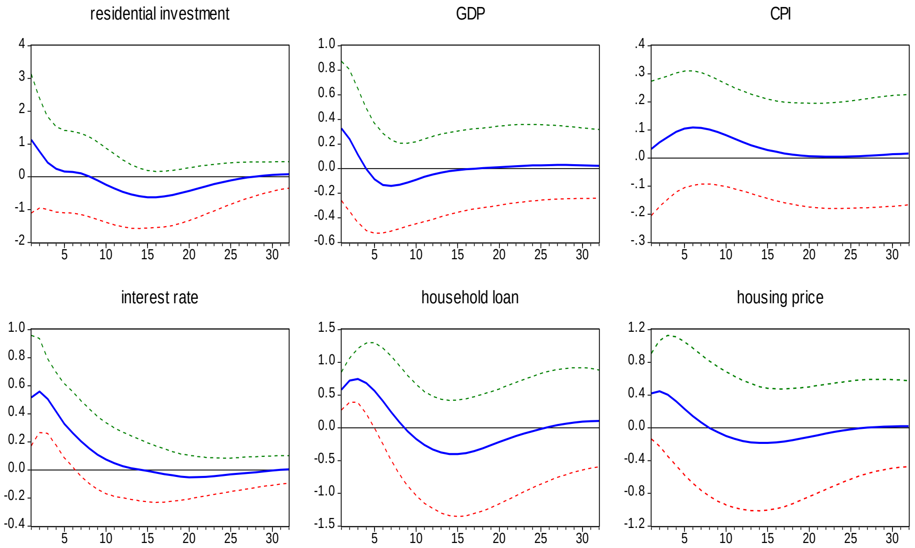
[19] The size of the dynamic response of housing price is rather small compared with that in the

Figure 2 Impulse Responses

(a) Monetary Policy Shock

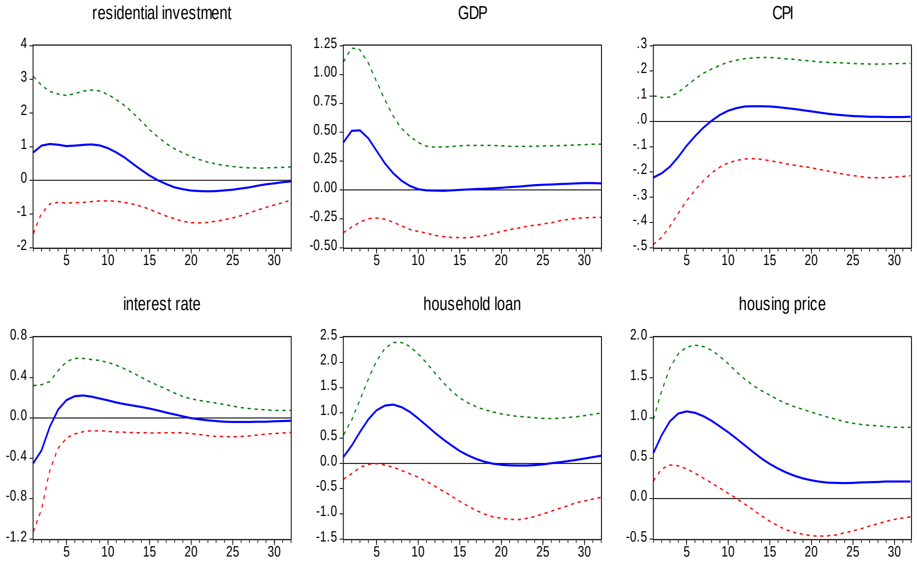


(b) Lending Shock

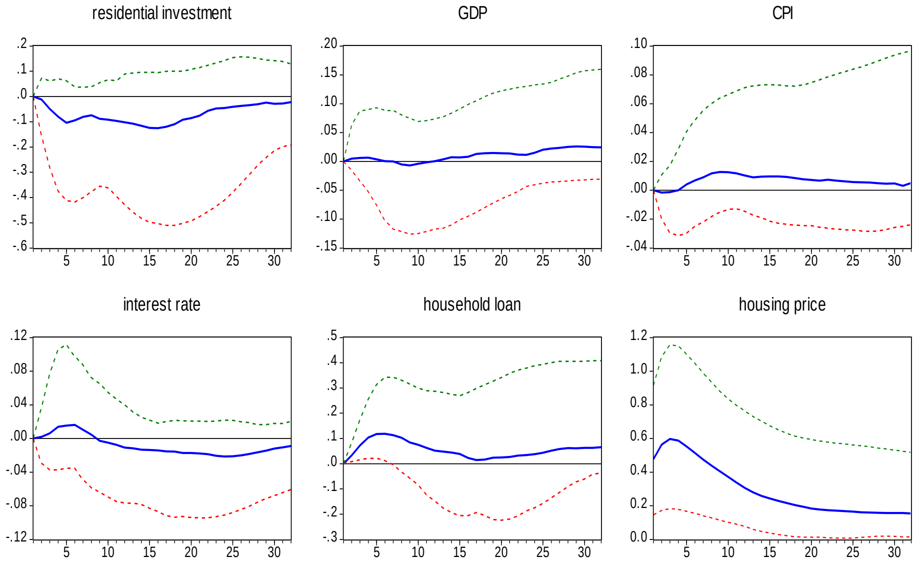


previous studies. For example, Lee (2008) reports that, following a 1% increase in interest rate, housing price decreases up to 2.8%.

(c) Housing Market Shock



(d) Expectations Shock



Note: Median impulse responses with 16th and 84th percentile error bands based on Monte Carlo integration.

Next, following a lending shock, the response of household loan, housing price, and real variables (i.e., GDP and residential investment) shows an *S*-shaped pattern; in all cases, they respond positively on impact, but reverse courses in a few years, overall effects disappearing over longer horizons.[20)] The result suggests that the overall effect of lending shock on the housing sector and other macro variables is short-lived and largely limited, even in the short-run; the initial increases are soon offset by subsequent decreases.

As regards the effect of a positive housing market shock, which can be considered associated with housing market boom, the increase in housing price turns out to be large in size and remains persistent and significant up to two and a half years. In addition, the behavior of other variables seems natural; housing market boom is accompanied by an increase in real variables and household loan and an initial decrease in interest rate.[21)]

Finally, in an expectations shock, note that the response of housing price is large and very persistent; the initial increase remains significantly positive over five years. This result is remarkable, given the tight restriction imposed on the other variables. The response of household loans also exhibits similar and persistent pattern, although small in magnitude, and the significance disappears after a year. However, the effects on other variables are by and large negligible in magnitude and insignificant over all horizons.

To summarize, monetary policy shocks have a significant effect on the housing sector. The developments in the housing sector in turn are associated with real and financial variables as well, at least in the short-run.[22)] On the other hand, the effect of the other two shocks, lending and expectations, on real variables is largely limited. One notable case is an expectations shock which has a significant and persistent effect on housing price.

[20)] Thus, it may be argued that a lending shock may generate a boom-bust cycle.

[21)] Although insignificant, the negative response of price is somewhat puzzling; Lee (2008) and Son (2010) report the similar result. One simple account will be that it is associated with the increase in housing demand due to increased real purchasing power.

[22)] However, there is one caveat; there is a large uncertainty surrounds the estimated effect of housing market shock. Therefore, the results should be interpreted with some reservations.

3.2. Forecast Error Variance Decomposition

How much responsible is each shock for the changes in housing prices and other macro variables? The forecast error variance decomposition results

Table 2 Forecast Error Variance Decomposition

Monetary Policy Shock							Housing Market Shock					
ri_t	y_t	p_t	r_t	l_t	hp_t	k	ri_t	y_t	p_t	r_t	l_t	hp_t
6.07	6.73	9.60	16.10	20.68	14.20	1	10.66	12.58	13.70	14.64	11.36	15.08
6.55	7.03	9.68	16.30	19.33	14.07	2	11.12	12.85	13.71	13.91	12.59	15.94
7.64	7.47	9.86	16.35	17.93	14.11	3	12.23	13.09	13.80	13.47	14.49	16.54
8.78	8.09	10.05	16.24	16.88	14.28	4	13.39	13.33	13.86	13.71	15.67	16.87
10.52	9.37	10.44	15.85	15.49	14.56	6	14.80	13.86	14.41	14.70	16.20	17.07
11.62	10.30	10.76	15.54	15.03	14.81	8	15.38	14.21	15.07	15.44	16.01	16.94
12.80	11.40	11.43	15.13	15.49	15.12	12	15.79	14.86	15.88	16.04	15.83	16.61
13.42	11.96	12.34	15.00	15.92	15.27	16	15.94	15.31	16.32	16.17	15.86	16.50
13.57	12.85	13.52	15.08	15.53	15.41	32	16.05	16.00	16.53	16.26	16.22	16.55
Lending Shock							Expectations Shock					
ri_t	y_t	p_t	r_t	l_t	hp_t	k	ri_t	y_t	p_t	r_t	l_t	hp_t
10.11	8.32	8.74	17.54	15.22	13.88	1	0.00	0.00	0.00	0.00	0.00	9.89
10.38	8.64	8.89	17.88	14.93	14.04	2	0.01	0.01	0.01	0.01	0.03	8.65
11.02	9.06	9.11	18.07	14.96	14.28	3	0.02	0.02	0.02	0.02	0.09	7.53
11.82	9.69	9.40	18.04	14.95	14.56	4	0.05	0.03	0.04	0.05	0.13	6.63
12.83	10.91	10.09	17.80	14.55	14.89	6	0.08	0.07	0.08	0.10	0.15	5.41
13.46	11.78	10.70	17.64	14.49	15.16	8	0.10	0.10	0.13	0.13	0.16	4.66
14.33	12.77	11.53	17.34	15.30	15.46	12	0.15	0.15	0.20	0.19	0.20	3.90
14.98	13.22	12.39	17.25	15.75	15.62	16	0.23	0.20	0.24	0.24	0.24	3.53
15.19	13.84	13.62	17.12	15.77	15.76	32	0.40	0.37	0.34	0.40	0.41	3.05

Note: The number is the median of variance decompositions from 5,000 draws and k is the forecast horizon.

provided in table 2 help answer this question. In housing price, monetary policy shocks, lending shocks, and own housing market shocks are accountable with roughly equal size, about 15% respectively, and the shares change only a little over horizons. On the other hand, expectations shocks are responsible about 10% on impact, with its importance decreasing over longer horizons.[23)]

Housing market shocks also seem to be responsible for the rest of the economy by a substantial amount. Overall, housing market shocks explain a significant part of other variables, more than 11% in the short-run and up to 16% in the long-run.

Although the contribution of monetary policy and lending shocks to real variables is relatively small in the short-run, their importance increasingly matters over longer horizons, accounting for about 15% to 20%. Finally, the role of expectations shock is generally negligible for the variables other than housing price, explaining less than 1%.

3.3. Historical Decomposition

With the set of identified shocks in the previous section, it is now straightforward to calculate the cumulative effects of these shocks on the variables in the system, using the technique called historical decomposition.[24)]

[23)] Again, the literature reports mixed results on this aspect. For example, Lee (2008) finds that house price movements are largely driven by housing market shock (more than 50% in the long-run), followed by monetary policy and money demand shock (each by 15%). On the other hand, Son (2010) argues that the effects of shocks for interest rate and money supply seem to be limited for housing price change, at most 2% and 6%, respectively. Instead, household loan (up to 12%) and other variables (i.e., foreign exchange rate, price level, and GDP in the short-run, and residential investment in the long run) seem to matter.

[24)] Historical decomposition is a useful tool to decompose the historical values of a set of time series into a base projection and the accumulated effects of the current and past shocks. The idea of historical decomposition is based on the following partition of the moving average representation (omitting the constant term for simplicity): $x_{t+j} = \sum_{s=0}^{j-1} \psi_s \varepsilon_{t+j-s} + \sum_{s=j}^{\infty} \psi_s \varepsilon_{t+j-s}$, where the first sum represents the part of x_{t+j} due to innovations in periods t+1 to t+j (the j-step forecast error), and the second term is the forecast of x_{t+j} based on the information available at time t. Thus, for example, housing price can be written as the sum of a deterministic component (baseline) and the contribution of current

In particular, this exercise enables us to examine the role of potential factors in the movements of housing price in the 2000s and how their effects vary over time. Figure 3 presents the historical decomposition of housing price, household loan, and residential investment. The top panel shows that housing market cycles in the 2000s are mainly associated with own housing market shocks and that lending shocks also play a notable role. An interesting observation is that, during the 2002 boom, these two shocks initially comove closely, but there is a difference in timing when each has the fully-fledged effect. After the lending shock's peak, the maximal effect of housing market shocks follows with one year lag. On the other hand, the 2006 boom is mainly driven by the housing market shock.

The middle panel presents the result for the household loans. Although their time series behavior is similar to that of housing prices since 2000, the decomposition result reveals some interesting differences. As in housing prices, the spikes in lending in 2002 are largely attributable to lending shocks. However, since then, their importance becomes smaller, and changes in household loan are mainly driven by own housing market cycle and (loose) monetary policy. Finally, the movements in residential investment in the 2000s (shown in the bottom panel) are associated with the lending boom initially and the housing market boom and loose monetary policy afterwards.

It is worth mentioning that monetary policy shocks play a relatively minor role in housing price fluctuations and that they are not tightly related to the two lending booms. This result indicates that monetary policy cannot be much attributed for the movements in housing prices, at least directly. The historical contribution of expectations shocks is also intriguing. They account for a non-negligible part of housing price fluctuations, mainly serving as a downside adjusting factor, while they matter only slightly in household loan and residential investment.

To sum up, the historical decomposition exercise suggests that part of the housing market boom around 2002 is partly triggered by a lending shock, starting the housing price-lending spiral. Given the increased price in housing

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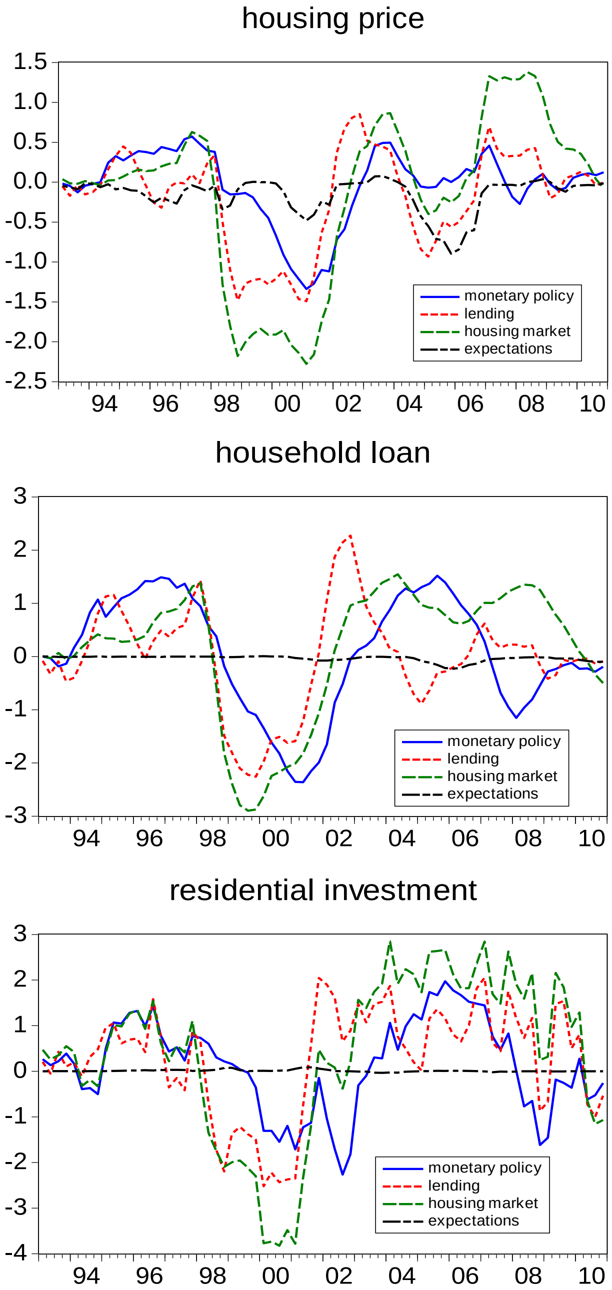
and past shocks identified previously.

Figure 3 Historical Decomposition



Note: Figures are medians of the posterior distribution.

that serves as a collateral for a loan, another spike of household lending in 2006 follows. However, this lending boom seems to matter relatively less in the housing price increase around the time, when housing market shocks are mainly attributable. In the course of these episodes, loose monetary policy also partly contributes, but its role seems to be relatively minor.[25)]

4. ROBUSTNESS CHECKS

The estimation in the previous section involves several important issues. The first is the response horizon. In the main text, we assume that, for a certain type of shock, some variables in the system respond in a particular direction for a specified period, that is, four quarters, which is selected in an ad-hoc manner. In the sign-restricted identification strategy, it is not clear how we need to specify this horizon a priori and setting a different response horizon length may yield a different result.[26)] How sensitive are the results to changes in the response horizon?

With the response horizon set to either two or six quarters, the overall results are largely the same as those in the baseline case. However, with the response horizon set to two quarters, some interesting differences emerge.[27)] As shown in figure A1(a), following a lending shock, the response of housing price and household loan is more short-lived. Moreover, the initial response of GDP is now negative and price increases much more sharply. Hence, the nature of lending shock resembles a negative aggregate supply/price shock in this case.

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25) These results are generally in accordance with Song (2008a, 2008b) and Son (2010). Both argue that the variations of housing prices since 2000 have not been strongly affected by monetary policy shock, that is, change in interest rate. Instead, other macro variables may matter more.

26) Setting the response horizon shorter implies that the restriction imposed is relatively less stringent, while failing to incorporate possibly more persistent nature of the shock. On the other hand, imposing a longer horizon may be overly restrictive. This issue is particularly relevant in identifying lending shock, following which the responses of most variables seem to be rather short-lived.

27) All the figures and tables associated with robustness check are reported in Appendix B.

The second issue is the identification of a monetary policy shock. This paper is largely agnostic and no direct restriction is imposed on its effect on output. Given that the output significantly responds to a positive monetary shock beyond short-run horizons, one may question whether the overall result will change when this outcome is imposed as part of identification restriction. This question is interesting because, with the short-run positive effect of a monetary policy on output assumed, the driving forces behind housing price fluctuations may be affected, both directly and indirectly, so that the response of housing price may potentially differ even qualitatively.

With the inclusion of the positive response of output as part of identifying restrictions, although the short-run response of output turns out to be more responsive to monetary policy shock, the overall results do not change much (see figure A1(b)). This suggests that the additional restriction is not at odds with data and confirms that monetary policy shock indeed significantly affects real output, at least given the specification of VAR model. The only notable difference is that the responses of housing price and household loan are now larger and more persistent than those in the baseline case, indicating the result from the baseline specification may be the conservative estimates of the response of housing sector to a monetary policy shock.

Finally, aside from the robustness checks above, we also estimate the model using monthly data. The use of monthly data enables us to examine the immediate and direct effects of shocks, which may be blurred with quarterly data, due to time aggregation.[28] At the same time, the use of monthly data does not come without costs. Monthly data are often noisier, which may render estimation difficult or imprecise. In a more practical aspect, the data of residential investment and GDP are not available at a monthly frequency and the available sample length is shortened for some other variables. Hence, in the actual estimation, because of the data

[28] In fact, when estimating the effect of a monetary policy shock, it is usually argued that monthly rather than quarterly data are more reasonable and are used more widely in the literature (Geweke and Runkle, 1995; Bernanke and Mihov, 1998).

availability, residential investment and GDP are replaced by consumption expenditure index and industrial production index, respectively.[29)]

As before, the estimation using monthly data yields a largely similar result (figure A2). Overall, the shapes of impulse responses and their magnitudes are similar to those with quarterly data. However, two noticeable differences stand out. On impact of lending shock, housing price initially drops as in the case of housing market shock. In addition, following a housing market shock, industrial production exhibits an *S*-shaped rather than a hump-shaped response.[30)]

With the data on consumption included in the VAR system, we can also estimate the consumption wealth effect due to housing price change as a by-product. Following a housing market shock which is associated with an initial increase in housing price of 0.7%, consumption is estimated to increase up to 0.8% in the short-run, but most of the effects disappear in the long-run.[31)] The estimated wealth effect is by and large greater than those reported in the literature. This result is supposedly due to the fact that the identified housing market shocks are to some extent synchronized with business cycle booms, in which consumption typically increases. In this sense, the notion of wealth effect is somewhat different from that used in some of the related literature.[32)]

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29) For monthly consumption data, I use the retail sales index, which can be downloaded from the National Statistical Office. In the estimation, the lag length is set to 13, and the response horizon is 60 months. The sample period is January 1995 to December 2010, and a similar Bayesian estimation technique as in the previous section is adopted.

30) It is not clear what lies behind these differences. They may be partly due to the noisier nature of high frequency data or the revealed natures of these shocks, which is hidden because of the time aggregation.

31) When we estimate the quarterly model with the residential investment replaced by private consumption, similar results are obtained.

32) The estimates of housing wealth effect vary depending on the estimation method and measure of consumption, among others. For example, Kim and Moon (2001), using an error-correction time-series model, find that the estimated elasticity of consumption with respect to house price is 0.36. Lee (2008) reports that, based on the estimates from a structural VAR, after a 1% increase in housing price, consumption increases up to 0.4% in five months, and the cumulative response is about 1.5%. On the other hand, Lee (2004) reports a relatively smaller wealth effect; 1% increase in housing asset price is associated with 0.03-0.05% and 0.06-0.09% increases in non-durable and non-residential consumption, respectively.

Rather, the wealth effect associated with an expectations shock is more interesting. Following a positive expectations shock, which is identified as an increase in housing price of 0.15% on impact and up to 0.35% in ten months, the response of consumption is substantial; it increases by more than 0.15% when the full effect takes place.

Finally, in all the three cases above, the forecast error variance decomposition (tables A1-A3) and historical decomposition (figures A3-A5) also deliver largely similar results to the baseline case. The only noticeable difference is found in the case where the response horizon is set to two quarters, where the (historical) contribution of lending shocks becomes slightly larger in housing price changes.

5. CONCLUDING REMARKS

This article identifies four underlying shocks behind the housing price fluctuations in Korea using a VAR model with sign-restriction and estimates their effects on housing price and other macro variables. The overall results from impulse responses and forecast error variance decomposition indicate that development in housing sectors is closely interrelated to other macro variables/factors, including monetary policy. When we decompose the historical contribution of each shock for the actual time series variations in housing price, non-monetary policy shocks, such as lending shock and own housing market shock, seem to be mainly accountable for since 2000. In the course of these episodes, loose monetary policy also partly contributes, whose role seems to be relatively minor.

To sum up, the results suggest that, once we become relatively agnostic about the effect of monetary policy, that is, imposing less restrictions on its effect on housing price, its quantitative role becomes relatively less important than that of other factors in explaining the historical behavior of housing price. Instead, we highlight the importance of own housing market development, lending boom, and possible bubble in the housing price fluctuations.

APPENDIX

A. Identification Algorithm

What follows is an informal summary of the sign-restricted identification methodology (see Uhlig (2005) and Mountford and Uhlig (2009) for more details). We look for a shock impulse vector as one in which the sign restrictions hold. For example, an expansionary monetary policy impulse vector is an impulse vector such that the responses of prices and household loan are non-negative, and the response of the interest rate is non-positive at all horizons $h = 0, 1, \ldots, H$. Specifically, the procedure is as follows:

1. Take n_1 draws of (B, Σ) from the VAR posterior.
2. For each draw:
   2a. Calculate the Cholesky decomposition, $\Sigma = AA'$.
   2b. Take a draw α from the unit sphere (whose dimension equals the number of variables).
   2c. Calculate impulse vector, $a = A\alpha$, for individual orthogonal shocks at horizons, $h = 0, 1, \ldots, H$.
3. Check if the impulse response functions satisfy the sign restrictions.
   3a. If all the impulse response functions satisfy the sign restrictions, keep the draw.
   3b. If not, discard the draw.
4. After obtaining n_2 impulse response functions with the desired sign, stop the algorithm.
5. Using the draws kept, calculate the error bands when needed.

In the estimation, we use $n_1 = 20{,}000$, $n_2 = 5{,}000$, and $H = 2, 4, 6$ for quarterly data and 12 for monthly data.

B. Additional Tables and Figures

Table A1 Forecast Error Variance Decomposition

Monetary Policy Shock							Housing Market Shock					
ri_t	y_t	p_t	r_t	l_t	hp_t	k	ri_t	y_t	p_t	r_t	l_t	hp_t
7.17	9.00	11.35	16.16	16.96	13.41	1	9.28	8.82	10.78	16.51	14.31	13.69
7.55	9.15	11.19	16.14	16.68	13.51	2	9.55	8.97	10.83	16.43	14.32	14.36
8.47	9.38	11.51	16.07	16.98	13.67	3	10.14	9.30	11.20	16.40	14.51	14.59
9.14	9.74	12.07	15.99	16.87	13.65	4	10.70	10.00	11.54	16.42	14.39	14.69
10.38	10.70	12.91	15.66	15.50	13.85	6	11.59	11.23	12.01	16.41	13.84	14.90
11.73	11.59	13.49	15.46	15.04	14.42	8	12.46	12.14	12.50	16.32	13.89	15.27
13.29	12.36	14.10	15.38	15.66	15.56	12	13.22	13.11	13.52	16.53	14.62	15.71
13.64	12.62	14.24	15.46	15.64	15.80	16	13.52	13.54	14.22	16.52	15.05	15.66
13.98	13.03	14.14	15.49	15.05	15.69	32	14.03	14.34	15.30	16.53	15.66	15.87
Lending Shock							Expectations Shock					
ri_t	y_t	p_t	r_t	l_t	hp_t	k	ri_t	y_t	p_t	r_t	l_t	hp_t
10.29	12.44	13.13	15.44	11.62	14.50	1	0.00	0.00	0.00	0.00	0.00	10.83
10.60	12.55	13.16	15.09	12.99	15.37	2	0.00	0.01	0.00	0.02	0.05	9.31
11.23	12.73	13.41	14.69	14.90	16.09	3	0.02	0.01	0.01	0.04	0.12	8.09
11.90	12.96	13.62	14.78	15.87	16.24	4	0.03	0.02	0.01	0.13	0.15	7.23
12.84	13.46	14.18	15.29	15.63	16.45	6	0.05	0.06	0.03	0.26	0.13	6.22
13.73	13.99	14.64	15.66	15.44	16.46	8	0.09	0.14	0.07	0.36	0.15	5.54
14.80	14.55	15.59	15.96	15.19	16.54	12	0.21	0.28	0.18	0.38	0.21	4.70
15.00	15.00	15.87	16.03	15.17	16.46	16	0.31	0.41	0.29	0.41	0.33	4.40
15.40	15.72	16.30	16.15	15.98	16.57	32	0.52	0.56	0.60	0.48	0.56	3.94

Notes: The response horizon is set 2 quarters. The number is the median of variance decompositions from 5,000 draws and *k* is the forecast horizon.

Table A2 Forecast Error Variance Decomposition

Monetary Policy Shock							Housing Market Shock					
ri_t	y_t	p_t	r_t	l_t	hp_t	k	ri_t	y_t	p_t	r_t	l_t	hp_t
6.22	8.54	13.99	17.11	15.83	13.78	1	10.68	13.15	13.09	14.15	12.24	15.21
6.61	8.77	14.01	17.21	15.39	14.11	2	10.99	13.33	13.08	13.33	13.42	15.85
8.54	9.59	14.06	16.65	15.25	14.72	3	11.62	13.51	13.19	13.10	15.31	16.32
7.46	9.18	13.96	17.09	15.30	14.44	4	12.43	13.68	13.09	13.58	16.25	16.71
10.66	10.46	14.15	16.11	15.00	15.24	6	13.91	13.97	13.86	14.68	16.34	16.74
12.05	11.24	14.20	15.74	15.12	15.56	8	14.73	14.34	14.72	15.12	15.93	16.57
13.34	12.08	14.21	15.56	15.89	15.85	12	15.19	14.94	15.48	15.52	15.63	16.06
13.82	12.57	14.66	15.69	16.04	15.83	16	15.23	15.23	15.79	15.65	15.51	16.02
13.97	13.36	15.11	15.56	15.77	15.52	32	15.62	15.62	15.71	15.74	15.69	16.19

Lending Shock							Expectations Shock					
ri_t	y_t	p_t	r_t	l_t	hp_t	k	ri_t	y_t	p_t	r_t	l_t	hp_t
10.13	8.10	8.99	17.62	15.19	13.48	1	0.00	0.00	0.00	0.00	0.00	9.62
10.32	8.34	9.06	18.26	14.70	13.64	2	0.01	0.00	0.00	0.00	0.03	8.55
10.86	8.98	9.27	18.63	14.53	13.87	3	0.03	0.01	0.01	0.02	0.07	7.41
11.38	9.47	9.58	18.88	14.63	14.02	4	0.06	0.02	0.02	0.05	0.10	6.55
12.52	10.53	10.08	18.45	14.34	14.34	6	0.10	0.06	0.05	0.10	0.13	5.42
13.47	11.37	10.60	17.96	14.58	14.69	8	0.13	0.09	0.07	0.13	0.13	4.85
14.41	12.57	11.46	17.45	15.48	15.16	12	0.20	0.15	0.12	0.19	0.18	4.30
14.87	12.84	12.25	17.36	16.14	15.47	16	0.27	0.19	0.17	0.22	0.22	3.93
15.18	13.61	13.98	17.28	15.89	15.64	32	0.47	0.33	0.30	0.34	0.37	3.30

Notes: The positive response of output is imposed in identification of monetary policy shock. The number is the median of variance decompositions from 5,000 draws and k is the forecast horizon.

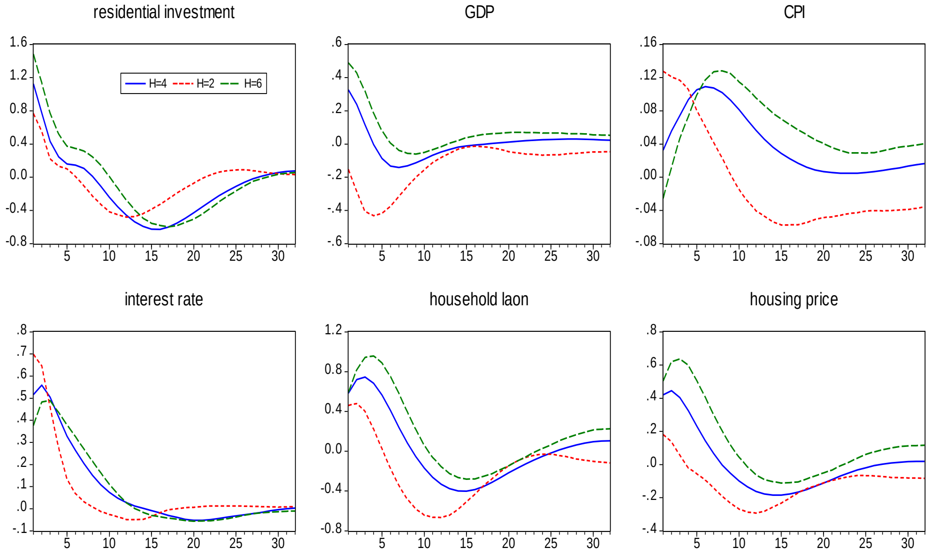
Table A3 Forecast Error Variance Decomposition

Monetary Policy Shock							Housing Market Shock					
c_t	y_t	p_t	r_t	l_t	hp_t	k	c_t	y_t	p_t	r_t	l_t	hp_t
3.84	7.23	17.21	13.05	23.21	8.75	1	10.44	11.84	11.40	11.57	7.90	13.35
4.33	7.50	17.26	13.22	22.55	8.93	2	10.66	12.32	11.72	11.46	8.47	13.79
5.68	8.33	17.31	13.26	20.81	9.18	4	11.54	13.33	12.13	11.45	10.67	15.11
8.27	10.35	17.03	13.09	17.67	10.36	8	13.39	14.73	13.17	12.12	13.40	16.56
9.68	11.38	16.78	13.19	16.04	10.90	12	14.41	15.40	13.89	13.50	14.74	16.73
10.71	12.18	16.03	13.53	15.48	11.61	18	15.03	15.67	14.89	14.74	15.50	16.89
11.36	12.81	15.30	13.74	15.22	12.22	24	15.32	15.99	15.38	15.32	15.47	16.88
12.24	13.57	15.08	13.99	15.35	12.97	36	15.67	16.25	15.93	15.69	15.42	16.52
12.84	13.93	15.07	14.09	15.54	13.45	48	15.93	16.30	16.05	15.79	15.54	16.40
13.19	14.09	15.11	14.13	15.80	13.78	60	16.13	16.40	16.08	15.84	15.79	16.36
Lending Shock							Expectations Shock					
c_t	y_t	p_t	r_t	l_t	hp_t	k	c_t	y_t	p_t	r_t	l_t	hp_t
11.38	10.16	8.55	15.96	12.74	11.49	1	0.00	0.00	0.00	0.00	0.00	9.08
11.65	10.66	8.68	15.95	13.15	11.99	2	0.02	0.00	0.01	0.00	0.03	8.66
12.40	11.88	9.14	15.83	14.44	13.48	4	0.11	0.02	0.05	0.01	0.17	7.54
13.78	13.78	10.52	16.09	16.60	14.98	8	0.32	0.07	0.18	0.06	0.41	5.54
14.67	14.78	11.51	16.49	16.86	15.55	12	0.43	0.14	0.25	0.18	0.54	4.52
15.21	15.35	12.62	16.71	16.68	15.71	18	0.59	0.24	0.38	0.49	0.54	3.73
15.35	15.57	13.32	16.67	16.56	15.89	24	0.65	0.37	0.50	0.75	0.55	3.15
15.44	15.65	14.14	16.55	16.30	16.02	36	0.77	0.50	0.65	0.89	0.64	2.42
15.56	15.67	14.36	16.45	16.04	15.92	48	0.80	0.56	0.70	0.93	0.78	2.16
15.60	15.62	14.50	16.44	15.88	15.88	60	0.83	0.66	0.69	0.96	0.85	2.04

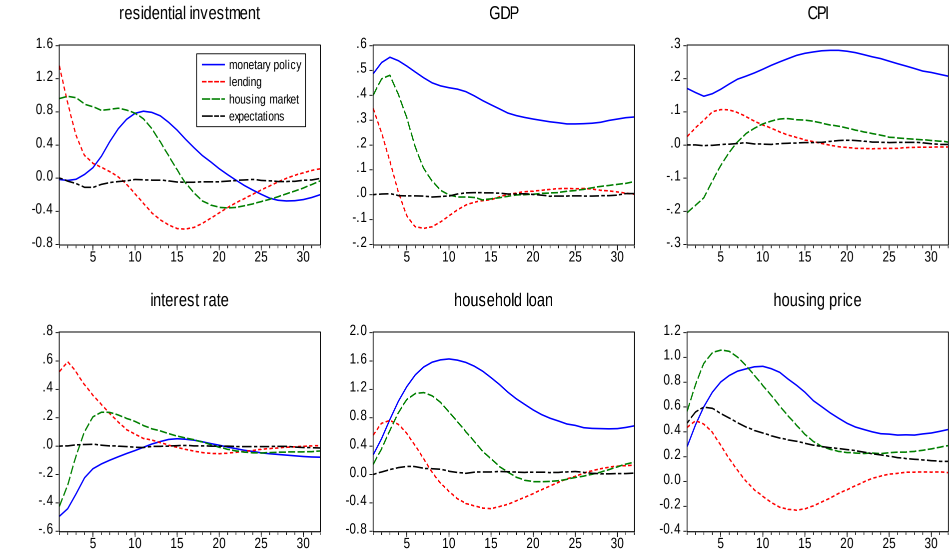
Notes: The monthly data are used. The number is the median of variance decompositions from 5,000 draws and k is the forecast horizon.

Figure A1 Impulse Responses Under Alternative Identification

(a) responses to a lending shock with different response horizons

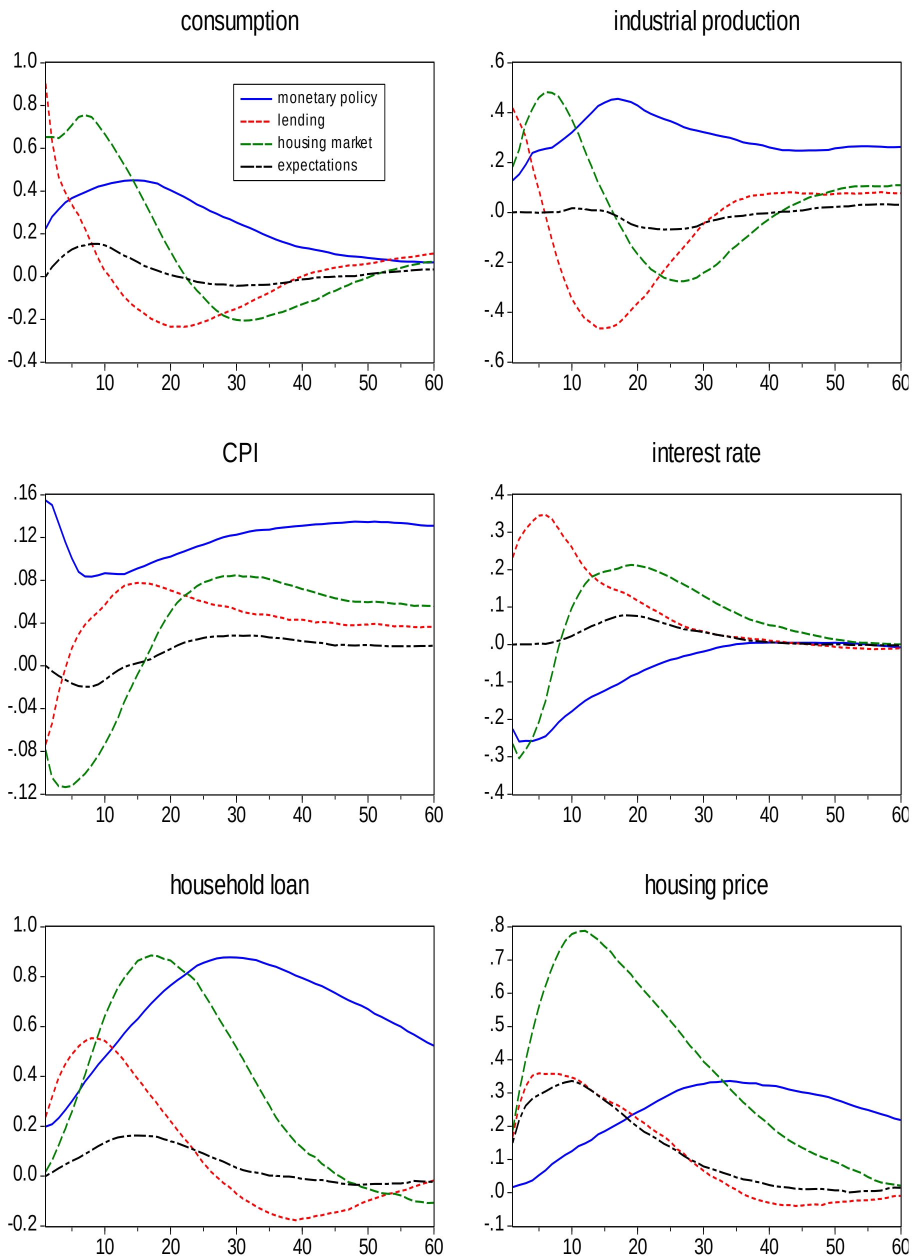


(b) when the positive response in output is imposed in monetary policy shock identification



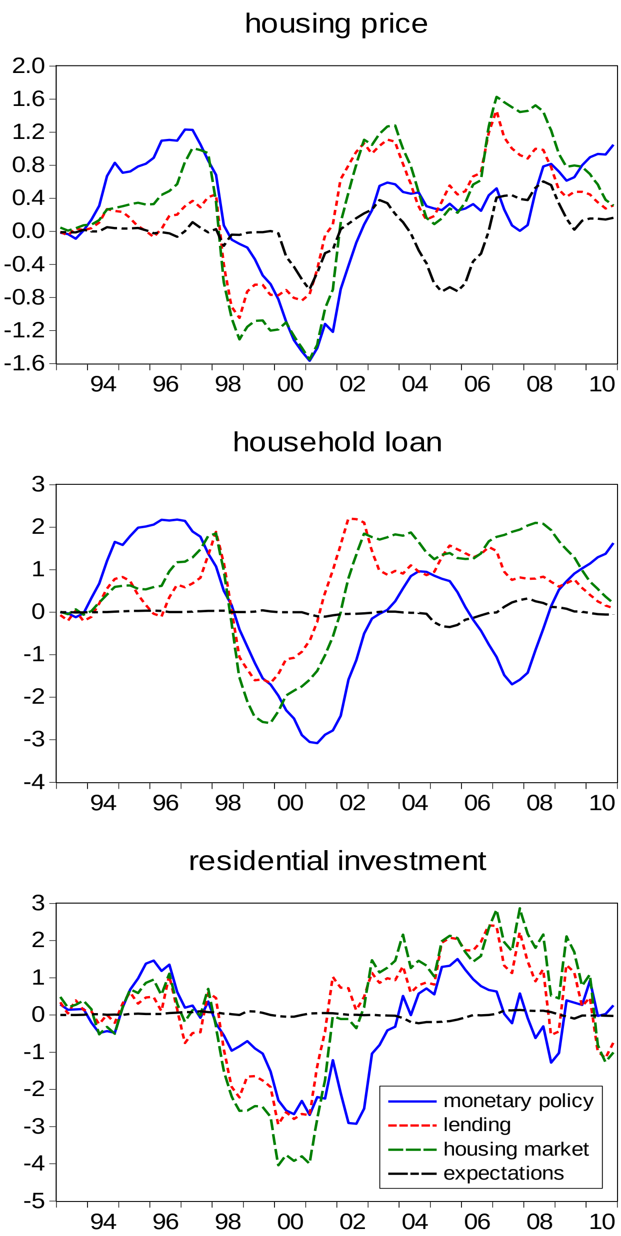
Note: Figures are medians of the posterior distribution.

Figure A2 Impulse Responses



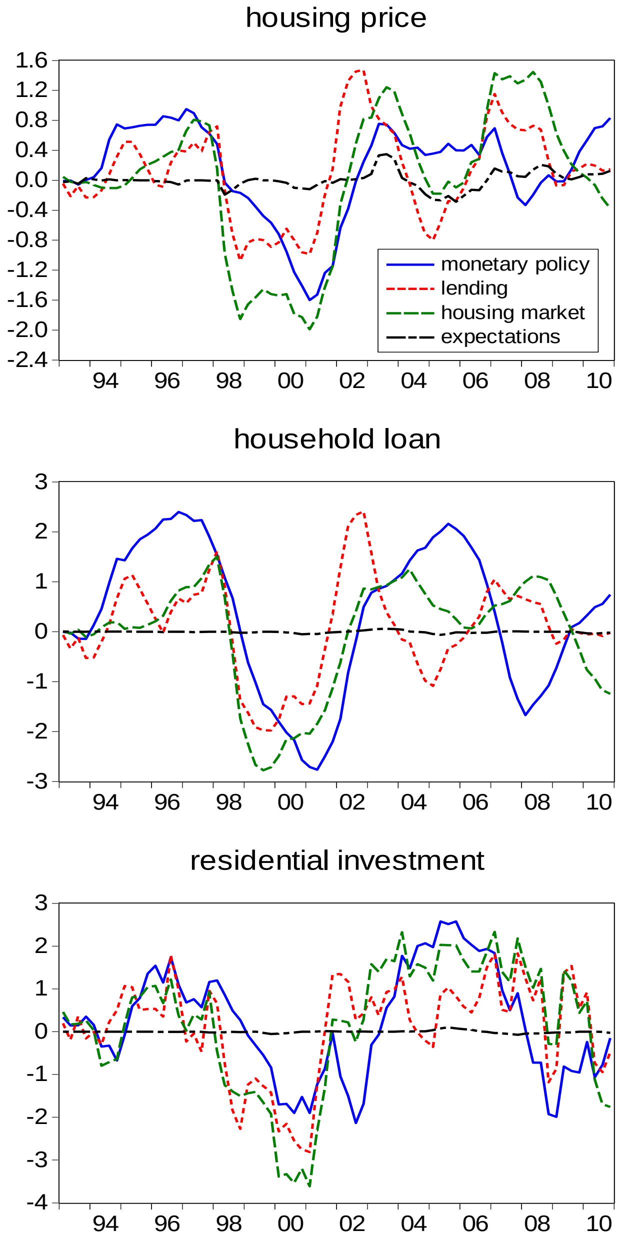
Notes: The monthly data are used. Figures are medians of the posterior distribution.

Figure A3 Historical Decomposition



Notes: The response horizon is set to two quarters. Figures are medians of the posterior distribution.

Figure A4 Historical Decomposition



Notes: The positive response of output is imposed in identifying monetary policy shock. Figures are medians of the posterior distribution.

Figure A5 Historical Decomposition

Notes: The monthly data are used. Figures are medians of the posterior distribution.

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