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Too Late To Lean Against The Wind

-Timing dependent Trade-offs in monetary policy shocks-

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Too Late To Lean Against The Wind

: Timing dependent Trade-offs in monetary policy shocks

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Abstract

This paper estimates a nonlinear SVAR model to study the trade-offs in leaning against the wind in regimes characterized by the Bubble vs Normal housing market. This is achieved by combining TVAR approach and SVAR Identification. I find that in the Bubble regime where house price to income ratio shows an upward trend, leaning against wind policy faces more stronger and prolonged trade-offs between output and house prices. In particular, one year after one percentage point monetary policy shock, the percentage point change in house price growth rate(%p) per percentage loss in output(%) is 3.54 in the Normal regime and 1.53 in the Bubble regime. That is, central banks should take more output loss to curb house prices during house price peaks. Meanwhile, I find that the ratio of house price loss relative to output is 2.58 in a single regime model which does not allow a regime shift. This implies that if one dose not consider the threshold effect in leaning against the wind, there is a serious risk of either under or over estimation.

Keywords: Threshold VAR, Structural Identification, House Prices, Monetary Shocks, Bubble, Threshold effect, Leaning against the wind
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1 Introduction

Should central banks use interest rates to curb housing market price booms? If so, when is the right time for leaning against the wind? Housing is one of the most important financial assets that play a significant role in the monetary policy transmission mechanism. Housing is important with respect to monetary policy in that it is not only an asset by which households could accumulate wealth and get mortgages, but also a consumption good which provides housing service to households. Moreover, what makes it different from other asset classes is that its purchases are typically leveraged through mortgages.(Jordà et al., 2015b) The 2007-09 Great Recession has sparked debate about the relationship between monetary policy and house prices. Many argue that the Federal Reserve deserves blame for the early 2000s house price bubble which has been thought to be the main cause of the Great Recession.(Kuttner, 2012) In this regard, they argue for the policy so-called “Leaning against the wind” where central banks should respond to asset price boom proactively by keeping interest rates higher than what is justified by the dual mandate of stable prices and maximum employment.(Smets et al., 2014)

The key presumption for the leaning against the wind is that monetary policy is the most effective means on curbing asset price booms such as housing bubble.(Stein, 2014) Regarding this, Riksbank recently had been leaning against the wind since the summer of 2010, keeping lower level of inflation and higher level of unemployment than the target level in order to curb the household debt-to income(DTI) ratio.(Svensson, 2015) But others don’t agree with this. They argue that macro prudential policy alone is capable enough to deal with threats to the stability of the financial system. In particular, a large increase in interest rates to prevent financial crises could result in larger output loss than the crisis itself, which is an trade-off in leaning against the wind.(Bernanke, 2002; Svensson, 2015)

It is well known that interest rates play a significant role in determining house prices theoretically(Himmelberg et al., 2005; Poterba, 1984) and empirically.(Del Negro and Otrok, 2007; Goodhart and Hofmann, 2008; Jarocinski and Smets, 2008; Sá et al., 2011) The problem is that raising interest rates to deal with house price booms entails a negative impact on inflation and output, which is called a monetary policy trade-off. Therefore, measuring the monetary policy trade-offs between house prices and output precisely is important when determining whether to conduct leaning against the wind. In particular, after the Great Recession the volume of housing finance has been increasing again in many countries, which makes it more important to measure the trade-offs in leaning against the wind.(Mian and Sufi, 2014)

This article has a contribution to the literature by that it allows "threshold effects" before and after house price bubble when measuring the trade-offs between house prices and output. Especially, I estimate a Double regime Threshold-SVAR model using the trend component of house price to income ratio growth rate as a threshold variable to compare the effect of monetary policy shock when house price bubble is rampant and not. In fact, Jordà et al. (2015a) and a large volume of research estimate the trade-offs of monetary policy on house prices and output. However, this paper is different from them in that they do not consider a regime shift and just draw an average effect of the monetary shock from the whole sample. Meanwhile, Paul (2019) estimates Time varying parameter VAR to study the monetary policy trade-offs. While both papers allow for a structural change, but our paper has much more policy implication since it proposes the trend component of house price to income ratio growth rate as a key variable of a regime shift, not simply estimating the time varying effect.

Moreover, I estimate Threshold-SVAR model to study the trade-offs in leaning against the wind policy by using a combination of long-run and short-run restrictions, which is an advanced attempt from previous Threshold-VAR model with Cholesky decomposition. Empirical literature using Cholesky decomposition assumes that either house prices are restricted from reacting immediately to monetary policy shocks(Goodhart et al., 2001; Giuliodori, 2005), or that monetary policy is restricted form reacting immediately to innovations in house prices.(Assenmacher and Gerlach, 2008; Iacoviello, 2005; Iacoviello and Minetti, 2003, 2008) In short, they assume the one-direction contemporaneous relationship between house prices and monetary shocks. Both restrictions have their own limitations since it is unrealistic for monetary policy and house prices for which forward-looking behavior is important.(Bjørnland and Jacobsen, 2010) I try to overcome this by estimating T-SVAR model with small open economy structural identification of Bjørnland and Jacobsen (2010) to each regime.

Based on small open economy Threshold-SVAR model, I obtain empirical evidence on the monetary policy trade-offs between house prices and output in Korea since 1999Q2. First, I document that the monetary trade-offs are stronger in the Bubble regime where house price to income ratio shows an upward trend above a threshold level. Especially, in the Normal regime, after unexpected one percentage point increase in interest rates, real house price growth rate decreases about 10 percentage point but output is back to normal after four quarters. On the other hand, in the Bubble regime, real house price growth rate decreases moderately while output decreases significantly and continues to decrease after the same shock. This result is consistent with the sacrifice ratio estimates of Paul (2019) showing that central bank tends to take more output loss to curb house price as house price index keeps increasing. It implies that after house price to income ratio is above the certain level, central bank would not be able to curb house price boom through leaning against the wind.

Second, in a single regime SVAR model which does not allow structural change, the estimated trade-offs are bigger than those in the Normal regime and smaller than those in the Bubble regime. In particular, the response of output falls persistently as in the Bubble regime but the level of response is much smaller than that of the Bubble regime. This implies that there would be a risk of over/under estimation if one estimates the response of house price to monetary shock without considering structural change. Furthermore, it is remarkable that evidence of the price puzzle appears more strongly in the response of house price and inflation in a single regime model, which does not in T-SVAR model. Since a price puzzle appears due to omission of key information in VAR system(Giordani, 2004), it implies that ignoring boom-burst cycle in housing market when analyzing monetary trade-offs might generate misspecification errors.

Third, my structural specification is better than the standard Cholesky decomposition in terms of efficiency. Especially, given the same ordering of the variables and the lags order, T-VAR model using Cholesky identification shows insignificant response for all variables after one quarter at 90 percent confidence level. On the other hand, the T-SVAR model of this paper shows significant response for all variables over the entire horizon and the confidence interval is much narrower. This results emphasize the importance of using an identification that allows for simultaneous interaction between monetary policy and asset prices when analyzing the effect of monetary shocks with asset prices.

The paper is organized as follows. Section 2 describes the previous literature on monetary policy and house price. In Section 3, the T-SVAR methodology is explained. Section 4 describes the data and obtains evidence of the regime dependent trade-offs between output and house prices. Section 5 documents the robustness of the empirical results. Section 6 concludes.

2 Literature Review

After the Great Recession, many empirical studies focus on measuring the monetary policy trade-offs between house prices and output. A recent paper by Ajello et al. (2016) examines this trade-off quantitatively with New Keynesian model where the probability of financial crisis could be increasing. Jordà et al. (2015a) estimates SVAR model using an identification method that exploits the trilemma of international finance. For the 17 countries that fixed

Table 1: The ratio of the effect on house prices relative to that on real GDP after two years

Source(Year)	Number of countries	Sample period	House prices	Outputs	Trade-offs (House prices /Outputs)
International evidence					
Jordà, Schularick, and Taylor (2015a)	17	1870-2011	-6.3	-1.9	3.3
Sá, Towbin, and Wieladek (2011)	18	1984:1-2006:4	-7.8	-7.6	1.0
Assenmacher and Gerlach (2008)	17	1986:1-2007:2	-10.8	-3.0	3.6
Goodhart and Hofmann (2008)	17	1973-2006	-7.2	-1.7	4.2
Iacoviello and Minetti (2003)	4	1978-1999	-8.8	-2.1	4.2
Calza, Monacelli, and Stracca (2013)	19	1970:1-2008:2	-2.3	-0.3	7.9
US evidence					
Fratantoni and Schuh (2003)		1986-1996	-1.7	-2.1	0.8
Ungerer (2015)		1969-1996	-7.2	-9.3	0.8
Otrok and Terrones (2005)		1980:1-2004:1	-5.7	-1.9	2.9
Jarocinski and Smets (2008)		1987:1-2007:2	-7.8	-1.3	6.0
Del Negro and Otrok (2007)		1986:1-2005:4	-10.4	-0.9	12.0
Median					3.9

1) Responses estimated as percent change two years after one percentage point monetary policy shock
2) Outputs measured as real GDP except for the following : Otrok and Terrrones(global GDP), Sá, Towbin and Wieladex and Calza, Monacelli and Stracca(private consumption), Ungerer(industrial production), Fratantoni and Schuh(real non housing GDP), Jorda and Talyor(real GDP per capita)
Source : Williams (2016)

their exchange rate to a foreign currency and two years after one percentage point increase in the short-term interest rate, real house prices are estimated to decrease by over 6 percent, while real GDP per capita falls by nearly 2 percent. There are varieties of research papers regarding this topic with different samples and methodologies, but they have a similar conclusion that response of house prices to monetary shocks is stronger than that of output. In these papers, the median estimate of the percentage change in house price(%) per percentage loss in the level of output(%) after two years is 3.9(see Table. 1)

But what is less discussed in these papers is the possibility of structural change. In particular, the timing issue, whether a central bank leans against the wind before or after a bubble in housing market, may have a significant impact on policy effectiveness. This is like even with the same brake, the vehicle may or may not stop depending on the speed of the running vehicle. Furthermore, the timing issue is also important regarding to the debate in leaning against the wind since the degrees of monetary policy trade-offs between house prices and output may vary depending on its timing.

In this regard, a recent strand of empirical studies focus on structural change in analyzing the effect of monetary policy. Brunová (2018) examines the effects of monetary shocks on the housing market using TVP-VAR model. Paul (2019) estimates time varying effects of monetary policy on asset prices and the economy through High-frequency instruments and TVP-VAR model. He documents that the sacrifice ratio, which is defined as the percentage loss of output per percentage change in house price, is likely to comove with house price index. But these papers do not document what is a key variable that causes the structural change. Instead, they just estimate the time varying effect of monetary policy shocks and plot the results with a variety of variables, which has less policy implications.

So I assume the trend component of quarter to quarter growth rate of real house price to income(GDP per capita) ratio as a threshold variable and identify two regimes to compare the trade-offs of the regimes - the Bubble regime where real house price to income ratio keeps increasing above a certain level, and the Normal regime where it does not. The reason why I infer the trend component of house price to income growth rate as a threshold variable is as follows. First, if real house price to income growth rate exhibits upward trend for a time, it may affect the behavior of traders in real estate market. After the housing market bubble bursted in the U.S, a numerous amount of research focuses on the irrational behavior of traders to explain inefficiency in housing markets. For instance, Kurov (2010) demonstrates that the effect of monetary news on a stock market depends on market condition. That is, monetary policy actions have a stronger effect in bear market periods than in bull market periods. I apply this behavioral model intuition to a housing market in order to compare the monetary policy trade-offs of the Bubble regime and the Normal regime, which are consistent with bull and bear market respectively.

Second, housing market polarization, which results from ongoing increases in house prices to income ratio, may affect the behavior of traders. If house price continues to rise faster than income growth trends, housing wealth tends to be concentrated among a limited number of household. In particular, according to Arundel and Ronald (2018), in the United States housing equity share of top 20% rises from 74.83% in 1995 to 81.89% in 2010, which reflects the fact that home ownership tends to be concentrated on a fewer households. In Korea, with house prices having been rising since 2016, the number of households with less then one house per the number of households with more than one house increases from 14.12% in 2012 to 16.55% in 2018. Meanwhile, Genesove and Mayer (2001) examines the housing market trading data of central Boston during the 1990s and finds the existence of the 'disposition effect', which is defined as a tendency of investors to sell stocks with prices that increases while holding assets that decreases in value, in housing market.

The effectiveness of leaning against the wind can vary when a few but wealthy homeowners try to defy downward pressure on housing market based on their own wealth.

Third, the monetary policy trade-offs in a presence of house price bubble can decrease the signal-to-noise ratio of monetary policy. As I previously mentioned, after the Great Recession, considerable debate occurs regarding how central banks might play a stabilizing role in asset prices. In many circumstances, such as there are bubbles both in the housing sector and overall economy, tighter monetary policy can stabilize the economy without a huge cost. The problem is when macroeconomic and financial stability may conflict, i.e. rising house price to income ratio above a certain level. (Williams, 2016) Historically, low interest rate tends to precede periods of house price bubble, which implies the trade-offs that expansionary monetary policy aimed to stabilize price and foster employment can harm the stability of financial market.(Kuttner, 2012) That is, if macroeconomic and financial stability goals do not coincide, the effectiveness of leaning against the wind may be weaker since it becomes harder for agents to extract true signal from any monetary policy action.[1]

Lastly, this study is closely related to Bjørnland and Jacobsen (2010), who estimate SVAR model with short/long-run restrictions to analyze the role of house prices in the monetary policy transmission mechanism in Norway, Sweden and the UK. Their identification method and choice of variables have several advantages with respect to studying monetary shocks in Korea.

[1] Blinder et al. (2008) points to the importance of keeping signal to noise ratio high to achieve the central bank's goal, emphasizing central bank communication for this.

First, They allow the interest rate and house prices to interact simultaneously each other by short/long-run restrictions, which not only is a more plausible assumption, but also improves the estimation efficiency. As Bjørnland and Jacobsen (2010) pointed out, assuming unidirectional contemporaneous restrictions between monetary policy and house prices is unrealistic and has a potential for bias because not only policy maker considers the information from housing market when designing monetary policy, but also house prices are forward-looking and will respond quickly to monetary policy shocks. Second, their identification includes foreign interest rate and exchange rate into the model, reflecting the characteristics of small open economy. It is especially appropriate in analysing the monetary policy transmission mechanism in Korea economy, of which international trade makes up a relatively large percentage.

However, current study improves Bjørnland and Jacobsen (2010), since it takes TVAR approach using real house price growth rate as a threshold variable and provides regime-contingent estimation with structural identification, which I call 'T-SVAR' approach. Moreover, our T-SVAR approach is different from other TVAR research papers which usually use Cholesky decomposition for identification purposes. I discuss T-SVAR approach in details in section 3.

3 Methodology

3.1 Threshold Vector Autoregression

This study estimates Two regime Threshold VAR model to identify the conditional effect of monetary policy shock in presence of house price bubbles. According to Tsay (1998), I estimate the reduced form VAR model as follows.

$$Y_t = \begin{cases} \alpha^b + \sum_{j=1}^{L^b} B_j^b Y_{t-j} + u_t^b, & \text{if } phi_{t-1} \geq \Gamma \\ \alpha^n + \sum_{j=1}^{L^n} B_j^n Y_{t-j} + u_t^n, & \text{if } phi_{t-1} < \Gamma \end{cases} \tag{1}$$

where Y_t is a vector of endogenous variables, α is a vector of constants, B is a matrix of coefficients, u_t^i is a vector of reduced form residuals whose variance-covariance matrix is Ω^i. and the super-scripts b and n indicate the Bubble and Normal regimes, respectively. The two regimes are identified based on the threshold variable phi, the trend component of quarter to quarter growth rate of real house price to income ratio with one lag. The lag in the threshold variable reflects the time it takes for agents to fully appreciate the difference between a temporary shock and regime shift.[2] When a value of the threshold variable bigger than or equal to(smaller than) the threshold value Γ, the economy behaves according to the Bubble(Normal) regime.

The TVAR model has a number of advantages for my purposes.(Afonso et al., 2018) First, it is a relatively simple to capture potential nonlinearities

[2]On the basis of Akaike Information Criteria(AIC), the AIC of the model using the threshold variable with one lag is -4804.834, which is lower than that with two lags(-4747.975) and three lags(-4795.121), but bigger than that with four lags(-4857.574). However, I use the threshold variable with one lag since is is awkwardly long to assume that agents take four quarters to differentiate a shock and regime shift.

such as asymmetric reactions to shocks. In particular, TVAR model allows different coefficients as well as lag order according to the regime.(Tsay, 1998) Second, the threshold value Γ is determined endogenously in the TVAR model. Γ is the value that minimizes the RSS(Residual Sum of Squares) in equation 2. It can be computed by doing grid search on the subset of the threshold variable *phi*.

$$\hat{\Gamma} = \arg\min_{\Gamma} S_1(\Gamma) \tag{2}$$

Meanwhile, I test the significance of a threshold effect that the coefficients are the same in each regime. Regarding this, I use F-statistics using bootstrap design proposed by Hansen (1999)(See Appendix A for details)

3.2 SVAR Identification

3.2.1 Choice of variables

This paper refers to Bjørnland and Jacobsen (2010) for choice of variables and structural identification of the T-SVAR model. As Ramey (2016) pointed out, innovations, the reduced-form residuals from TVAR model, are distinct concepts from structural shocks with causality since they are not exogenous with respect to the other current and lagged endogenous variables in the model. Therefore, imposing additional restrictions to the simultaneous relationship among endogenous variables is required to identify structural shocks. Regarding this, common identification strategies used in TVAR approaches are the standard Cholesky decomposition method.(Castelnuovo and Pellegrino, 2018) But this paper identifies structural shocks in each regime with strategies combining short run and long run restrictions.

First of all, the choice of variables in this paper is based on the standard theoretical setup of a New-Keynesian small open economy model. (Svensson, 2015; Clarida et al., 2001)

$$Y_t = [i^*, \Delta y, \pi, ph, \Delta e, i]'_t \tag{3}$$

where i^* is foreign interest rate, y is log of real GDP, π is the quarter to quarter changes of the log of the domestic consumer price index, ph is the quarter to quarter changes of the log of real house prices, e is the log of the real exchange rate against a basket of trading partner, and i is the interest rate of CD(91-day). y and e are first-differenced since they are I(1) time series and other variables are stationary. The reason why I use the nominal interest rate i to capture the monetary policy shocks is that it is consistent with monetary policy setting in reality.(Bjørnland and Jacobsen, 2010)

Meanwhile, phi, the trend component of quarter to quarter growth rate of real house price to income ratio, is calculated by dividing real house prices by Gross Domestic Product(GDP) per capita and applying Hodrick-Prescott filter.($\lambda = 1600$)[3] It is remarkable that phi is an exogenous threshold variable, so not incorporated into the model as an endogenous variable but might be affected by other endogenous variable such as ph and y by its definition. In terms of nonlinear model, Koop et al. (1996) propose a nonlinear impulse response analysis method which allows a regime shift responding to the level of the

[3] I use GDP per capita instead of GDP as income statistics since it captures real purchasing power of individuals better than gross GDP, which would be more likely to affect the behavior of each trader in domestic housing market.

endogenous threshold variable after shocks. But this paper does not consider the endogenous regime switch. That is, the economic system is unlikely to escape from the regime where it belongs to. In TVAR literature, the assumption like this is called "deep regimes".(Castelnuovo and Pellegrino, 2018) I assume deep regimes for two reasons. First, the purpose of this paper is to compare the trade-offs in leaning against the wind policy in the Bubble and the Normal regime. Assuming endogenous regime switch makes it difficult to compare the trade-offs in two regimes. Second, a total of three structural changes appears in the whole sample after TVAR estimation. Thus, deep regime assumption is persuasive in that the regime switch does not occur frequently in the data.

3.2.2 Identification

Our identification mainly refers to Bjørnland and Jacobsen (2010). Assuming that Y_t, a vector of endogenous variables in the regime i(i=b, n), to be invertible, it can be written in terms of its moving average.(deterministic term omitted)

$$Y_t = B^i(L)u_t^i, \quad \text{where } i = b, n \tag{4}$$

Where u_t^i is a 6x1 reduced form residuals in the regime i, assumed to be identically and independently distributed, i.e. $u_t^i \sim iid(0, \Omega^i)$, with positive definite covariance matrix Ω^i. $B^i(L)$ is the 6x6 convergent matrix polynomial in the lag operator L in the regime i, i.e. $B^i(L) = \sum_{j=0}^{\infty} B_j^i L^j$. There may be some bias when estimating impulse responses with the reduced form residuals since they are not exogenous in terms of contemporaneous and lagged endogenous variables.(Ramey, 2016) Thus, assume that reduced form residuals can be written as a linear combination of orthogonal structural shocks, i.e. $u_t^i = S^i \epsilon_t^i$. By this, Y_t in each regime i can be expressed as a Structural Moving Average(SMA) representation as follows.

$$Y_t = C^i(L)\epsilon_t^i, \quad \text{where } i = b, n \tag{5}$$

Where $B^i(L)S^i = C^i(L)$. $B^i(L)$ and u_t^i can be estimated from reduced form VAR. Thus, the SMA representation of Y_t and its impulse response for each regime can be derived by identifying S^i. To identify S^i, the ϵ_t^i's are normalized so that they have unit variance, i.e. $S^i S^{i\prime} = \Omega^i$. With a six variable system, the S^i matrix has 36 elements, but there are 21 elements in Ω^i. So I need 15 additional restrictions to uniquely identify the system.

With a six variable system, I can identify six structural shocks. The main shocks this paper interested in is the shock to monetary policy(ϵ_t^{MP}). I follow standard practice in the VAR literature and roughly identify the other four shocks as inflation shocks(ϵ_t^{π}), output shocks(ϵ_t^{Y}), exchange rate shocks(ϵ_t^{ER}), foreign interest rate shocks($\epsilon_t^{i^*}$), and house price shocks(ϵ_t^{PH}). Then the vector structural shocks are ordered as follows.

$$\epsilon_t^i = [\epsilon^{i^*}, \epsilon^{Y}, \epsilon^{\pi}, \epsilon^{PH}, \epsilon^{ER}, \epsilon^{MP}]_t^{i\prime}, \quad \text{where } i = b, n \tag{6}$$

The reasons behind the order of the variables are as follows. First, the foreign interest rate is ordered first because we assume a small open economy where the foreign interest rate does not react to current domestic economic conditions. In particular, the foreign interest rate is affected only by exogenous foreign monetary policy contemporaneously, which is a plausible assumption to Korea. Second, like Christiano et al. (1999), I accept recursive assumption that output and prices are not allowed respond to changes in the interest rate within the period. That is, place output and inflation before the interest rate in the ordering and impose zero restrictions on the relevant coefficient in the S^i matrix. As the last short-run restriction, I assume that house prices do not respond to exchange rate shocks within the period. Therefore, we can derive the matrix of short-run restriction S^i as follows.

$$\begin{bmatrix} i^* \\ \Delta y \\ \pi \\ ph \\ \Delta e \\ i \end{bmatrix}_t^i = B(L) \begin{bmatrix} S_{11} & 0 & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & 0 & S_{46} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & S_{56} \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} \end{bmatrix}^i \begin{bmatrix} \epsilon^{i^*} \\ \epsilon^{Y} \\ \epsilon^{\pi} \\ \epsilon^{PH} \\ \epsilon^{ER} \\ \epsilon^{MP} \end{bmatrix}_t^i \tag{7}$$

The main difference in the equation. 7 against the standard short-run recursive matrix is that it allows interaction among house prices, exchange rate, and monetary policy shocks within the period. In particular, monetary policy responds contemporaneously to shocks in house prices and exchange rates(i.e. S_{64}, $S_{65} \neq 0$) and house prices and exchange rates respond contemporaneously to monetary policy shocks.(i.e. S_{46}, $S_{56} \neq 0$) This is because the assumption restricting simultaneous responses among these shocks is lack of a theoretical framework and does not fit the data as well. In order to identify the system uniquely, However, I need a total of 15 restrictions, but there are only 13 contemporaneous restrictions. Thus, two additional long-run restrictions which are theoretically plausible are needed to identify the system uniquely keeping the short-run restrictions above.(Mansur, 2015)

For this, I impose two long-run restrictions as follows: (i) a monetary policy shock can have no long-run effect on the level of the real exchange rate. (ii) a monetary policy shock can have no long-run effect on the level of the real output. As Bjørnland and Jacobsen (2010) mentioned, these long-run restrictions are better than the restriction of no bidirectional interaction between house prices and monetary policy within the period.

Identifying the system through the combination of long and short-run restrictions is done as follows.(Blanchard and Quah, 1988; Gali, 1992) Let S^i is the matrix of short-run restriction and F^i is the matrix of long-run restriction both in the regime i.(i=b, n) Assuming that the model has six endogenous variables and p lags, B^i, which is an 6x6 inverse matrix of autoregressive parameters from $Y_t = B^i(L)u_t^i$, is specified as follows.

$$B^i = \left[I_6 - \widehat{B_1^i} - ... - \widehat{B_p^i}\right]^{-1}, \text{ where } i = b, n \tag{8}$$

The matrices of short-run restriction S^i and long-run restriction F^i are then as follows.

$$S^i = \begin{bmatrix} S_{11} & 0 & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & 0 & S_{46} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & S_{56} \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} \end{bmatrix}^i, F^i = \begin{bmatrix} f_{11} & f_{12} & f_{13} & f_{14} & f_{15} & f_{16} \\ f_{21} & f_{22} & f_{23} & f_{24} & f_{25} & 0 \\ f_{31} & f_{32} & f_{33} & f_{34} & f_{35} & f_{36} \\ f_{41} & f_{42} & f_{43} & f_{44} & f_{45} & f_{46} \\ f_{51} & f_{52} & f_{53} & f_{54} & f_{55} & 0 \\ f_{61} & f_{62} & f_{63} & f_{64} & f_{65} & f_{66} \end{bmatrix}^i \tag{9}$$

Since $F^i = B^i S^i$, and both f_{26}^i and f_{56}^i are equal to zero in the long-run, the following holds.

$$\begin{aligned} f_{26}^i &= [B_{21}S_{16} + B_{22}S_{26} + B_{23}S_{36} + B_{24}S_{46} + B_{25}S_{56} + B_{26}S_{66}]^i \\ &= [B_{24}S_{46} + B_{25}S_{56} + B_{26}S_{66}]^i = 0 \\ f_{56}^i &= [B_{51}S_{16} + B_{52}S_{26} + B_{53}S_{36} + B_{54}S_{46} + B_{55}S_{56} + B_{56}S_{66}]^i \\ &= [B_{54}S_{46} + B_{55}S_{56} + B_{56}S_{66}]^i = 0 \end{aligned} \tag{10}$$

Where B_{nm}^i is an nth row and mth column element of B^i. We can solve these for S_{46}^i and S_{56}^i

$$\begin{aligned} S_{46}^i &= \left[\left(\frac{B_{25}B_{56} - B_{26}B_{55}}{B_{24}B_{55} - B_{25}B_{54}} \right) S_{66} \right]^i \\ S_{56}^i &= \left[\left(\frac{B_{26}B_{54} - B_{24}B_{56}}{B_{24}B_{55} - B_{25}B_{54}} \right) S_{66} \right]^i \end{aligned} \tag{11}$$

Putting these all together, the matrix S^i becomes

$$S^i = \begin{bmatrix} S_{11} & 0 & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & 0 & \left(\frac{B_{25}B_{56}-B_{26}B_{55}}{B_{24}B_{55}-B_{25}B_{54}}\right) S_{66} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & \left(\frac{B_{26}B_{54}-B_{24}B_{56}}{B_{24}B_{55}-B_{25}B_{54}}\right) S_{66} \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} \end{bmatrix}^i \tag{12}$$

OLS estimation of the equation.12 would be biased by its non-recursive structure.(Martin et al., 2013) Thus, I estimate the parameters of S^i in the regime i(i=b, n) by the maximum likelihood method as follows.(Mansur, 2015)

$$\begin{aligned} \ln L_t^i &= -\frac{N}{2}\ln 2\pi - \frac{1}{2}\ln|\Omega^i| - \frac{1}{2}{u^i}'_t {\Omega^i}^{-1} u_t^i \\ \Rightarrow \ln L^i &= \sum_{t=1}^{T} \ln L_t^i, \quad \text{where } i = b, n \end{aligned} \tag{13}$$

Where N is the number of endogenous variables(N=6), u_t^i is the reduced form residuals in the regime i, and Ω^i is the variance-covariance matrix of the SVAR, i.e. $S^i S^{i\prime} = \Omega^i$. The equation. 13 is maximized with respect to the parameters in S^i matrix using svar and solnp function in R. 3.6.1.

4 Empirical Results

4.1 Data Description

I study Korea quarterly data from 1999Q2 to 2019Q4. The reasons why I examine that sample period are as follows. First, it is hard to identify a stable system before 1999 June when the Bank of Korea began inflation targeting where central bank sets a specific inflation rate as its goal, which means a regime shift in Korea monetary policy. Second, using the data before 1999Q2 will also make it difficult to identify a stable system since Korea economy had an IMF financial crisis in 1997. Lastly, the sample ends at 2019Q4 since it is the latest data I can obtain. Data and sources are described in Appendix B.

The TVAR model of this paper consists of six endogenous variables: foreign interest rates, quarter to quarter inflation, quarter to quarter real house price growth rate, quarterly growth rates of GDP, real exchange rates, and domestic interest rates. The threshold value of model is estimated by grid-search with conditional least square as Tsay (1998). The threshold variable is the trend component of quarter to quarter growth rate of real house price to income ratio with one lag. The lag order of the threshold variable is determined by Akaike Information Criteria(AIC). Also I include a trend in the T-SVAR model as Bjørnland and Jacobsen (2010) did, since some of the variables may be in the borderline of being stationary and non-stationary due to low power of the tests. Lastly, the lag order of the model is four, determined by AIC and the sample size.[4]

[4] Since with four lag order, there is a serious price puzzle in the response of house prices right after the shock during the Bubble regime, so I assume three lag orders for the Bubble

First of all, I test the threshold effect of the model by LR-test proposed by Hansen (1999). Setting the trend component of quarter to quarter growth rate of real house price to income ratio with one lag as a threshold variable, the LR test statistics for H0 : Single Regime is 2122.915 with p-value 0.0000, rejecting the null hypothesis of a single regime at 1% significance level. This result supports the choice of double regime model with respect to T-SVAR study for the data.[5] Next, threshold value estimated is -0.004220955, which is near to zero. The number of samples in the Normal regime where the trend component of real house price to income growth rate with one lag is under the threshold value is 42, 53.2 percent of the entire sample. Whereas the number of samples in the Bubble regime where the threshold variable is over the threshold value is 37, 46.8 percent of the entire sample.

Figure.1 shows quarter to quarter growth rate of real house price and that of real house price to income ratio, and its trend component with a regime shift in Korea housing market estimated from the model. The blue bold line in figure.1 represents the trend component of quarter to quarter growth rate of real house price to income ratio which is a threshold variable in our specification.(with one lag) The red solid line in figure.1 is a threshold value(-0.4220955%) and gray shaded area represents the periods belonging to the Bubble regime. It remarks that the threshold variable above the threshold value does not necessarily mean the Bubble regime since I presume one lag for agents to differentiate structural change from temporary shocks. Over the

regime. In TVAR literature, assuming distinct lag orders among the regimes is theoretically allowed.

[5] Due to not fitting with the purpose of this study and a lack of samples, Three Regime Model is not considered.

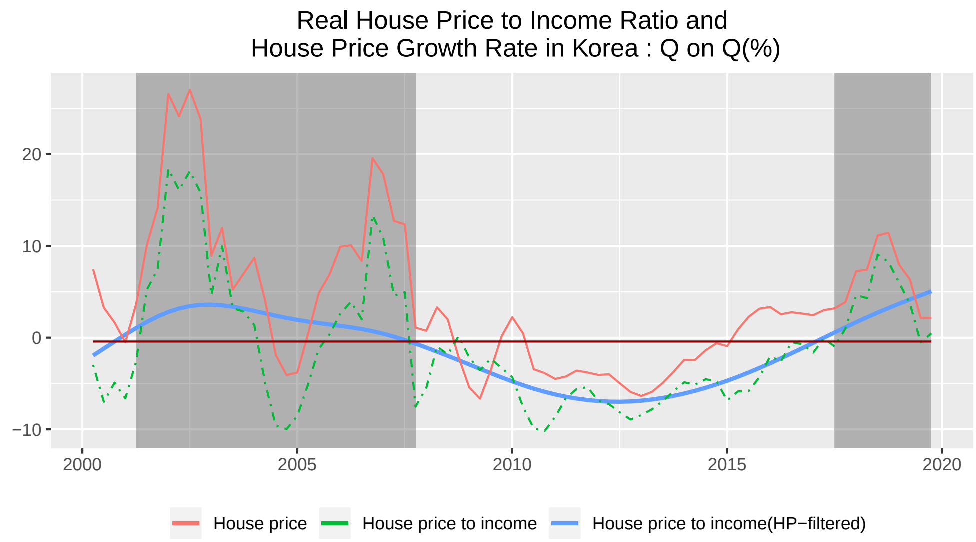

Figure 1: Real House Price to Income Ratio and Regime Shift in Korea
[1]The trend component of quarter to quarter growth rate of house price to income ratio is calculated using HP(Hodrick-Prescott) filter with $\lambda = 1600$(for quarterly data)

entire horizon, a regime shift occurs total three times and its average persistence is 18.5 quarters in the Bubble regime and 21 quarters in the Normal regime. Regime switches occurring less frequently in the data makes it easier to compare monetary policy shocks between regimes. Meanwhile, it shows that the Bubble regime begins with rapid increase of the trend component of real house price to income growth rate above zero percent and ends with it less than the threshold value.

4.2 Effects of a monetary policy shock

Figure. 2 shows the response of interest rates, output, inflation, and real house prices to unexpected one percentage point increase in interest rates during the

Normal and Bubble regime.[6] In particular, the left columns of Figure. 2 shows the impulse responses during the Normal regime with the trend component of real house price to income ratio growth rate below the threshold value, and the right columns show those during the Bubble regime with the trend component above the threshold value. The shaded areas in figure. 2 are 90% confidence intervals computed from bootstrapping(500), and the horizon is 48 quarters(12 years). The reason why I impose the same increase of the interest rate in the two regimes of interest is to compare the effect of the same monetary policy moves across the regimes.(Castelnuovo and Pellegrino, 2018) The effect of leaning against the wind represented by unexpected rise in the interest rate seems to have four characteristics across the regimes.

First and most importantly, the effect of the monetary policy to curb the house price boom is stronger during the Normal regime. The first row of figure. 2 shows that in the Normal regime, the real house price growth rate falls by 3.23%p right after the impact shocks, hits its lowest point(- 10.77%p) at the fifth quarter, and keeps negative until eighth quarters. Whereas in the Bubble regime, it increases by 0.89%p right after the impact shocks, begins to decreasing after two quarters, and hits its lowest point(-5.84%p) at the fifth quarter. The relatively moderate decrease of house price growth rate observed during the Bubble regime after the shock is consistent with the prediction of this paper that there would be a stronger defensive effect in housing market during the Bubble regime due to the expectation that house prices would continue to rise, polarization of housing market, and decreasing signal-to-noise

[6] I assume the deep regime for impulse response analysis. That is, I do not consider the endogenous regime shift caused by the response of real house prices to shocks.

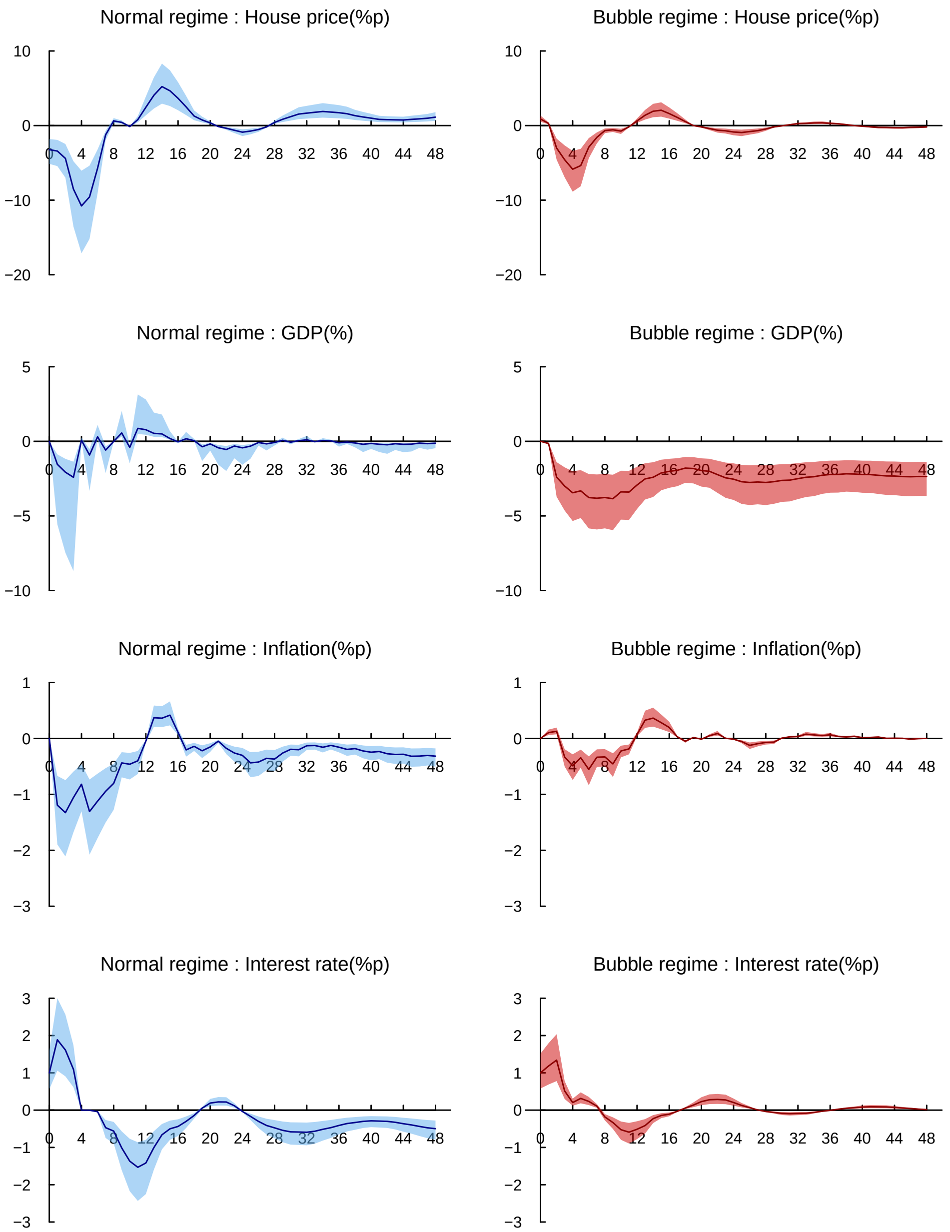

Figure 2: T-SVAR based regime-dependent responses for the bubble and normal regimes

ratio with respect to monetary policy.

Second, the response of output to monetary shocks is more stronger and persistent during the Bubble regime than the Normal regime. The second row of figure. 2 shows that after the same size of monetary shocks, output falls by 2.41% after four quarters then back to zero during the Normal regime, whereas it continues to fall by 1-3% over the entire horizon during the Bubble regime. I infer the reason why the strength and persistence in the response on output varies across the regimes as follows. During the Normal regime, agents may respond to negative house price shocks by selling their properties, so the economy is likely to get back to normal quickly. Whereas in the Bubble regime, as the expectation of future house prices stays relatively high, agents are more likely to refuse selling their properties and try to reduce other consumption expenditures, which keeps house prices high and output growth low. It is consistent with the analysis of Lettau and Ludvigson (2001), Lettau et al. (2002), who document that a change in asset prices after monetary shocks has a neutral impact on consumption expenditures.

Third, with respect to the response of inflation to monetary shocks, evidence of the price puzzle, a consumer price increase right after monetary shocks, is hardly being observed in both of the Normal and Bubble regimes. In particular there is no price puzzle during the Normal regime and somewhat weak(0.1%p for the first three quarters) during the Bubble regime. This result improves that of Bjørnland and Jacobsen (2010) where a price puzzle still pops up in UK and Norway even with the structural identification. Sims (1992) points out that the price puzzle may be due to VAR-misspecification that is not able to capture the relevant information in the monetary transmission mechanism.(Ramey, 2016) Therefore, I can infer that allowing the structural change by the state of housing markets might contribute to capture the key information in the monetary transmission mechanism which might not by the structural identification alone, resulting in curbing degrees of the price puzzle.

Lastly, I examine the systematic response of interest rates to unexpected monetary shocks in each regime. In the Normal regime, the response of the interest rate shows high volatility right after the initial shocks but keeps falling with 0.3-0.5%p after twenty five quarters. Meanwhile, in the Bubble regime, the response of the interest rate shows similar dynamics with the Normal regime but the strength of responses is weaker. I infer that this weaker response of the interest rate during the Bubble regime might be due to the fact that as central banks face stronger trade-offs in leaning against the wind during the Bubble regime, it cannot help but managing monetary policy more conservatively afterwards, which might lead to deteriorating the trade-offs. Thus it documents that in presence of house price bubbles, leaning against the wind may not be able to reduce house price enough to the target level as well as bring about a recession as side effects.

As I mentioned in Section 2, the median estimate of the percentage change in house price(%) per percentage loss in the level of output(%) after two years is 3.9. But the problem is that I include house prices to the S-VAR model in the form of quarter to quarter growth rate, not the house price index level as in previous literature. So I have to use the percentage point change in house price growth rate(%p), instead of the percentage change(%). Also, since there is rapid recovery of output right after the shock in our model, I have to compute the percentage point change in house price growth rate(%p) per percentage loss in the level of output after one year, not two years as in previous literature. Thus it can be misunderstanding if one compares these figures directly.[7] Taking these points into account, the impulse response estimates show that after one year of unexpected monetary shocks, real house price growth rate falls by 8.53%p and output falls by 2.41% in the Normal regime, while real house price growth rate falls by 4.58%p and output drops by 3.00% in the Bubble regime. Putting these together, the percentage point change in house price growth rate(%p) per percentage loss in the level of output(%) after one years is 3.54 in the Normal regime and 1.53 in the Bubble regime. The difference in the estimates of the trade-offs during each regime implies the possibility of a serious monetary policy misjudgement when estimating the trade-offs without considering a regime shift. I will discuss this issue in Section 5.1.

Overall, I conclude that after house price boom begins leaning against the wind would not be able to reduce house prices enough to its target level and the response of output would show more persistent trade-offs than during the Normal regime. In particular, real house price growth rate falls by more than 10%p at maximum during the Normal regime but only more than 5%p during the Bubble regime. Furthermore, during the Normal regime, output falls by 2.41% at the fourth quarter and begins to show a fast recovery, while during

[7] I consider an alternative computation method to calculate percentage change in house price(%) using percentage point change in house price growth rate(%p), which is (1+median of house price growth rate in each regime+impulse response coefficient at the fourth quarter). But I do not report it since it can give wrong implications that house price keeps increasing after monetary shocks as median of house price growth rate in Bubble regime is too high.

the Bubble regime, it keeps falling by about 1-3% over the entire horizon. Especially the percentage point change in house price growth rate(%p) per percentage loss in the level of output(%) is 3.54 in the Normal regime and 1.53 in the Bubble regime, which implies central bank might take more loss in output in order to curb the same size of real house price growth rate compared to the Normal regime. This implies that without considering a threshold effect, leaning against wind may not be successful in achieving its goals of reducing house prices, while increasing the possibility of recession.

5 Robustness Check

5.1 Single Regime Model

As I mentioned in Literature Review, according to Jordà et al. (2015a) and varieties of studies, the median percentage change in house price(%) per percentage loss in the level of output(%) after two years is estimated 3.9. However, the similar ratio estimated with the T-SVAR identification of this paper, the percentage point change in house price growth rate(%p) per percentage loss in the level of output(%) after one year, is 3.54 in the Normal regime and 1.53 in Bubble regime. The estimated trade-offs during the Bubble regime show significant differences from that during the Normal regime. Regarding this, I infer that whether the model allows a threshold effect may have a significant impact on the estimation results, so I estimate a single regime model with no threshold effect and compute the ratio between the response of house prices and output. In particular, I use the same data and structural identification, including trends as in the T-SVAR model. The lag order of the model is four, which is the same with the Normal regime of the T-SVAR model.[8] Estimation is done for whole samples, not for the samples belonging to the specific regime.

Figure. 3 shows the responses of endogenous variables to an unexpected one percentage point increase of the interest rate and the corresponding 90% confidence bands estimated with single regime and double regime T-SVAR model. The left column depicts the state-independent response of house price growth rate, output, inflation, and interest rates estimated with the single regime model. The right column depicts the state-dependent response of the economy during the Normal regime(Blue solid line) and the Bubble regime(Red dotted line) The impulse response of output estimated using the single regime model is quite similar with those of T-SVAR model during the Bubble regime. But the strength of the response is smaller than that during the Bubble regime. In particular, output falls by 1-2 percentage over the entire horizon in the single regime model, while it falls by 1-3 percentage in the Bubble regime model.

Note that evidence of the price puzzle observed in the responses of house price growth rate and inflation with the single regime model is eased by allowing a threshold effect. In particular, house price growth rate rises by 5.39%p right after the shock in the single regime specification while it rises only by 0.89%p during the Bubble regime and falls by 3.23%p during the Normal regime. In terms of inflation, inflation increases by 0.44%p three quarters after the shock in the single regime specification while it rises only by 0.13%p during the Bubble regime and falls by 1.33%p during the Normal regime. Thus

[8] Due to irrational response of house price(price puzzle) during the Bubble regime with lag order four, the lag order of the Bubble regime model is estimated as three.

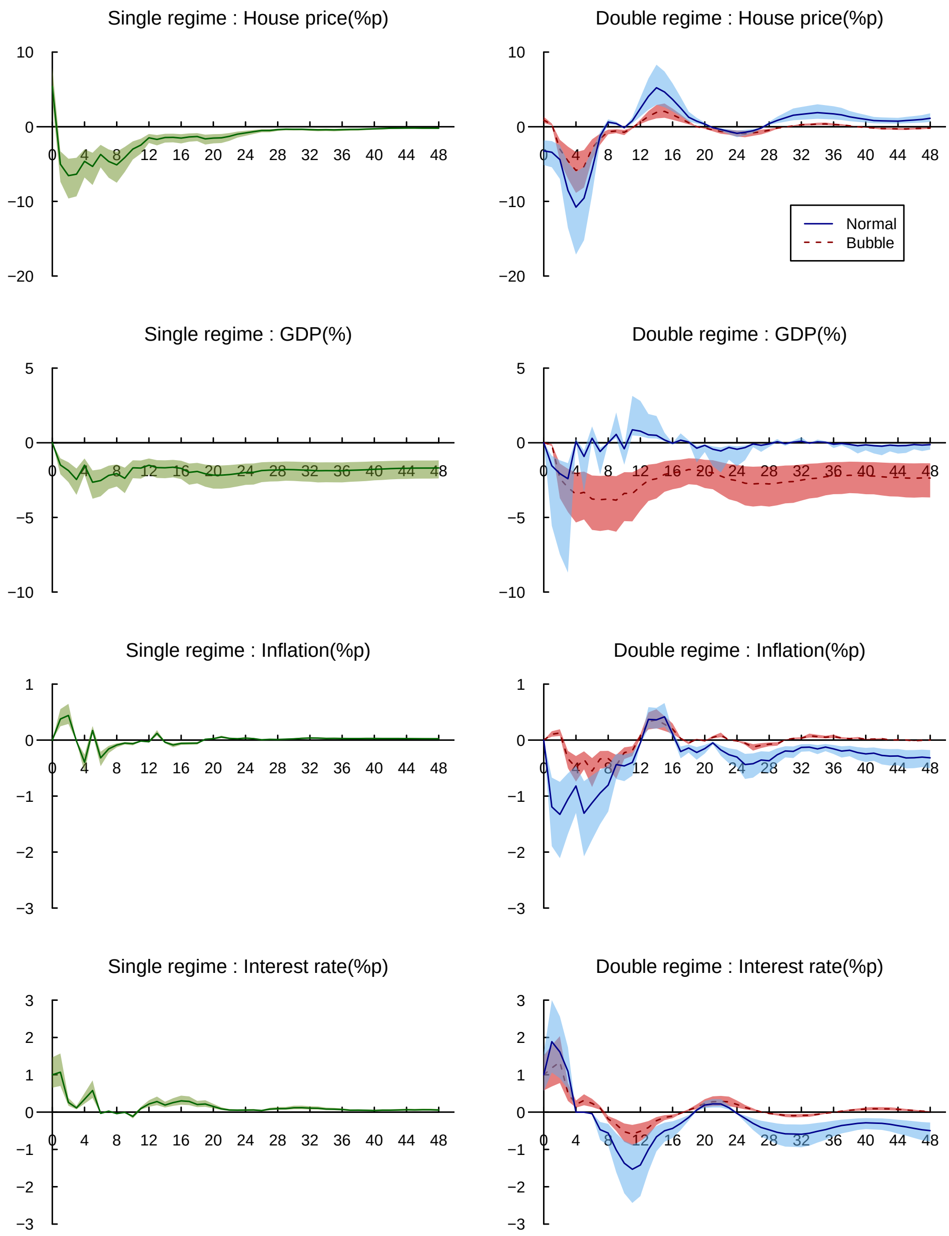

Figure 3: SVAR based regime-independent responses for the Single Regime

it confirms the guess that when analyzing monetary shocks, allowing a structural change in an asset market may contribute to solve the price puzzle in both inflation and asset prices.

I compute the percentage point change in house price growth rate(%p) per percentage loss in the level of output one year after the shocks with the single regime specification to study the effect of assuming a threshold effect in monetary trade-offs. The percentage point change of real house price growth rate to the unexpected monetary shocks after one year is - 6.36 in the single regime specification. Since the response of output after one year is - 2.46 percent, the percentage point change in house price growth rate(%p) per percentage loss in the level of output(%) estimated with the single regime model is 2.58. Note that this figure is median of the estimates allowing a threshold effect by T-SVAR specification, which are 3.54 in the Normal regime and 1.53 in the Bubble regime.

Overall, the single regime model which does not allow a threshold effect shows similar response of the economy with the T-SVAR model during the Bubble regime. But the strength of the response is weaker than the Bubble regime. Moreover, the evidence of the price puzzle in the response of real house price growth rate and inflation appears stronger in the single regime model. The regime independent estimate of the trade-offs in leaning against the wind is 2.58, which is more than that of the Bubble regime(1.53) and less than that of the Normal regime(3.54). That is, the single regime model shows stronger monetary trade-offs than the Normal regime and weaker trade-offs than the Bubble regime. I conclude that without considering a threshold effect, central banks may misjudge the impacts of leaning against the wind.

5.2 Cholesky Decomposition

The most commonly used identification method in empirical macroeconomics is the Cholesky decomposition which imposes recursive zero restrictions on the contemporaneous coefficients of endogenous variables.(Ramey, 2016) Instead, I use the structural identification which combines short-run with long-run restrictions to identify the system. Thus, to show what we could gain by using the structural identification, I estimate the impulse responses using the Cholesky decomposition and compare them with ours. In particular, if the impulse responses using the structural identification have steeper confidence intervals as well as more significant coefficients than those using the Cholesky decomposition, it can be proved to be a better specification. Regarding this, based on the same ordering of the six variables[9], I estimate the impulse responses with the Cholesky decomposition. The main difference between the two specifications is whether it allows contemporaneous interaction among real house prices, real exchange rates and monetary policy shocks.

Figure. 4 depicts the impulse responses during the Normal regime to an unexpected one percentage point increase of the interest rate and the corresponding 90% confidence intervals using Cholesky decomposition and structural identification.[10] In particular, the left column shows the responses of

[9] I also consider the Cholesky decomposition with different ordering, switching the order of monetary and house price shocks. But this generates much similar results with no order change.(wider confidence interval, insignificant responses, stronger price puzzle especially in the Normal regime) The impulse response results are shown in Appendix C.

[10] Computed with bootstrap=500

the house price growth rate, output, inflation, and interest rate with Cholesky decomposition during the Normal regime and the right column shows those with the structural identification. First, in terms of the significance of variables and confidence intervals, the structural identification of this paper improves efficiency of the coefficients better than that of the Choleksy. Especially the estimated responses of house prices, output and interest rates are found to be statistically insignificant after first two quarters and the response of inflation is insignificant over the entire horizon. Regarding confidence intervals, the responses of house prices, output, inflation, and interest rates seem to have wider confidence intervals under Cholesky decomposition. Also, even though it is insignificant with 90% confidence intervals, the Cholesky decomposition shows some evidence of the price puzzle(0.48%p at the third quarter), while the structural identification does not. This result is consistent with the Bjørnland and Jacobsen (2010) that the structural identification method of this paper may help to solve the price puzzle in monetary VAR.

The efficiency gains of the impulse response estimates through the structural identification are greater especially in the Bubble regime. Figure. 5 depicts the impulse responses during the Bubble regime to an unexpected one percentage point increase of the interest rate and the corresponding 90 percent confidence intervals using Cholesky decomposition and structural identification.[11] In particular, the left column shows the responses of the house price growth rate, output, inflation, and interest rate with Cholesky decomposition during the Bubble regime and the right column shows those with the structural

[11] Computed with bootstrap=500

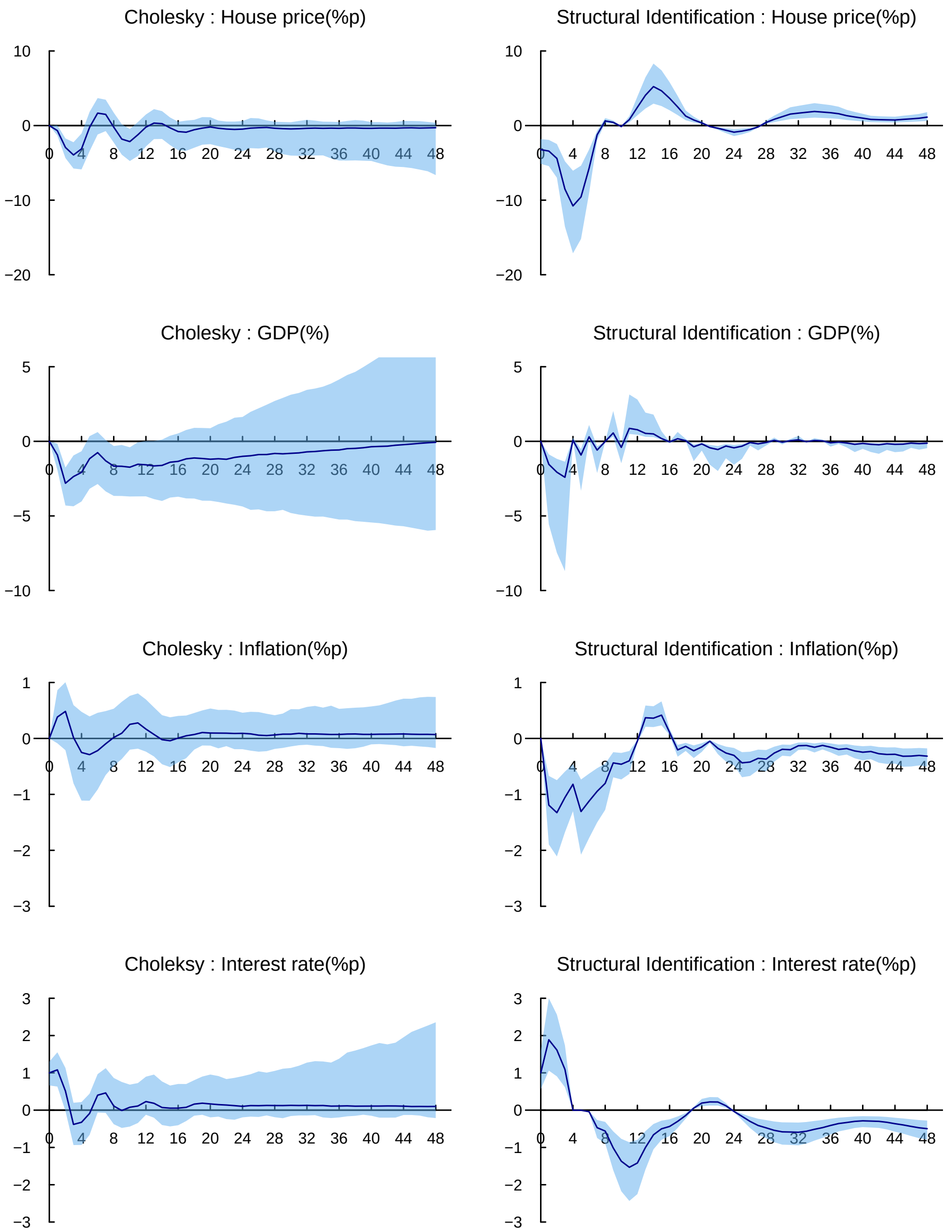

Figure 4: Cholesky and SVAR based regime-dependent responses - Normal regime

identification. In contrast to the Normal regime where the impulse coefficients with Cholesky decomposition are significant during the first few quarters, the impulse coefficients of all four variables(except for the interest rate for the first quarter) are insignificant over the whole horizon during the Bubble regime. Further, 90 percent confidence intervals computed with Cholesky decomposition are much wider than those with the structural identification.

Meanwhile, regarding the puzzle, there is some evidence of the price puzzle regarding the responses of house price growth rate and inflation in the structural identification. But the degree of the price puzzle is quite moderate.(0.1%p increase of house price growth rate and inflation for the first two quarters) Also, under Cholesky decomposition, there is increase of output right after the shock, which is less likely to be theoretically justified. Thus, although some evidence of the price puzzle still appears in the structural identification method of this paper during the Bubble regime, it seems to be a more reasonable specification, given that the degree of puzzle is low and temporary.

Finally, I compute the percentage point change in house price growth rate(%p) per percentage loss in the level of output(%) one year after the shocks with Cholesky decomposition to examine whether the findings of this paper are robust under Choelsky decomposition. The percentage point change of real house price growth rate to the unexpected monetary shocks after one year is -3.94 in the Normal regime and -1.27 in the Bubble regime. Since the response of output after two years is - 2.36 percent in the Normal regime and -0.84 percent in the Bubble regime, the percentage point change in house price growth rate(%p) per percentage loss in the level of output(%) estimated with

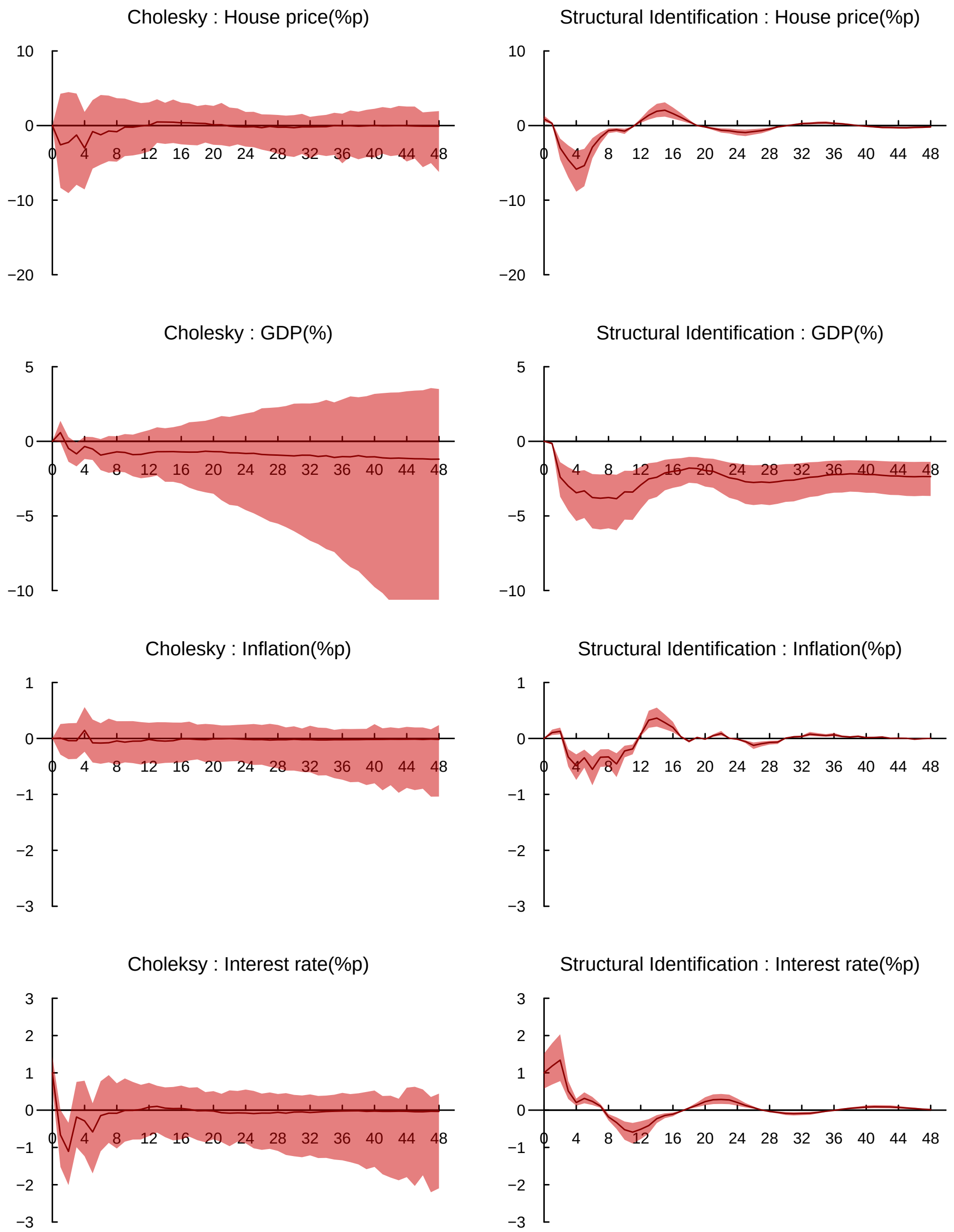

Figure 5: Cholesky and SVAR based regime-dependent responses - Bubble regime

Cholesky decomposition is 1.67 in the Normal regime and 1.51 in the Bubble regime. The results differ from the estimates using the structural identification, which are 3.54 in the Normal regime and 1.53 in the Bubble regime.

It might be confusing that there exists stronger trade-offs in the Normal regime, which is contrary to the reasoning of the study. However, note that under Cholesky decomposition, (i) the responses of variables are insignificant under 90% confidence interval and (ii) there is a sharp decrease in the response of interest rates right after the impact shock during the Bubble regime only, which is not observed in the structural identification. Thus we can infer that the difference in the systematic response of interest rates might lead to the weaker response in both house prices and output during the Bubble regime. Also, though the response of output might differ, the inference from this paper that there is a stronger disposition effect in a housing market during the Bubble regime is still valid under Cholesky decomposition as during the Bubble regime, the percentage point reduction in house price growth rate(%p) one year after the shock is smaller than that during the Normal regime.(1.27%p < 3.94%p)

Comprehensively, compared to Choleksy decomposition, the structural identification of this paper improves efficiency of the coefficients, while keeping the coefficients of variables to have the expected sign. Meanwhile, the finding of this paper that there is stronger monetary policy trade-offs in the Bubble regime than in the Normal regime is invalid under Choleksy decomposition due to the weaker response of output caused by the systematic response of interest rates after the shock. However, not only responses of the variables are insignificant under Cholesky decomposition but also the existence of stronger disposition effect during the Bubble regime is still proved to be valid by the response of house prices after the same size of the shock during each regime.

6 Conclusion

After the Great recession, many economists argue for leaning against the wind, which is defined as a bias for a somewhat tighter policy than justified by the dual mandates, stabilizing inflation and unemployment.(Svensson, 2015) The problem is that the trade-offs in leaning against the wind may be affected by the presence of bubbles in housing market. I use Korea quarterly data from 1999Q2 to 2019Q4 to estimate double regime T-SVAR model which combines the structural identification with TVAR modelling. The results shows that the trade-offs in leaning against the wind are more persistent and stronger during the Bubble regime when the trend component of quarter to quarter growth rate of real house price to income ratio has been above the threshold value. That is, central banks should take more output loss to curb house prices and may not be able to sedate house prices to its target level during house price peaks. In particular, to an unexpected one percentage point increase of the interest rate, house price growth rate falls severely while output falls temporarily during the Normal regime. In contrast, to the same increase of the interest rate, house price growth rate falls moderately while output falls severely and persistently during the Bubble regime. The percentage point change in house price growth rate(%p) per percentage loss in the level of output(%) after one year is 3.54 in the Normal regime and 1.53 in the Bubble regime. This implies that leaning against the wind can achieve housing market stabilization without a huge cost of output loss before house price booms, whereas it may not achieve its policy target and be likely to bring out a persistent recession as side-effects. So it is necessary to consider the state of housing market and timing before introduction of leaning against the wind.

The T-SVAR Identification of this paper has special features which allow i) a threshold effect using house price growth rate as a threshold variable, and ii) contemporaneous interaction between monetary policy and housing market. To check the robustness of this specification, I estimate a single regime SVAR model without a threshold effect, where the percentage point change in house price growth rate(%p) per percentage loss in output(%) after one year is 2.58. It remarks that without allowing a regime shift, any try to estimate the trade-offs in leaning against the wind can be misleading. Meanwhile, I estimate the TVAR model with standard Cholesky decomposition and compare it with ours. The structural identification of this paper has narrower confidence intervals than Cholesky decomposition while keeping the coefficients to have the expected signs. In particular, the coefficients of the economy estimated with Cholesky decomposition are all insignificant with 90% confidence intervals except for the first few quarters during the Normal regime.

But analysis of this paper has several shortcomings. First, the price puzzle pops up regarding the response of real house price growth rate and inflation during the Bubble regime. While inflation begins to fall after the third quarter and the degrees of the puzzle is quite low(0.89%p in house price growth rate and 0.1%p in inflation), the existence of the price puzzle may be due to some misspecification with regard to forward-looking behavior of central banks and private sectors.(Sims, 1992) Thus, it is necessary to develop more orthogonal measures of monetary policy shocks in Korea which excludes foresight problem.

Second, I estimate the Bubble regime model with three lags as there is a serious price puzzle in the response of house price growth rate, which does not equal with the Normal regime model with four lags, making it difficult to compare the difference between regimes precisely. Moreover, the financial crisis in 2007 and Quantitative Easing of Fed after it might influence the estimation result. Also, the change in real estate policy in Korea might affect the estimation result. Regarding this, it would be necessary to examine the relationship between the global financial environment, domestic real estate policy, and the trade-offs in leaning against the wind, which I've left for future analysis.

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Appendix A. Threshold effect test [12]

Testing for a threshold effect is equivalent to testing if the coefficients are the same in each regime. In particular, let β_b, β_n, the coefficients in the Bubble regime and the Normal regime. Then the null hypothesis and the alternative hypothesis(the linear versus double-regime model) are

$$H_0 : \beta_b = \beta_n, \quad H_a : \beta_b \neq \beta_n \tag{14}$$

The F statistics is as follows

$$F_1 = \frac{(S_0 - S_1)}{\hat{\sigma}^2} \tag{15}$$

Hansen (1999) proposes the following bootstrap design to compute the critical value of the F statistic.

Step 1: Estimate the model under H_a and get the residual $\hat{\epsilon_t^*}$.

Step 2: Make a cluster resampling $\hat{\epsilon_t^*}$ with replacement, and get the new residual v_t^*.

Step 3: Create a new series under the H_a data generating process, which is $y_t^* = X_t^* \beta + v_t^*$.($\beta$ can take arbitrary values)

Step 4: Estimate the model under H_0 and H_a, and compute the F statistic using equation.3.

Step 5: Repeat steps 1-4 B times, and the probability of F is Pr=I($F > F_1$).

[12] Refer to Wang (2015)

That is, the proportion of $F > F_1$ in boostrap number B.

Appendix B. Data

I use quarterly Korea data from 1999Q2 to 2019Q4. The details of data is as follows.

(i_t^*): I use the Federal Funds rate as the foreign interest rate, as the US is the second[13] largest export destination for Korea.
Sources : Federal Reserve Economic Data

(y_t): Log of quarterly real GDP.
Sources : Bank of Korea Economic Statistics System(ECOS)

(π_t): Inflation, measured as quarter to quarter change in the log of the Consumer Price Index(CPI). The CPI is adjusted for agricultural products and energy prices.
Sources : Bank of Korea Economic Statistics System(ECOS)

(ph_t): House prices, measured as quarter to quarter change in the log of the real house price index. Specifically, I use the Housing Purchase Price Index(KB) on the basis of Apartment in Seoul as house price index. The reason why I choose house price index based on the Purchase Price of Apartment in Seoul is that the corresponding variable reflects the state of Korea housing market better than other indexes.

[13] China is the first largest country, but its financial system is somewhat closed, so I do not consider.

Sources : Bank of Korea Economic Statistics System(ECOS), KB Kookmin Bank

(e_t): Log of the quarterly real effective exchange rate(CPI-based), measured against a basket of trading partners.
Sources : BIS

(i_t): Quarterly yields on CD(91-day)
Sources : Bank of Korea Economic Statistics System(ECOS)

(phi_t): Trend component of quarter to quarter growth rate of real house price to income ratio, measured as HP-filtered quarter to quarter change in the log of the real house price index(calculated as in ph_t) minus the log of GDP per capita.(current price, seasonally adjusted)
Sources : Bank of Korea Economic Statistics System(ECOS), KB Kookmin Bank

Appendix C. Cholesky based regime-dependent responses with different order

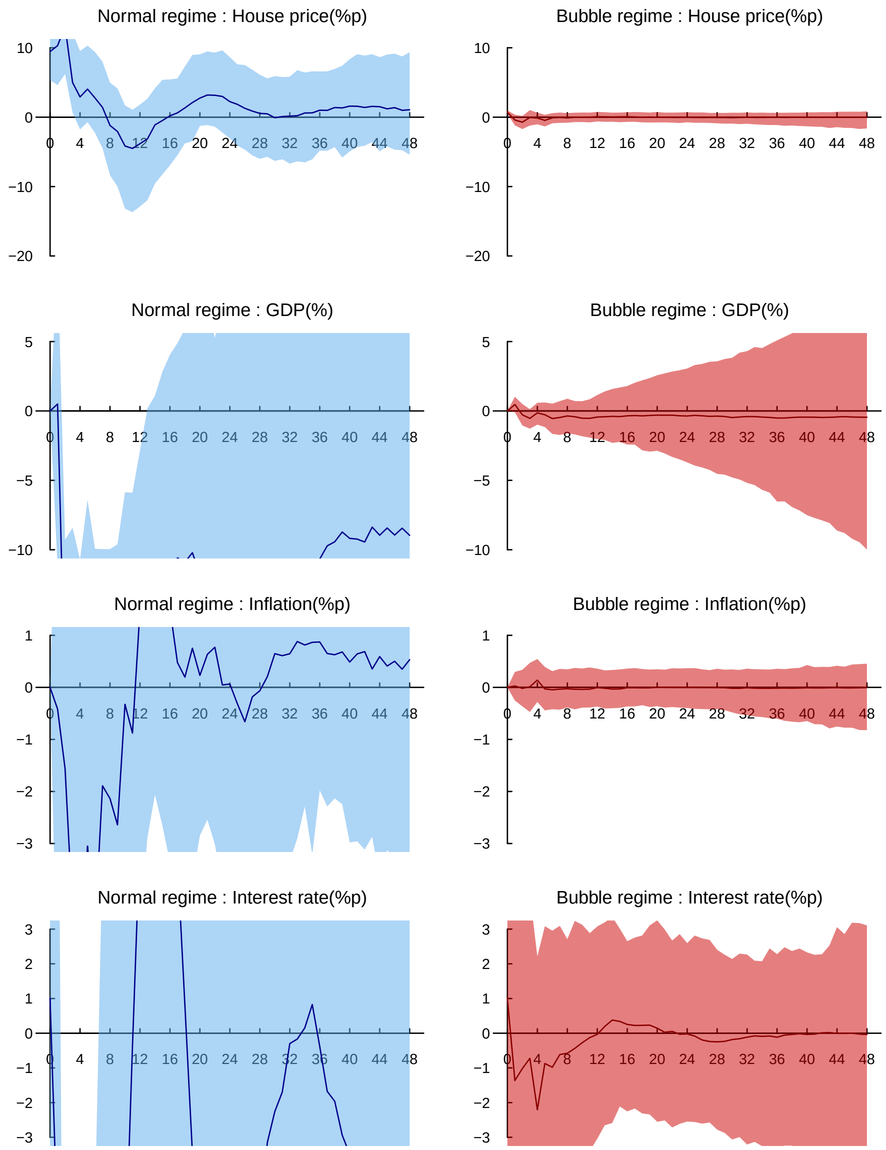

Figure 6: Cholesky based regime-dependent responses - switching order between monetary and house price shocks

Too Late To Lean Against The Wind
: Timing dependent Trade-offs in monetary policy shocks

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요약(국문초록)

본고는 부동산 시장의 버블 유무에 따른 역풍정책(Leaning against the wind)의 상충관계(Trade-off)를 비교하기 위해 Bubble vs Normal regime의 비선형 SVAR 모형을 추정하였다. 구체적으로 TVAR 모형과 구조적 식별법(SVAR Identification)을 결합한 T-SVAR 방법론을 사용하였으며, 추정결과 소득 대비 부동산 가격 비율이 상방 추세를 보이는 Bubble regime에서 역풍정책이 더 강력하고 지속적인 상충관계에 직면하는 것으로 나타났다. 구체적으로 1%p 예측하지 못한 통화정책 충격에 대해 4분기 이후 GDP 1% 감소 대비 부동산 가격 증가율 감소분(%p)은 Normal regime에서 3.54, Bubble regime하에서 1.53으로 추정되었다. 이는 부동산 시장에 이미 버블이 형성된 이후 시점부터는 중앙은행이 동일한 부동산 가격 하락 효과를 위해 더 많은 성장률의 희생을 감수해야함을 시사한다. 한편 Regime shift를 고려하지 않은 Single regime 모형에서는 동 수치가 2.58로 추정되었다.

이는 역풍정책의 효과 및 상충관계 분석에 있어 부동산 시장에 따른 정책 타이밍을 고려하지 않는 경우 과소/과대평가의 위험이 존재함을 시사한다.

주 요 어: Threshold VAR, Monetary VAR, Threshold effect, 구조적 변화, 부동산 가격, 통화정책 충격, 자산가격 거품, 역풍정책

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