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The Credit Channel of Monetary Policy through the Housing Market An Analysis with VAR sign restriction

주택 시장을 통한 통화정책 신용 경로의 유효성 분석 VAR 부호제약 모형을 이용한 분석

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Abstract

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The main purpose of this paper is to verify that the credit channel of monetary policy, especially the balance sheet channel, is effective through the housing market. In general, the decrease in house price after the contractionary monetary policy is accompanied by the decrease in consumer loans and consumption level. For the analysis, VAR model is implemented and the shocks are identified with sign restrictions. To be specific, this paper estimates the effects of monetary policy shocks by imposing sign restrictions on the impulse responses of real GDP, prices including CPI and commodity price, non-borrowed reserves, total reserves and Federal Funds rate. And no restrictions are imposed on housing variables including house price, house quantity, mortgage rates and consumer loans and consumption level.

First, an indirect effect of an interest rate change which occurs through the change in house price would be analyzed. Second, a direct effect of an interest rate change which occurs through the mortgage rate would be analyzed. Finally, how the consumer loans are influenced would be analyzed which reflects a contraction of loan supply originated by the credit channel.

Keywords : Monetary policy transmission, the Credit Channel, the Balance Sheet Channel, Monetary policy shock, VAR, Sign restrictions, Impulse response functions, Housing market

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Chapter 1

Introduction

On October of 2016, the total household debt of United States reached 14756.09 billion dollars. This is almost 80.15% of the GDP in United States on the same period. In other words, the household debt to GDP ratio for United State on the same period is 80.1%. That of Korea recorded 87.2% on the fourth quarter of 2016 and that of United Kingdom was 91% on the third quarter of 2016. As it could be noted, the household debt has been recognized as an impending issue in many countries including Korea, United Kingdom and United States. The household debt mostly consists of borrowing for housing.

One of the main sources of household debt is a loan from the commercial bank. And the consumer loans are main evidence of the bank lending channel of the monetary policy transmission. Hence, in this paper, the consumer loans and consumer credits would be analyzed to see if the credit channel of the monetary policy is effective.

Also, the role of central bank on the household debt has been rising lately. Hence, it would be significant to see how the housing market variables respond to the monetary policy shock. Moreover, according to Vargas-Silva(2007), the housing market is considered to have a predictive power over the future course of economy. Therefore, it would be mean-

ingful to consider the monetary policy transmission through the housing market.

In particular, the main interest of this paper is to see how the monetary policy transmission works through the housing market. Especially, the credit channel of monetary policy, and particularly the balance sheet channel, would be the main focus. The analysis would be based on the VAR model identified with sign restrictions. This paper would approach the issue with the data of United States of America before the 2008 financial crisis. After the 2008 financial crisis, the Federal Reserve almost lost its means of monetary policy with interest rate. The Fed had faced with the zero lower bound of nominal interest rate and started the policy of quantitative easing in order to recover from the collapsed economy. Therefore, for the purpose of discerning how an increase in the interest rate impacts house price, house quantity and mortgage rate and finally consumption level and other variables, the data before the 2008 financial crisis would be analyzed.

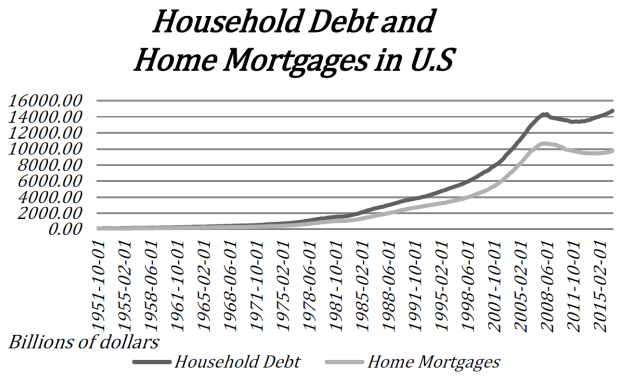

Figure1. Household debt has increased drastically in U.S. And most of the household debt consists of Home

To be specific, the monetary policy transmission mechanism through the housing market works as below. There are a direct effect and an indirect effect of an increase in interest rates. First, the direct effect, often called as

the interest rate channel, is when interest rates go up, interest payments on variable rate also rises. And as an extra payment for the interest emerges, consumption of household is lowered subsequently. Second, the indirect effect is that the house prices go down as interest rates go up. And this lowered house price subsequently lowers owner-occupier wealth and collateral value of house. Specifically, as most people own the house as their main asset, when the price level of houses goes down the wealth effect occurs. As a result of the wealth effect, the consumption level of an economy goes down either. Both of them result in a decreased level of consumption. (Mishkin2007, Elbourne 2008)

In this paper, as noted, the main focus is how the credit channel works. Especially, how the monetary policy works through the demand side of housing market. Hence the latter, meaning the indirect effects, especially how house prices and quantities change would be verified first. After seeing how house prices and quantities respond, we would see how consumption reacts to a contractionary monetary shock. And then, in order to see if the direct effect of an increase in interest rates works properly, how the adjustable mortgage loan rate responds to the monetary policy shock would be analyzed, since the direct effects mostly rely on how fast mortgage interest rates change following a monetary policy contraction.

Finally, back to the original issue, in addition to the credit channel of monetary policy through the housing market stated above, how the consumer loans respond to the monetary policy would be analyzed. According to the credit channel of monetary policy transmission, a contraction in loan supply could result from the credit channel. Hence, in this paper, how the consumer loans respond to the contractionary monetary policy would be verified.

Chapter 2

Literature Review

The attempt of imposing the sign restriction in identifying the monetary policy was conducted by Uhlig (2005). In Uhlig's paper, the sign restrictions were imposed on the variables following the conventional wisdom that contractionary monetary policy shocks yield the rise of the federal funds rate, the fall of prices and also the fall of real output. Unlike the method by Blanchard and Quah(1989) or Lippi and Reichlin(1994), in the paper, Uhlig(2005) does not impose a zero impulse response at infinity or a particular shape of the impulse responses. Instead, imposing the sign restriction for a certain period was used in order to identify the monetary policy shock. The purpose of this restriction was to be minimalistic and to use as little a priori reasoning about other shocks. In the paper, the main focus was the monetary policy shock hence other fundamental innovations were not identified. As in Bernanke and Mihov(1998 a,b) real GDP, the GDP deflator, a commodity price index, total reserves, non-borrowed reserves and the federal funds rate for the US at monthly frequencies from January 1965 to December 1996 was used. The bench mark result was that the sign restriction was imposed for 5 months after the shock(K=5). To be specific, the responses of the GDP price deflator, the commodity price and non-borrowed reserves had been restricted not

to be positive and the federal funds rate not to be negative for 6 months after the shock.

2.1 VAR identification with sign restrictions

2.1.1 Uhlig(2005)

The attempt of imposing the sign restriction in identifying the monetary policy was conducted by Uhlig (2005). In the paper, the sign restrictions were imposed on the variables following the conventional wisdom that contractionary monetary policy shocks yield the rise of the federal funds rate, the fall of prices and also the fall of real output. Unlike the method by Blanchard and Quah(1989) or Lippi and Reichlin(1994), in the paper, Uhlig(2005) does not impose a zero impulse response at infinity or a particular shape of the impulse responses. Instead, imposing the sign restriction for a certain period was used in order to identify the monetary policy shock. The purpose of this restriction was to be minimalistic and to use as little a priori reasoning about other shocks. In the paper, the main focus was the monetary policy shock hence other fundamental innovations were not identified. As in Bernanke and Mihov(1998 a,b) real GDP, the GDP deflator, a commodity price index, total reserves, non-borrowed reserves and the federal funds rate for the US at monthly frequencies from January 1965 to December 1996 was used. The bench mark result was that the sign restriction was imposed for K=5 and the responses of the GDP price deflator, the commodity price and non-borrowed reserves had been restricted not to be positive and the federal funds rate not to be negative for 6 months. Following the shock,

2.2 Housing Market

2.2.1 Vargas-Silva(2007)

A VAR analysis regarding the monetary policy and the U.S. housing market imposing the sign restrictions was conducted by Vargas-Silva(2007). As the identification procedure, the sign restrictions are imposed on the response of some variables for a certain period. The variables that the researcher had imposed the sign restriction on were real GDP, house prices, price deflator, commodity price, Federal Funds rate, Non-borrowed reserves and total reserves.

As the housing market variables, residential investment and housing starts were included and analyzed. However, residential investment and housing starts mostly relevant to how many houses are supplied to the housing market at a given period. To be specific, housing starts is the number of privately owned new houses on which construction has been started in a given period. Also, investment in residential structures is represented by new construction of permanent-site single-family and multi-family units, improvements to housing units. Likewise, residential investment and housing starts do not show how the demand side of the housing market responds to the monetary policy shock.

Therefore, in this paper, in order to see a ramification between demand and supply of housing market, house prices and house quantities would be considered. On Vargas-Silva(2007), the house price was also included, but it was imposed with a sign restriction that house prices will fall following the contractionary monetary policy. In order to see, how the variable genuinely reacts to the monetary policy shock, it is significant that no restriction is imposed on the variable of interest. Since the main focus of this paper is to see how house prices and house quantities react to the monetary policy shock, sign restrictions would not be imposed.

Therefore, in this paper the house price and the amount of houses sold will be included. The price of house and the amount of houses sold are decided by the interaction of both supply and demand side of housing market. Compared to the housing starts and the residential investment, the price and the quantity of house are determined relatively heavily counting on the demand of house. And no sign restriction would be imposed on house price and house quantity.

2.2.2 Lastrapes(2001)

Another study was conducted to measure the effect of money supply shocks on the aggregate market for owner occupied housing by Lastrapes(2001). In the paper, the researcher had applied two different estimation and identification methods. The first set of restrictions for identifying the model depends on the idea that nominal money supply shocks are neutral in the long run. The second set of restrictions for identifying the model is based on only contemporaneous relationships and that does not require first differencing of the data. Specifically, the variables are partitioned into three parts. First, z_{1t} contains the variables that are restricted not to respond to contemporaneous monetary policy but at the same time can affect such policy. Second, s_t is the monetary policy instrument. And third, z_{2t} is restricted to have a contemporaneous impact on neither z_{1t} nor s_t. Therefore, these restrictions show the lower block recursive.

The research was conducted based on two different data sets, new house data and existing house data. In all results based on the new house data and the existing house data with short run and long run restriction, both the house prices and the house sales increased after the expansionary money supply shock.

2.3 The Credit Channel of Monetary Policy Transmission

2.3.1 Mishkin (2007), Elbourne(2008)

According to Mishkin(2007), by raising the short term interest rates, the monetary policy affects the housing market and the overall economy directly or indirectly through at least six channels.

The direct effects of interest rates on (1) the user cost of capital, (2) expectations of future house-price movements, (3) housing supply The indirect effects of interest rates through (4) standard wealth effects from house prices (5) balance sheet, credit channel effects on consumer spending, (6) balance sheet, credit channel effects on housing demand.

The contractionary monetary policy will increase the demand for housing which result in higher house prices. The increased house prices indicates an increase in total wealth, and this ends up stimulating household consumption. This standard life cycle wealth effect operating through the house prices is a significant factor in the monetary policy transmission mechanism. According to the life cycle wealth effect, all types of wealth could be considered. However, as the house prices fluctuate less than the stock prices, the changes of the housing wealth could be considered as longer lasting than changes of a stock market wealth. This is why a housing wealth should have a larger effect on consumption than a stock market wealth.

In this paper, first of all, the indirect effect of interest rate through the house price and the house quantity would be analyzed. And later, since the credit channel is assumed to work with the interest rate channel, the direct effect of interest rate through the mortgage rate would be analyzed either.

2.3.2 Iaocoviello and Minetti(2008)

In the paper, a VAR approach was employed to analyze how the efficiency of housing finance affects the credit channel of monetary policy in four countries including Finland, Germany, Norway and the UK. The monetary shocks are identified using a combination of short and long run restrictions. The house prices are more suitable than the housing investment to test the existence of a credit channel.

First of all, in the housing market, the prices adjust faster than the quantities, hence the house prices can cast more information on changes in the housing demand in the short run. Also house prices can be the essentials in the transmission of monetary policy through credit supply shift. To be specific, the house prices have impact on borrowers' wealth and credit capacity. Moreover, house price affect lenders' willingness to lend.

Chapter 3

Data

In this paper, largely two categorized data sets had been considered. The first categorized data set represents the overall economic status. And the second categorized data set involves the housing market data.

3.1 Data of overall Economic Status

As in Uhlig(2005), real GDP, Consumer Price Index, Commodity Price Index, Non-borrowed reserves, total reserves, Federal Funds rate are included in the model. As stated in the Lastrapes(2001), the price level and output are included in the model to refine the identification of the monetary policy shocks based on the macroeconomic theory. To be specific the following variables will be included Real GDP, Consumer Price Index, Commodity Price Index(PPI), Federal Funds rate, Non-borrowed Reserves and the total reserves. All of them consist of the monthly data. As the real GDP is officially only calculated quarterly, in this paper, the monthly stock and Watson real GDP index would be considered. In order to consider impact of the price level in the model, Consumer Price Index would be included. CPI data is from Federal Reserve Economic Data and the consumer price index is for all urban consumers and for

all items. The base year of the index is from 1982 to 1984, therefore on August 1983 CPI has its value of 100.10. Commodity Price Index(PPI) is included to control the case that policy makers use information about future inflation in setting policy(Lastrapes2001). The data used for commodity price is Producer Price Index for all commodities. The base year of the data is 1982 and the data is not seasonally adjusted. The source of the data is Federal Reserve Economic Data. And the Federal Funds rate, Non-borrowed reserve and total reserve are also from Federal Reserve Economic Data.

In this paper, the price level (Consumer Price index) and non-borrowed reserves and Federal Funds rate all of three define the monetary policy. These are included following Uhlig(2005) where they were included in order to solve the problem of liquidity puzzle and price puzzle with monetary policy shock. When identifying monetary policy shock with VAR model, the liquidity puzzle and the price puzzle had been recognized. Specifically, a liquidity puzzle is that theoretically the interest rate should go down when there is an increase in money supply however the interest rate goes up following the increase of the money supply. The price puzzle is that in prediction the price level should go down following the increase in the interest rate but it goes up after an increase of the interest rate in a VAR analysis.

3.2 Housing market Data

The second categorized data set entails the housing variables. As the housing variables, we would include house prices, house quantities, mortgage loans and mortgage rates. These are the variables that represent the housing market especially concentrating on the demand side. The followings are details of why the chosen housing variables are meaningful.

3.2.1 House Price

We include the house price in order to see if the credit channel of monetary policy is valid. That is by verifying that house price changes as a result of monetary policy, and then by seeing that consumption level responds to the change in monetary policy and house price, the validation of the credit channel could be determined.

If the mechanism from the interest rate to house price and finally to consumption level works effectively, it can be concluded that the effect of the credit channel of monetary policy stands. Iacoviello and Minetti(2008) had shown the evidence of the credit channel of monetary policy from the housing market with VAR model.

In the paper of Iacoviello and Minetti(2008), the shocks are identified with the combination of short run and long run restriction. As stated in the paper, house prices can play a significant role in the transmission of monetary policy through credit supply shifts. Hence, in this paper, we would see how the house price responds to the monetary policy shock which is identified with the sign restriction.

3.2.2 House Quantity

House quantity is included in the model in order to see the credit channel of the monetary policy. Both house prices and house quantities are effective in capturing changes in housing demand. In most cases, when considering the demand side of the housing market, house prices are considered. That is because house prices adjust faster than the house quantity in the short run. However, since the quantity itself reflects the demand side of the housing market in the long run, the quantity would be included either and verify the effectiveness of the credit channel of the monetary policy. In brief, if the house price and the house quantities respond to the monetary policy shock as they did on Iacoviello and Minetti(2008),

it can be concluded that the credit channel of the monetary policy shock is again indeed effective with identification of the monetary policy shock with sign restriction.

3.2.3 Effective Interest Rate of adjustable rate Mortgage

Before stating why the mortgage loan variables are included in this paper, the types of mortgage loans should be clarified. Regarding the mortgage loan, there are largely two types of mortgage loan with respect to an interest rate : An adjustable-rate mortgage and a fixed-rate mortgage.

First, an adjustable-rate mortgage is a 30 year home loan starting with a fixed rate for 3 to 10 years and then the interest rate should change on an annual basis since the fixed portion of the loan expires. Adjustable-rate Mortgage loans generally are characterized with lower rates and monthly payments compared to a fixed rate loans during the starting period. However, the interest rate might increase once the period with fixed rate is over. Most people prefers an adjustable rate mortgage loan to a fixed rate mortgage loan, but an adjustable rate mortgage is preferred by people who will be moving within the next few years.

Second, a fixed rate mortgage means that an interest rate for a mortgage loan would not change for the whole period of loan repayment. Monthly payments on a conventional fixed-rate mortgage remain the same for the life of the loan, making it an attractive option for borrowers who plan to stay in their home for several years.

In order to see the direct effect of monetary policy transmission, it is important to see if the adjustable mortgage loan rate follows the change of interest rate quickly. Since the main point of considering the adjustable mortgage loan rate is to identify how large the burden of mortgage repayment increases as the Federal Funds rate goes up, for this case the effective interest rate of an adjustable mortgage loan rate for all homes

and newly built and previously occupied would be included in the model.

3.2.4 Consumer Loans

According to Jorgenson(1963) and Mishkin(2007), standard neoclassical models of housing activity take the user cost of capital as a significant factor that decides the demand for residential capital. The user cost can be represented as the following.

$$uc = ph[(1-t)i - \pi_h^e + \delta]$$

where ph is the relative purchase price of new housing capital, i is the mortgage rate,$\pi_h^e$is the expected rate of appreciation of housing prices, δ is the depreciation rate for housing.(Mishkin 2007)

Therefore, if the mortgage rate goes up as the Federal Funds rate increases, the user cost for residential capital also increases. Hence, for those households who do not own the house yet but was planning to buy the house will be reluctant to get a mortgage loan in order to buy the house. Thus, it could be anticipated that the amount of mortgage loan would decrease following an increase in interest rate (Fed Funds rate).

Also, the household who owns the house will experience the devaluation of their assets since the house price decreases. Thus, a contraction in loan supply will result from a credit channel, since the lenders would not be willing to lend money to people who own the low valued collateral.

3.3 The Source of Data

The real GDP data is from monthly Stock-Watson real GDP data. Consumer Price Index for all urban Consumer (seasonally adjusted and the base year is 1982-1984) and Producer Price Index for all commodities (not seasonally adjusted and the base year is 1982) are from Federal

Reserve Bank of St. Louis. Effective Federal Funds rate (not seasonally adjusted and represented with percent (%) units) and Reserves of Depository Institutions, Non-borrowed (billions of dollars, not seasonally adjusted) are from Federal Reserve Bank of St. Louis. Total Reserves of Depository Institutions (billions of dollars, not seasonally adjusted) is from Federal Reserve Bank of St. Louis. The data for house price and house quantities are also from Federal Reserve Bank of St. Louis. Moreover, consumer loans at all commercial banks(billions of U.S dollars) and total consumer credit owned and securitized, outstanding(billions of dollars) are from Federal Reserve Bank of St. Louis. Finally, the adjustable mortgage rate is an effective rate for the adjustable-rate mortgage loan from Federal Housing Finance Agency.

Chapter 4

Model

4.1 VAR analysis

4.1.1 The sign restriction

Imposing the sign restrictions with the VAR estimation works as the following. First of all, consider the following structural vector autoregressive model.

$$A_0 y_t = A_1 y_{t-1} + ... + A_p y_{t-p} + \varepsilon_t$$

The variance-covariance matrix of the structural error term ε_t is a diagonal matrix. And it can be normalized to I_K

$$E(\varepsilon_t \varepsilon_t^{'}) = \Sigma_\varepsilon = I_K$$

Let $u_t = P\eta_t$where u_t is the reduced form VAR innovation and P is the lower triangular Cholesky decomposition of Σ_u. By assumption, the shocks η_t are mutually uncorrelated and own unit variance. The possible solution ε_t^* can be searched for the unknown structural shocks ε_t by creating a large number of combinations of the shocks η_t of the form $\varepsilon_t^* = Q'\eta_t$, where $Q'$is a square orthogonal matrix which satisfies the

following condition $Q'Q = QQ' = I_K$. Here K is the number of variables included in the vector y_t.

Hence, $u_t = PQQ'\eta_t = PQ\varepsilon_t^*$ holds, and each candidate solution ε_t^* could be composed of uncorrelated shocks with unit variance. Whether any of these candidate solutions ε_t^* is a convincible solution for the unknown structural shock ε_t, given the vector of reduced form parameters, counts on whether the implied structural impact multiplier matrix, PQ, satisfies the maintained sign restrictions on A_0^{-1}. In the process the solutions that satisfy these sign restrictions are retained and the remaining solutions are discarded.

Identification of monetary policy shock

In this paper, the identification of monetary policy shock with sign restrictions would follow the procedure on Uhlig(2005). Hence, briefly, on Uhlig(2005), the identification through sign restrictions follows as below.

Consider the following reduced form VAR(1) model with n endogenous variables.

$$y_t = Ay_{t-1} + \varepsilon_t, t = 1, 2, \ldots, T$$

Where y_t is an n×1 vector of variables, A is an nn matrix of coefficients and ε_t is a set of errors with mean zero, no autocorrelations and have a variance-covariance matrix $\Sigma = E(\varepsilon_t\varepsilon_t')$. As stated by Canova and Nicolo(2002), orthogonal innovations from a reduced form model possesses no economic interpretation, however they possesses the property of being contemporaneously and serially uncorrelated . And guided by aggregate macroeconomic theory, the sign of the theoretical co-movements of chosen variables in response to an orthogonal innovation is imposed.

The one step ahead forecast errors of a reduced form VAR model are functions of some fundamental innovation as follow.

$$B\varepsilon_t = e_t$$

Where B is a nn structural parameters and e_t are the structural shocks following a standard-normal distribution with zero mean and a unit-variance. The structural parameters B can be recovered as below.

$$BB' = \Sigma = E(\varepsilon_t \varepsilon_t')$$

Here, Σ can be obtained from the estimation of reduced form VAR by Ordinary Least Squares.

Since it is difficult to impose sign restriction directly on the coefficient matrix of the model, the sign restrictions are imposed ex-post on a set of orthogonalized impulse response functions as stated on Canova and De Nicolo(2002). The specific process goes as below.

First, unrestricted VAR is estimated to obtain $\hat{A}$ and $\hat{\Sigma}$. And second, extract the orthogonal innovations from the model by using a Cholesky decomposition. Third, calculate the resulting impulse responses from the second step. Fourth, randomly draw an orthogonal impulse vector $\boldsymbol{\alpha}$. Fifth, multiply the responses from the third step and see if they correspond to the imposed signs. Finally, if it corresponds to the imposed sign, keep the response otherwise drop the draw and repeat the above steps.

According to Uhlig(2005), a vector is an impulse vector, if and only if there is an n-dimensional vector a of unit length that satisfies the following.

$$\alpha = B\tilde{a}$$

where $\tilde{B}\tilde{B}' = \Sigma$ is a matrix decomposition of Σ. And on Uhlig(2005), given an impulse vector $\boldsymbol{\alpha}$, one can simply calculate the impulse responses by multiplying the impulse vector with the impulse responses obtained

in the third step. Also, on Uhlig(2005), the impulse vector is generated based on a Givens rotation.

According to Moon and Schorfheide(2012), sign restrictions are only well defined from a Bayesian point of view. The steps from the second step to the final step are based on a joint draw from a flat Normal inverted-Wishart posterior for the VAR parameters and a uniform distribution for α.

In the paper, Uhlig(2005) has proposed two different approaches based on a Bayesian method to identify the impulse vector α. The first method is called "pure sign restriction approach" which considers all impulse vectors equally if they satisfy sign restrictions. The second approach is called "penalty function approach" which incorporates an additional criterion to choose the best of all impulse vectors. Specifically, the penalty function approach exactly identifies a monetary policy shock by minimizing some penalty function. For both approaches a Normal –Wishart prior is used. Uhlig(2005) had chosen the pure sign restriction approach. Compared to the penalty function approach which only considers the estimation of the impulse vector, the pure sign restriction approach consider both the estimation of the reduced form VAR and the impulse vector. Hence, in this paper, the pure sign restriction would be applied likewise in Uhlig(2005).

Partial Identification

In the simple example with two variables, in order for the identified shocks to be distinguished by a unique sign pattern effectively implies a fully identified model. However, with more than two variables in y_t as the case of this paper which contains 7 variables including Real GDP, Consumer Price Index , Commodity Price Index, Federal Funds rate, Non-borrowed reserves, total reserves and the housing variables such as the house price, the house quantity for sale and sold, the mortgage loan,

and the mortgage rate including the 30 years fixed mortgage rate and the effective interest rate of an adjustable mortgage loan, a fully identified model is not required for the identified shock to be distinguished.

In most cases, the researchers do not impose the restriction on any of the unidentified shocks that they should have a specific sign pattern. In fact, the agreement has not been reached yet in the literature on if this additional requirement is needed to be imposed in estimating partially identified sign identified models. Hence, as on Uhlig(2005), the main interest is the monetary policy shock. The researchers focus on the responses to the shock of interest without inspecting the responses to other shocks. In other words, they consider only one column of the impact multiplier matrix at a time, looking for solutions that satisfy the pre-specied sign pattern, while ignoring the other columns. All columns satisfying the pre-specied sign pattern are considered admissible solutions, and the possibility that other shocks in the same structural model may have the same sign pattern is ignored.

The main interest of shock on Uhlig(2005) was the monetary policy shock. Therefore, in the paper the model was only partially identified with the sign restriction. This means that no other sign restrictions were imposed on the other shocks except for the monetary policy shock. In order to see the Forecast Error Variance Decomposition (FEVD) which determines how much of the forecast error variance of each variable could be explained by exogenous shocks to the other variables in the model, all of the shocks should be identified in the model. Specifically, if there are 7 variables in the model like in this paper, total 7 sign restrictions should be imposed for each possible shock.

On Uhlig (2005) involves a sign-identied model that is only partially identied. The set of variables consists of monthly U.S. data for the log of interpolated real GDP (gdp_t) and of its deator ($defl_t$), the log of a com-

modity price index ($pcom_t$), total reserves (tr_t), non-borrowed reserves (nbr_t), and the federal funds rate (i_t). The identication is deliberately agnostic. An unanticipated monetary policy tightening is assumed to cause an increase in the interest rate and to lower the GDP price deator, the commodity price index and non-borrowed reserves all for the rst six months, including the impact period.

$$\begin{pmatrix} u_t^{gdp} \\ u_t^{defl} \\ u_t^{pcom} \\ u_t^{tr} \\ u_t^{nbr} \\ u_t^{i} \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ - & 0 & 0 & 0 & 0 & 0 \\ - & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ - & 0 & 0 & 0 & 0 & 0 \\ + & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} \varepsilon_t^* \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \end{pmatrix}$$

0 means that elements are unrestricted and ε_t^* means the monetary policy shock.

A fundamental problem in interpreting VAR models identied based on sign restrictions is that there is not a unique point estimate of the structural impulse response functions unlike other identification.

A typical outcome in practice is that the structural impulse responses implied by the admissible structural models will disagree on the substantive economic questions of interest. One early approach to this problem, exemplied by Faust (1998), has been to focus on the admissible model that is most favorable to the hypothesis of interest. This allows us to establish the extent to which this hypothesis could potentially explain the data. (Kilian and Lutkepohl (2017), Chapter 13)

Lags for VAR estimation and the period that sign restrictions are imposed

The method of sign restriction in identifying structural VAR models was first attempted by Faust (1998), Canova and De Nicolo (2002) and Uhlig (2005). A critical choice in estimation with the sign restriction is for how long the restrictions should hold after the shock.

Before stating how long the sign restriction would be imposed, it is important to determine what lags would be implemented in VAR estimation. As a bench mark model, 12 lags which is the equivalent of a year, as in the previous studies.

Following Uhlig(2005) as the benchmark model in this paper, the restrictions are imposed for 10 periods(months) with the inclusion of the impacted period it would be total 11 periods(months). Afterwards, this paper would also see how the responses differ according to the periods that the restrictions are imposed in part 6 Robustness.

A structural dynamic analysis

The essential reason for the identification of structural shock is to conduct a structural dynamic analysis. And this procedure would be analyzed with the impulse responses, Forecast error variance decompositions and historical decompositions. From now on, the brief explanation of the above will be followed.

Impulse response function

Impulse response functions shows how the variables react over time to exogenous impulses in other words, shocks. In order for the control that changing one error while holding the others constant seems feasible, the errors should be uncorrelated across equations. Generally, the unit of impulse is considered. However when the units of the variables are different,

one standard deviation of impulse is applied.

With the impulse response function, how the variables react to the shock. In this paper, the main focus is to see how the house market variables react to the monetary policy shock. Therefore, after conducting the VAR estimation with variables, the impulse responses of variables representing the economic status and the housing market variables to the monetary policy shock will be analyzed.

4.2 The Credit Channel of Monetary policy transmission

The credit channel of monetary policy transmission is an indirect amplification mechanism that works together with the interest rate channel. Generally, the credit channel is not regarded as a distinct or free standing alternative to the traditional monetary transmission mechanism. Instead, it is considered as a mechanism that amplifies the effect of interest rate. The interest channel is that the changes in Federal Funds rate can affect the cost of capital and consequently consumption decreases. The credit channel influences the economy by modifying the amount of credit that households can access. Therefore, when there is a factor that reduces the availability of credit, for instance, a decrease of value on the asset that could be used as collateral, the households reduce the consumption level. As an interest rate rises the cost of borrowing broadly magnifies.(Bernanke and Gerlter 1995) In order to verify if this direct effect of changes in interest rate, in this paper an adjustable mortgage loan rate is analyzed. If an adjustable mortgage loan rate moves parallel with the Federal Funds rate, it indicates that the cost of borrowing is going up.

Chapter 5

Results

5.1 Details of Method

VAR estimation

The VAR estimation was conducted after the transformation of units of the variables. As the Federal Funds rate and the mortgage rates, namely the effective interest rates are represented with the unit of percentage (%), they are not transformed. However, other variables including Real GDP, CPI, Commodity Price Index PPI, Non-borrowed Reserves, Total Reserves, the house price and the amount of houses sold and mortgage loan were taken log in the first place and then multiplied with 100, in order to represent them as the unit of percentage likewise of Federal Funds Rate and the Mortgage rates.

Impulse response

Impulse responses to a contractionary monetary policy shock of one standard deviation in size will be considered throughout this paper. Although it is just a matter of rescaling, since the variables in the model have different scales, it is desirable to consider innovations of one standard deviation rather than unit shocks. The monetary policy shock is identified with the

pure sign restriction. In the VAR estimation, real GDP, CPI, Commodity price, federal funds rate, non-borrowed reserves and the total reserve are included. And in order to see the impact in the housing market, the house price and the house quantity and the mortgage rate and the amount of the mortgage loans would be included respectively for each.

Sign restriction

The sign restrictions are imposed as below. First, a contractionary monetary policy shock yields the increase in the federal funds rate. And the sign restriction imposed on the real GDP is negative. Also for the CPI and commodity price index the sign restriction is imposed as negative. Moreover, the negative sign restriction was imposed on non-borrowed reserve and total reserve. And as usual, no restrictions were imposed on the house price and the amount of houses sold in order to see how these variables react to the monetary policy shock.

According to the previous studies including Vargas-Silva(2008), after the contractionary monetary policy shock the imposed signs for the variables were identified. Hence, in this paper, we would follow the previous results and impose the sign restrictions that are in a line with. The identification procedure imposes restrictions on the responses of the real GDP, CPI, commodity price index PPI, non-borrowed reserves, total reserve and the federal funds. No restrictions are placed on the responses of the measures of housing market activity. (Vargas-Silva 2007)

Lastrapes(2001) had conducted the study about the house price and the amount of houses sold. He had used the long run restriction and the short run restriction to identify the monetary policy shock. And the result that we got from the sign restriction coincides with the result from Lastrapes(2001). With the short run and the long run restrictions in identifying the monetary policy shock, the result of responses to the

monetary policy were identical.

In the case of an adjustable rate mortgage loan, the mortgage rate is highly influenced by the monetary policy shock. Compared to a fixed rate mortgage loan, when there manifests a contractionary monetary policy shock, the demand for houses falls.

5.2 House Price

As the house price, Median Sales Price for New Houses Sold would be involved following the previous studies including Vargas-Silva(2008) and Lastrapes(2001). This price is included in order to consider especially the prices of house that are actually transacted.

Median Sales Price for New Houses Sold

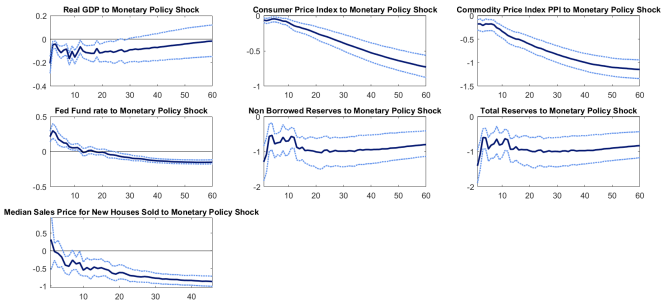

Figure2. Impulse response function with Median Sales Price unrestricted (lag 12, K=11)

The above impulse responses are originated from the VAR estimation which was conducted with lag 12 following Uhlig(2005), and as a baseline model the sign restriction was imposed for 10 periods. First, the real GDP responds negatively to a contractionary monetary policy shock. At the beginning, it dropped 0.2% of its value and the level of drop fluctuated. However, the effect was persistent for 60periods(months). The consumer price index and the commodity price index also dropped fol-

lowing a contractionary monetary policy and this indicates that there is no price puzzle. Non-borrowed reserves and total reserves decreased about 1.5% of its value as expected and persisted for 60 periods. Finally, after a contractionary monetary policy shock, the median sales price for new houses falls. The fact is at the beginning, the house price slightly increases about 0.25%, however after 2 or 3 periods it started to respond negatively to the shock and it persists till 60 periods. Thus, from the above impulse responses, it could be concluded that the house price indeed decreases after a contractionary monetary policy as it did on previous studies.

5.3 House Quantity

5.3.1 New One Family Houses Sold

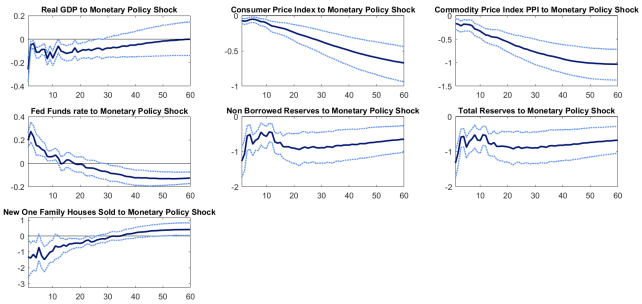

Figure3. Impulse response function with unrestricted New One Family Houses Sold (lag 12, K=11)

Figure3 shows the impulse responses and it is also from the VAR estimation with lag 12 and sign restrictions which are imposed for 10 periods. However, this time instead of the house price, the house quantity is included as a unrestricted variable. Lastrapes(2001) used the existing and new single family home sales as a house quantity variable. Similarly, in this paper, New one family houses sold will be incorporated as a house

quantity, especially to emphasize the demand size of the housing market. In comparison, New One family Homes for Sale was another candidate for a house quantity. However, for the aspect of considering the demand side of the housing market, the actual number of houses sold would be meaningful.

Real GDP, Consumer Price Index, Commodity Price Index and Non borrowed reserves, Total reserves responded similarly as it did in the case of house price. New One Family Houses Sold dropped about 1.5% of its value right after a contractionary monetary policy shock. And this impact lasts for 35 periods. And after 35 periods, the impulse responses recorded positive values. In Lastrepas(2001), both existing and new house sales increased after the expansionary money supply shock. Hence, the fact that New One Family houses Sold decreased following the contractionary monetary policy shock also is in a line with the previous studies.

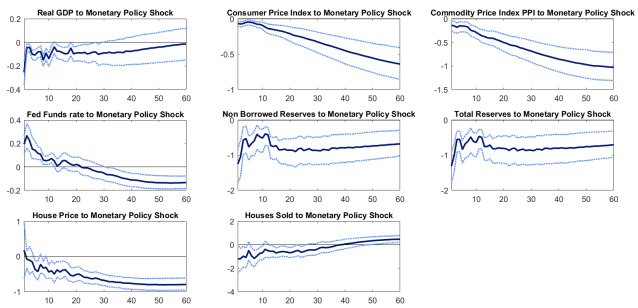

Figure4. Impulse response function with unrestricted house price and house quantity together (lag 12, K=11)

Figure 4 shows the impulse responses of the case when both the house price and the house quantity is included as unrestricted. As in figure 1 and 2, both the house price and the house quantity decreased after the contractionary monetary policy shock. The immediate impulse response was much bigger for the houses sold compared to the house prices. It could be explained as right after a contractionary monetary policy shock, people

decrease the transaction immediately. And as the number of transaction drops, the house prices are adjusted in order to make the transaction successful.

5.4 Mortgage Rate

5.4.1 Adjustable Mortgage Rate

Adjustable mortgage rates are included in order to see how closely the adjustable mortgage rate responds to the monetary policy shock. According to Elbourne (2008), the direct effect of an increase in interest rates is most effective when adjustable mortgage rates quickly follow up the changes in the policy interest rate. Thus, by confirming that the adjustable mortgage rates move in a line with the federal funds rate, it could be concluded that the direct effect of the change in interest rates is valid. Briefly, when the adjustable mortgage rate goes up, the burden for households who own the mortgage would increase. Hence, as the budget is restricted for the most of the households, the consumption level would be decreased.

As the adjustable mortgage rate, total three types of mortgages are included : All homes, newly built and previously occupied. As a baseline model, the VAR model were estimated for lag 12 and sign restrictions imposed for 10 months for each data set. Also, in order to measure how burdensome the mortgage is for the households, the effective interest rates had been analyzed. The effective annual interest rate is the interest rate that is actually paid on a loan due to the result of compounding over a given time period. Another name of the effective interest rate is the annual equivalent rate. And it is calculated as below.

$$(1 + i/n)^n - 1$$

$$(i = stated annual interest rate, n = number of compounding periods)$$

After confirming that an adjustable mortgage rate closely follows the Federal Funds rate, the consumption level would also be included to verify if the direct effect of an increase in interest rate on the consumption level.

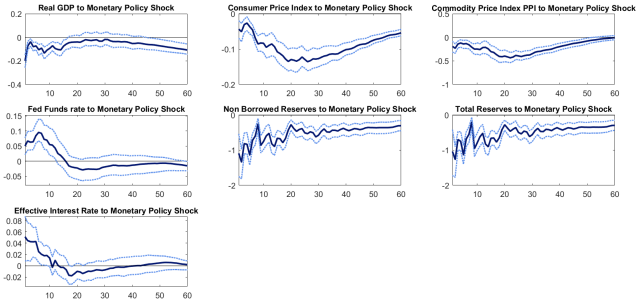

Figure5. Impulse response function with unrestricted effective interest rate (lag 12, K=11)

The data including the houses newly built and the houses previously occupied was used to see if the mortgage rate closely follows the Federal Funds rate. Likewise with other estimations, lag of 12 is imposed and the sign restriction was imposed for 10 periods. The mortgage rate moves quite similarly with the Federal Funds rate. When the Fed Funds rate goes up the mortgage rate goes up too and vice versa. The difference is that the level of impulse response is weaker in the case of mortgage rate. For instance, right after the monetary policy shock, the Fed Funds rate records the highest point of 0.1% increase of its value. However, the mortgage rate reaches its highest point of 0.05% increase of its value. The level of impulse response of mortgage rate is almost half of that of Fed Funds rate, and this continues for whole period in the IRF.

Therefore, by analyzing the above result, we can conclude that the mortgage rate rises after a contractionary monetary policy shock. An increase of mortgage rate would put a heavier burden on the households who got mortgages, and this would lead to the result of decreasing the consumption. The following is the analysis to see if the consumption level

falls after a contractionary monetary policy shock with the mortgage rate included.

5.5 Consumer Loans

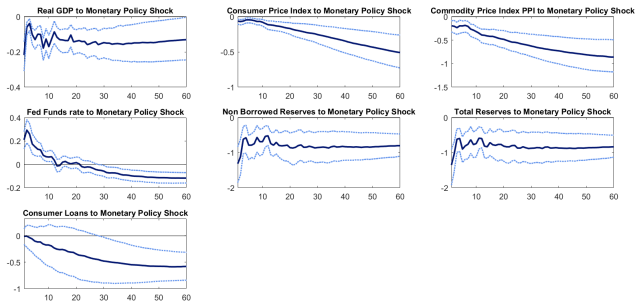

Figure6. Impulse response function with unrestricted consumer loans (lag12, K=11)

As it could be noted, the consumer loans decrease after the contractionary monetary policy shock. All the other variables including real GDP, CPI and PPI and non-borrowed reserves, total reserves decrease after the contractionary monetary policy shock.

The data used is the consumer loans at all commercial banks. The reason for the consumer loans decrease after contractionary monetary policy can be attributed to the reduction of asset value that the households hold. Generally, unlike the credit card loan which is not secured, the bank asks for collateral when the bank offers a loan. Hence, the loans from commercial banks are usually secured. And most commonly used collateral by the households is the house. Thus, when its value falls the amount of the loans that the bank offers goes down. This means that a contraction on loan supply occurs through the credit channel.

5.6 Consumption

5.6.1 House Price and House Quantity

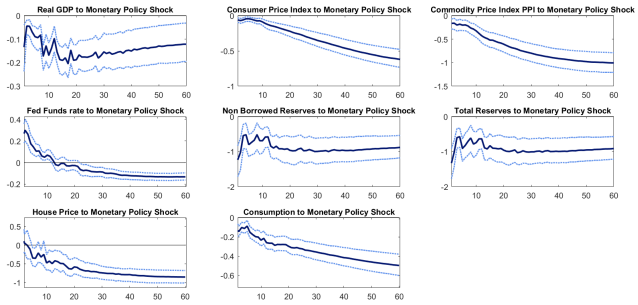

Figure7. Impulse response function with unrestricted house price and consumption level (lag 12, K=6)

The indirect effect of an increase in interest rate was that house price decreases after a contractionary monetary shock, and then this lowered house price also reduces the consumption level as due to the wealth effect. Thus, in order to see if this indirect effect really works, the house price and the consumption level are included in VAR model without sign restrictions imposed.

In this case, the house price is the median sales price for new houses sold. And the house price and the personal consumption expenditures both respond negatively to a contractionary monetary policy shock. This result corresponds with the result in K. Aoki et al(2004). Aoki(2004) had shown the impulse responses of consumption and house price with and without the financial accelerator. In both cases, the consumption and the house price increased after the expansionary monetary policy shock. Hence, as in this paper, the house price and the consumption level decreases following the contractionary monetary policy shock, we could see that the results correspond to the previous study.

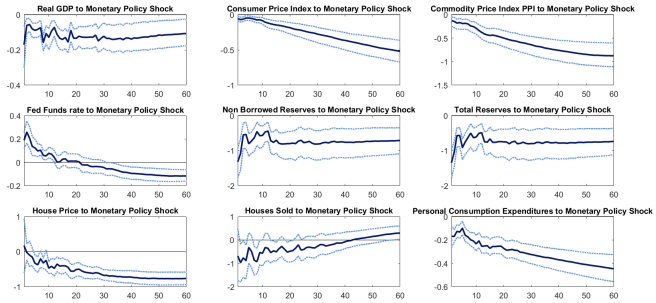

Figure8. Impulse response function with unrestricted house price, house quantity and consumption level (lag 12, K=11)

Figure8 shows the impulse response functions when the house price, the house quantity and the consumption level are included without restrictions. The purpose of these impulse response functions is to verify how consumption level responds in the existence of the housing market. The consumption level decreased as it did with only the house price included.

5.6.2 Mortgage Rate

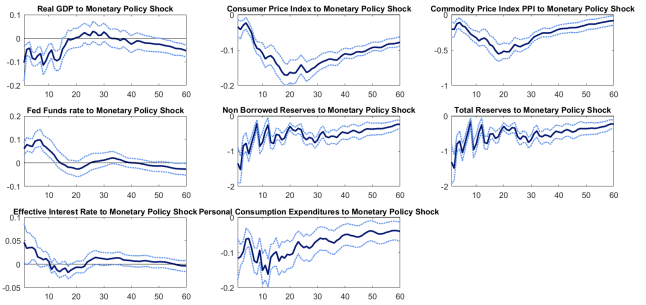

Figure9. Impulse response function with unrestricted effective interest rate and the consumption level (lag 12, K=11)

As expected, the mortgage rate(an adjustable rate mortgage loan) closely follows the Fed Funds rate throughout the whole period. And the consumption level also decreases after a contractionary monetary policy shock. The level of impulse response fluctuates for about 10 periods,

but the negative sign persists for the whole period. The level of impulse response gradually reduces and heads to zero.

From above results, we can conclude that the direct effects of interest rate on the consumption level are verified with the VAR identified with sign restriction. The mortgage rate closely follows the federal funds rate, and the consumption level decreases after a contractionary monetary policy shock.

5.6.3 Consumer Loans

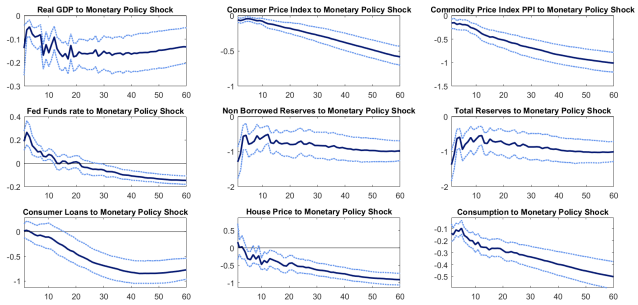

Figure10. Impulse response function with unrestricted Consumer Loans, House Price, Consumption (lag 12, K=11)

The above estimation is conducted with the consumer loans and the house price and the consumption level included. According to the credit channel of monetary policy transmission, the house price should fall following the contractionary monetary policy shock, and this result in the reduction of the value in asset that the household is holding. When the value of an asset which the household uses as a collateral decreases, the contraction of a loan supply occurs, since the lenders would be reluctant to lend based on the weak collateral.

By including house price, consumer loans and consumption together, we could clearly see that the credit channel is valid through the housing market. After the contractionary monetary policy shock, not only the

consumption level, but also the consumer loans decrease resulting from the credit channel.

5.6.4 Overall

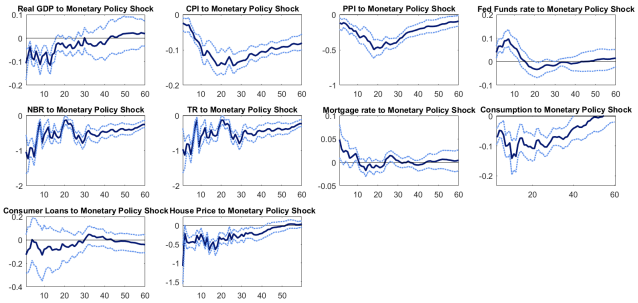

Figure11. Impulse response functions with unrestricted Mortgage rate, Consumption, Consumer Loans, House Price (lag 12, K=11)

Finally, all variables that were considered in this paper are included. And the results correspond to the previous studies and the theory. After the contractionary monetary policy shock, real GDP falls. The price indices including CPI and PPI fall either, hence no price puzzle occurs. Non-borrowed reserves and total reserves also fall.

The mortgage rate which is an effective interest rate for an adjustable rate mortgage loan moves along as the federal funds rate does. This opens the way to the interest rate channel of monetary policy transmission. Moreover, the house price falls indicating a stepping stone to the balance sheet channel. Finally, through a direct and an indirect effect of interest rate, the consumption level falls either. As a consequence, with the VAR model whose shocks are identified with sign restrictions on the impulse responses of variables, the credit channel of monetary policy through the housing market is verified.

Chapter 6

Robustness

6.1 House Price

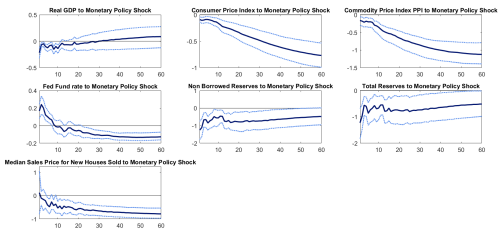

Figure12-1. Impulse response function with Median Sales Price for New Houses Sold (lag 12, K=6)

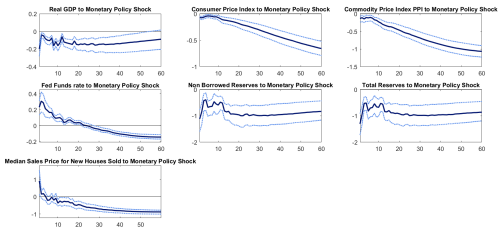

Figure12-2. Impulse response function with Median Sales Price for New Houses Sold (lag 12, K=21)

6.2 House Quantity

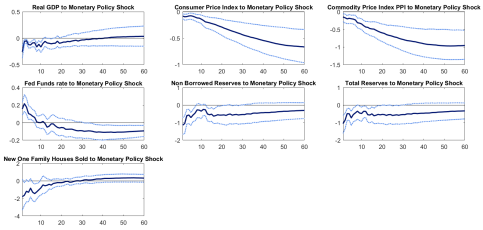

Figure13-1. Impulse response function with New One Family Houses Sold (lag 12, K=6)

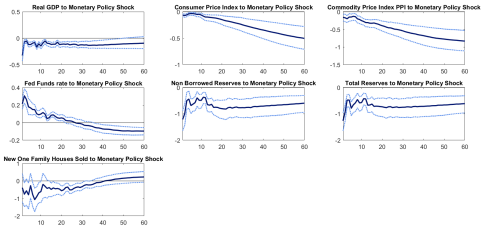

Figure13-2. Impulse response function with New One Family Houses Sold (lag 12, K=21)

6.3 Adjustable Mortgage rate

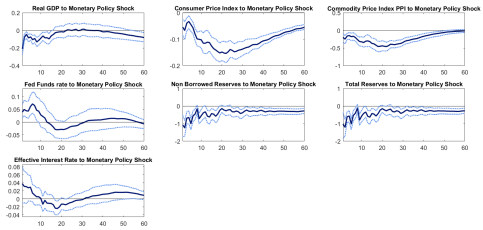

Figure14-1. Impulse response function with Effective interest rate all homes (lag 12, K=6)

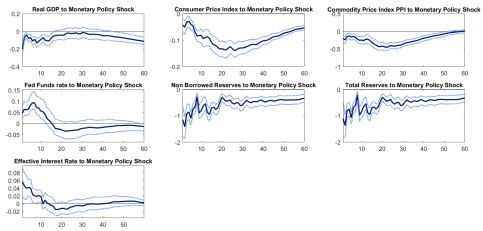

Figure14-2. Impulse response function with Effective interest rate previously occupied (lag 12, K=11)

6.4 Consumer Credits

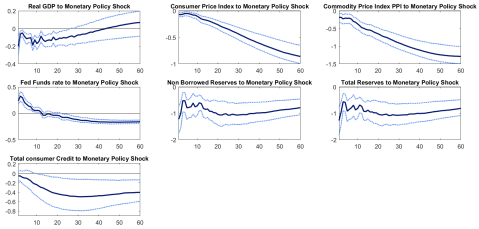

Figure16. Impulse response function with unrestricted Total Consumer Credit (lag 12 , K=11)

6.5 Consumption

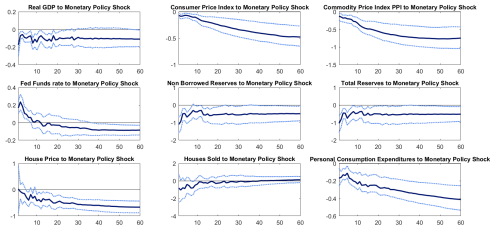

Figure17. Impulse response function with unrestricted house price and houses sold and consumption level (lag 12, K=6)

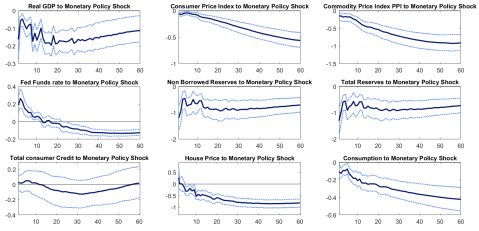

Figure18. Impulse response function with unrestricted Total consumer credit, House price, Consumption (lag 12, K=11)

In order to check the robustness of results stated above, similar VAR estimations but with slight differences were conducted. First of all, the lags imposed on VAR estimation and the period that sign restrictions are imposed varied. Also, for some variables another data that could represent the subject had been estimated to see if the similar outcome is identified.

The results are in a line with the previous analysis. Hence, it could be concluded that the credit channel of monetary policy through the housing market is valid by using the method of VAR estimation identified with sign restriction.

Chapter 7

Conclusion

In conclusion, the credit channel of monetary policy through the housing market could be verified with a VAR model where shocks are identified with sign restrictions.

First, the house price and the house quantity show a negative sign of impulse response after the contractionary monetary policy shock, as it did on the previous studies with other identification restrictions. Also, with the inclusion of the consumption level, the house price and the house quantity and the consumption level all decreased after the contractionary monetary policy shock. This indicates that the credit channel, meaning the indirect effect of interest rate is working through the housing market.

Moreover, the interest rate channel which is accompanied with the credit channel could be verified by the co-movement of Federal Funds rate and the mortgage rate. It had been identified that the mortgage rate closely follows the Federal Funds rate. And with the inclusion of consumption to the VAR estimation, it could be verified that the consumption level falls with the mortgage closely following the Federal Funds rate.

Finally, the consumer loans decrease after the contractionary monetary policy shock as it did on the previous study. On the previous study,

the monetary policy shock was identified with other restrictions. And the identification with sign restrictions supports the previous result. This reduction in consumer loans could be attributed to the contraction in a loan supply resulting from the credit channel.

As a consequence, according to the credit channel of monetary policy, it is inevitable to conduct a contractionary monetary policy to alleviate the problem of household debt. However, the contractionary monetary policy reduces real GDP, prices, and consumption all together. Thus, there should be a careful approach in dealing with the household debt.

In this paper, the consumer loans at all commercial banks and the total consumer credit owned and securitized outstanding have been analyzed. This means that merely total amount of loans and credits was inquired. However, depending on the actual composition of the household debt, more detailed analysis could be conducted with specific types of loans. The subsequent results would allow for a better prediction on the impact of monetary policy upon the household debt.

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국문초록

이 논문의 목적은 통화정책의 신용 경로 특히 대차대조표 경로가 주택 시장을 통해 유효한지를 확인하는 데에 있다. 일반적으로 긴축적 통화 정책 이후로 발생하는 주택 가격의 하락은 소비자 신용과 소비 수준의 감소와 함께 발생한다. 분석 과정에서는 VAR 모형이 사용되었고 충격은 부호 제약 모형을 이용하여 식별하였다. 구체적으로 이 논문은 실질 GDP, 가격 수준, NBR, Total Reserve, 미 연준 이자율의 충격 반응에 대해 부호 제약을 부과함으로써 통화 정책 충격의 효과를 측측정한다. 그리고 관심 변수인 주택 가격, 주택 거래량, 모기지 금리의 주택 시장 변수들, 소비자 신용과 소비 수준의 충격 반응에 대해서는 부호 제약을 부과하지 않는다.

첫번째로 주택 가격을 통해 나타나는 이자율 변화에 따른 간접적인 효과를 분석하였다. 두 번째로 모기지 금리를 통해 나타나는 이자율 변화에 따른 직접적인 효과를 분석하였다. 그리고 마지막으로 통화정책의 신용 경로로 인해 신용 공급의 위축을 반영하는 소비자 신용 수준의 변화 방향을 분석하였다.

주요어 : 통화정책 경로, 신용 경로, 대차대조표 경로, 통화정책 충격, VAR, 부호 제약, 충격 반응 함수, 주택 시장

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