

**EFFECTS OF EXPANSIONARY MONETARY POLICY SHOCKS ON FINANCIAL  
VARIABLES**

by

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## **Abstract**

This thesis uses a structural VAR approach with a recursiveness assumption to examine the effects of an expansionary monetary policy shock on financial variables. We build this on the established research of the effects of monetary shocks on macro variables by measuring the expansionary shock as an increase in the money supply. We also investigate interest rate policy and test whether financial market variables matter for the determination of interest rate. We analyze four different cases in this paper using the innovations in the money supply, non-borrowed reserves, the interest rate and bond yield (including bonds with remaining maturity period close to 30- years) as a measurement for the expansionary monetary policy shock.

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## **CHAPTER 1 - Introduction**

The effects of monetary policy shocks on macro variables have been analyzed by many researchers e.g. Christiano et al. (1999), Kim and Roubini (2000), Sellon (2004). We extend this literature by including some financial variables in order to measure the effects of monetary policy shocks on these variables. We analyze four different scenarios, where the shocks refer to the innovations in the federal funds rate, money supply, non-borrowed reserves and long-term bond rate. At present (Feb 2010), the U.S. economy is facing a liquidity trap, with the federal funds rate at 0.12 percent. In such a situation, monetary policy cannot be carried out by further lowering the federal funds rate. Also, when the monetary authority increases the money supply in the economy, people tend to hold money rather than spending it because the opportunity cost of holding money is very low. Therefore, the conventional measures for implementing monetary policy do not work in a liquidity trap situation. We will investigate alternative ways in which expansionary policy can be implemented in this situation. This paper is divided into four chapters; the first chapter is the introduction, the second presents a literature review, the third chapter focuses on the dataset analysis and the final chapter concludes. We use a structural Vector Auto Regression (VAR) approach with a recursiveness assumption for conducting the empirical research. The next section of this chapter explains the theory of the VAR.

Monetary policy broadly refers to the actions of the monetary authority of a country for controlling the supply, availability and cost of money (Federal Reserve Board (2006)). Expansionary policy increases the total supply of money in the economy, and contractionary policy decreases the total money supply. Expansionary policy involves the lowering of interest rates, for instance, in order to reduce unemployment in a recession. Contractionary policy is related to raising the interest rates in order to reduce inflation (Friedman (2001)).

## 1.1 Vector Auto Regression

Sims (1972, 1980) initiates the use of VARs to estimate the impact of money on the economy. Let us consider an example similar to Sims in a bivariate system in which  $y_t$  is the natural log of real gross domestic product (GDP) at time  $t$  and  $r_t$  is a measure of monetary policy such as a measure of a short-term interest rate (Walsh (2003)). The VAR (1) system can be represented as:

$$\begin{bmatrix} y_t \\ r_t \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ r_{t-1} \end{bmatrix} + \begin{bmatrix} u_t^y \\ u_t^r \end{bmatrix}. \quad (1.1)$$

Where,  $u_t^y$  and  $u_t^r$  are the reduced form errors not the structural shocks. To determine the effect of the shocks on GDP and the interest rate we have to find the structural errors as follows:

$$\begin{bmatrix} u_t^y \\ u_t^r \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} e_t^y \\ e_t^r \end{bmatrix}. \quad (1.2)$$

Let's assume that  $u_t = \begin{bmatrix} u_t^y \\ u_t^r \end{bmatrix}$ ,  $B = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$ ,  $e_t = \begin{bmatrix} e_t^y \\ e_t^r \end{bmatrix}$ ,

$$u_t = B e_t \text{ or } e_t = B^{-1} u_t, \quad (1.3)$$

$$u_t^y = b_{11} e_t^y + b_{12} e_t^r, \quad (1.4)$$

and  $u_t^r = b_{21} e_t^y + b_{22} e_t^r. \quad (1.5)$

Here,  $e_t^r$  is the monetary policy shock. We can find the impulse response functions (IRFs) to this monetary policy shock using the Choleski Decomposition.<sup>1</sup> In order to identify structural shocks as opposed to reduced form errors, we need to impose an additional restriction. We use a recursiveness assumption for the identification of the monetary policy shocks. The recursiveness assumption implies that the policy shock is orthogonal to all other contemporaneous variables.

---

<sup>1</sup> Any positive semi-definite symmetric matrix can be uniquely decomposed using the Choleski Decomposition (Enders (2004)).

For doing this we have to find a matrix  $B$  which pre-multiplies the error terms in the equation (1.2) to form a lower triangular matrix. By doing so  $u_t^y$  is only affected by  $e_t^y$ , whereas  $u_t^r$  is affected by both  $e_t^r$  and  $e_t^y$ . Now, this assumption enables us to look at the IRFs generated by  $e_t^r$ .<sup>2</sup> Therefore, for the identification of  $e_t^r$  in the VAR (1) system in equation (1.1) the restriction can be imposed as follows:

$$\begin{bmatrix} y_t \\ r_t \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ r_{t-1} \end{bmatrix} + \begin{bmatrix} b_{11} & 0 \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} e_t^y \\ e_t^r \end{bmatrix} \quad (1.6)$$

After imposing the restriction, we can generate the IRFs. To generate the IRFs for any shock, we turn on that particular shock making it one for the first time period and making all the other shocks zero for all time periods. This process can be well understood by looking at the following equations:

	$t = 1$	$t = 2$	$t = 3$	...	$t = \infty$
$\frac{\partial y}{\partial e_t^r}$	0	$a_{11}b_{22}$	$a_{11}a_{12}b_{22} + a_{11}a_{12}b_{22}$	...	0
$\frac{\partial r}{\partial e_t^r}$	$b_{22}$	$a_{22}b_{22}$	$a_{21}a_{12}b_{22} + a_{22}^2b_{22}$	...	0

From the above set of equations,  $b_{22}$  represents the first IRF at  $t=1$ , when  $t=2$  there is no policy shock, and when  $t$  goes to infinity,  $y_t$  and  $r_t$  both go to zero (their unconditional means). Thus, the monetary policy shock does not have a long-run effect on stationary variables because we are assuming that eigenvalues of  $a$  are less than unity. In more general form, IRFs for  $j$

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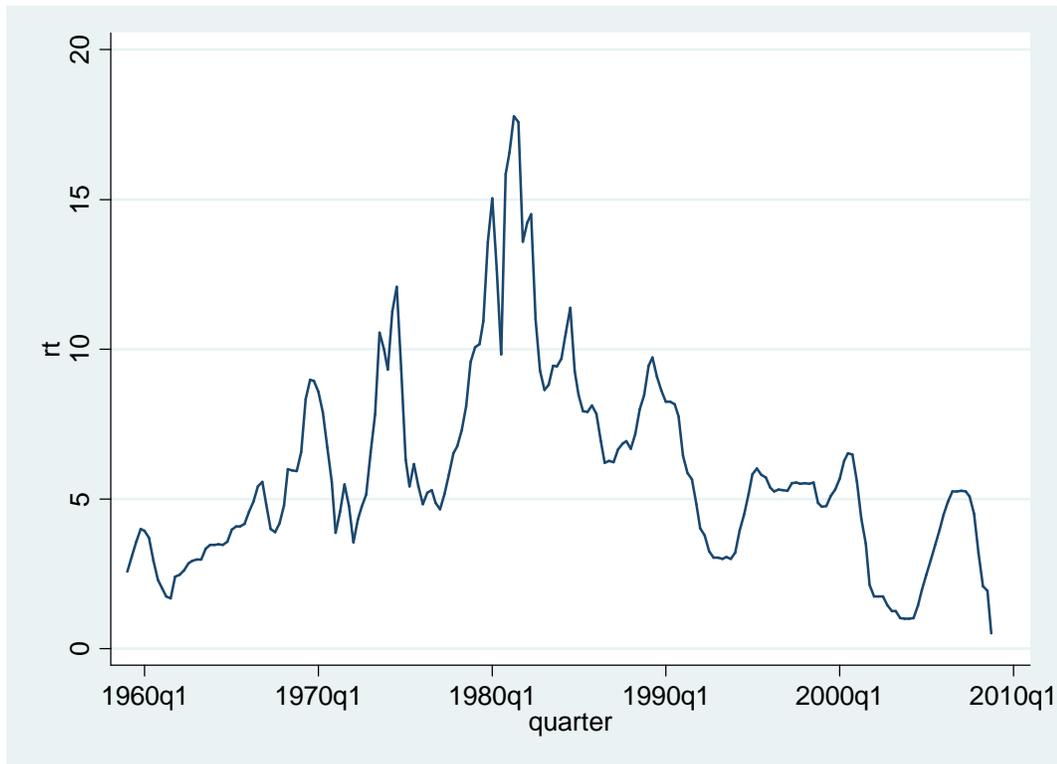
<sup>2</sup> Under the recursiveness assumption, the dynamic impact of  $e_t^r$  on the state variables (e.g.  $y_t$ ) in equation (1.1) is non-sensitive to the ordering of the variables before  $r_t$  if there are more than two variables in the VAR. Whereas ordering does matter if we are identifying  $e_t^y$  (Christiano, Eichenbaum and Evans (1999)).

periods after the shock can be represented as  $A^j B e_1$  where  $A$  is the coefficient matrix for all the variables in the VAR. Also,  $A^\infty B e_1$  is zero if the eigenvalues of the  $A$  are less than unity.

$j = 1$	$j = 2$	$j = 3$	$j = 4$	...	$j = \infty$
$A B e_1$ or $B e_1$	$A^2 B e_1$	$A^3 B e_1$	$A^4 B e_1$	...	$A^\infty B e_1$ or 0

In order to estimate the VAR, we use quarterly U.S. data on ten variables. These are gross domestic product ( $gdp_t$ ), gdp deflator ( $gdpdef_t$ ), the Federal Funds Rate ( $r_t$ ), housing price index ( $hp_t$ ), money supply ( $M2_t$ ), commodities price index ( $crb_t$ ), total new privately owned housing units started ( $hs_t$ ), spot oil price ( $op_t$ ), non-borrowed reserves ( $nbrec_t$ ) and the long term bond rate ( $bond_t$ ). A detailed explanation for all the variables is provided in the data analysis section.

Figure 1.1: Interest Rate, 1959:Q1 - 2008:Q4



Source: St. Louis Federal Reserve Bank

The above figure shows that the federal funds rate was very low during last eight quarters. Also, notice that this figure shows  $r_t$  from 1959 to 2008 but we are only going to use the

dataset from 1959 to 2007 for the analysis. The Taylor rule is a monetary policy rule which defines how the Fed should change the short-term interest rate depending on the behavior of the other state variables in the economy. We define the Taylor rule such that  $r_t$  is a function of the other nine variables mentioned above. The third chapter explains this in detail, by using the interest rate equation.

The VAR for the variables is represented as follows:

$$Y_t = A_c + A_1 Y_{t-1} + A_2 Y_{t-2} + \dots + A_p Y_{t-p} + u_t;$$

Here,  $Y_t$  is a vector of variables  $\{gdp_b, gdpdef_b, op_b, hs_b, hp_b, crbt_b, bond_b, r_b, nbrec_b, M2_t\}$  and the number of lags used,  $p = 4$ . We use the impulse responses to analyze the reaction of all these variables to an expansionary monetary policy shock. We review the existing VAR literature in the next section before presenting the empirical results of our VAR.

## CHAPTER 2 - Literature Review

Christiano, Eichenbaum and Evans (CEE) (1999) review the vast literature for identifying the effects of an exogenous shock to monetary policy. CEE find that there has been agreement over the qualitative impact of monetary policy shocks, whereas the quantitative effects of monetary policy shocks have been an issue of debate. The qualitative effect of an increase in the interest rate (monetary policy shock) shows a decline in aggregate output, employment, profits and various monetary aggregates. Wages fall slightly and the price level reacts to the increased interest rate very slowly. CEE emphasize on the importance of the identification schemes and assumptions for the analysis of the effect of monetary policy shocks since alternative identification schemes can lead to different results. They argue that one of the main contributions of the literature on monetary policy shocks is that it has provided researchers with a path from the identification assumptions to inference regarding the effects of monetary policy shocks. As alternative set of identifying assumptions lead to different inference about the effects of monetary policy shocks rather than just the qualitative impacts economists agree on.

CEE, like others in the literature (including Cooley and Hansen (1989, 1997), King (1991), and Christiano (1991)), break policy into a systematic and random component. The systematic response is a feedback rule relating the expected component of the interest rate to macro observables. CEE identify the monetary policy shocks with the function:

$$S_t = f(\Omega_t) + \sigma_s \varepsilon_t^s$$

Here,  $S_t$  is the monetary authority instrument like the federal funds rate or a monetary aggregate,  $f$  is the linear function for the feedback rule,  $\Omega_t$  is the monetary authority's information set (for this paper it includes lags of the variables mentioned in the introduction),  $\sigma_s$

represents the standard deviation of the monetary policy shock,  $\sigma_s \varepsilon_t^s$  is a monetary policy shock and  $\varepsilon_t^s$  is normalized to have a unit variance.

The authors use a VAR to explain the effects of monetary policy shocks for a  $k$ -dimensional vector of variables.

$$Z_t = A_c + A_1 Z_{t-1} + A_2 Z_{t-2} + \dots + A_p Z_{t-p} + u_t, \quad (2.1)$$

$$E u_t u_t' = V.$$

All the elements in  $u_t$  will respond to the effect of all the fundamental economic shocks as a whole. Therefore, it is not possible to identify the effects of a shock to monetary policy by shocking  $u_t$ . To resolve this issue, CEE assumes the following relationship which is same as what we have explained in the introduction section of this paper<sup>3</sup>

$$B_0 u_t = \varepsilon_t. \quad (2.2)$$

Here  $B_0$  is an invertible, square matrix and  $E \varepsilon_t \varepsilon_t' = D$ , where  $D$  is a positive definite matrix.

Pre-multiplying equation 2.1 by  $B_0$ , gives:

$$B_0 Z_t = B_0 A_c + B_0 A_1 Z_{t-1} + \dots + B_0 A_p Z_{t-p} + \varepsilon_t, \quad (2.3)$$

$$= B_c + B_1 Z_{t-1} + \dots + B_p Z_{t-p} + \varepsilon_t, \quad (2.4)$$

$$B_i = B_0 A_i, i = c, 1, 2, \dots, p, \text{ and } V = A_0^{-1} D (A_0^{-1})'. \quad (2.5)$$

From equation 2.2:  $u_t = B_0^{-1} \varepsilon_t, \quad (2.6)$

$$u_t = C \varepsilon_t. \quad (2.7)$$

In equation 2.7  $C$  is a lower triangular matrix, as explained in the introduction; this is how one imposes the restrictions for the identification of the shocks while using recursiveness assumption,

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<sup>3</sup>  $B_0 = B^{-1}$  from section 1

$$CC' = V \quad (\text{from above}) \quad (2.9)$$

$$\text{cov}(u_t) = V \quad (2.10)$$

CEE break  $Z_t$  into three parts, namely  $X_{1t}$  with  $k_1$  variables,  $X_{2t}$  with  $k_2$  variables and  $S_t$ . The dimension of the dataset is shown by  $k = k_1 + k_2 + 1$ , where  $k_1, k_2 \geq 0$ .  $Z_t$  is defined as follows:

$$Z_t = \begin{pmatrix} X_{1t} \\ S_t \\ X_{2t} \end{pmatrix}$$

The recursiveness assumption places the restrictions as shown below:

$$C = \begin{bmatrix} C_{11} & 0 & 0 \\ C_{21} & C_{22} & 0 \\ C_{31} & C_{32} & C_{33} \end{bmatrix}$$

The parenthesis above show that the dimension of the related matrix and  $a_{22} = \frac{1}{\sigma}$ , where  $\sigma_s > 0$ , because  $\sigma_s$  is the standard deviation of the independent and identically distributed monetary policy shock.

The zero elements in the middle row of the above matrix represent the assumption that while setting  $S_t$  the policy makers do not see  $X_{2t}$ . The two zeros in the first row relate to the two different ways in which a monetary policy shock can affect the variables in  $X_{1t}$ . The first zero shows the direct effect of  $S_t$  on  $X_{1t}$  and the second zero relates to the indirect effect of the monetary policy shock, which comes through  $X_{2t}$ . The recursiveness assumption is sufficient to identify the identification of the dynamic response of  $Z_t$  to a monetary policy shock, but it is not sufficient for identifying all of the elements of  $C$ . The authors present three results based on the recursiveness assumption. The first is that a number of non-empty  $C$  matrices exist and the lower triangular matrix with positive diagonal elements shown above is one of them. The next result shows that after the monetary policy shock, dynamic response functions produced by every

member of non-empty  $C$  matrices for the elements of  $Z_t$  are same. Finally, if the normalization is always done by using the lower triangular matrix, then the dynamic responses of the variables in  $Z_t$  are insensitive to the ordering of variables in  $X_{1t}$  and  $X_{2t}$ .

In this paper the empirical analysis involves two recursive identification schemes. In the first scheme, the policy instrument  $S_t$  is measured by the time  $t$  Federal Funds Rate (FFR). In this case,  $\Omega_t$  includes current and four lagged values of the variables real GDP, the GDP deflator and commodity prices and four lagged values of FFR, total reserves, non-borrowed reserves and the money supply. The monetary policy shock is measured with the use of FFR.

The second benchmark scheme measures  $S_t$  by non-borrowed reserves. This selection of scheme is motivated by Eichenbaum (1992) and Christiano and Eichenbaum (1992). In both of these papers, the authors find that any new change in non-borrowed reserves primarily reflects the exogenous shocks to monetary policy, whereas the changes in broader monetary aggregates primarily reflect shocks to money demand. The  $\Omega_t$  vector stays the same as described for the first scheme above.

The results after the policy shocks show that a contractionary monetary policy shock or a rise in the federal funds rate leads to a significant drop in non-borrowed reserves. This result is consistent with the presence of a strong liquidity effect. Also, the fall in total reserves is very small (negligible) initially but later on increases in magnitude. Therefore, the authors conclude that after the full impact of a contractionary shock on non-borrowed reserves, the Fed insulates total reserves in the short term by increasing borrowed reserves. CEE also find that the qualitative impact of  $M1$  is similar to that of total reserves, whereas  $M2$  drops instantly due to a federal funds rate policy shock. GDP also declines after a federal funds rate policy shock with a lag of two quarters. The index of commodity prices also decline persistently after an initial delay.

The GDP deflator declines after six quarters but until then remains flat. In other words, with a contractionary policy shock the federal funds rate increases, monetary aggregates decline, though with a lag, the aggregate price level reacts less in the beginning but declines over time, aggregate output declines, and commodity prices fall.

Christiano, Eichenbaum and Evans (1996) find that a contractionary federal funds rate policy shock leads to an increase in unemployment but with a delay of two quarters, whereas other variables like retail sales, corporate profits in retail trade and non-financial corporate profits decline instantly, though the manufacturing inventories increase instantly. Others have done research on the reaction of other economic variables to a contractionary monetary policy shock. Fisher (1997), for instance, examines and finds important differences in timing and sensitivity of various types of investments to a monetary policy shock. He finds that the residential investment shows the maximum decline, which is then followed by equipment, durables and structures. He also finds that residential investment falls most quickly reaching its trough many quarters before other variables. He refers it to as a unique lead-lag pattern in the dynamic response functions.

Gertler and Gilchrist (1994) have focused on the response of large and small manufacturing Firm's sales and inventories to a contractionary monetary policy shock. They find that small Firm's inventories decline instantly after a contractionary monetary policy shock, whereas large Firm's inventories first rise and then fall. They use these results along with other results of their paper in studying the monetary transmission mechanism, which focuses on the importance of credit market imperfections.

Campbell (1997) also focuses on the manufacturing sectors reaction to a contractionary monetary policy shock but from a different perspective. He finds total employment, job

destruction and job creation are caused by a contractionary monetary policy shock. The author shows that the contractionary monetary policy shock leads to a decline in manufacturing employment, reaching its maximum effect with a lag of one year and hence, it instantly increases the job destruction but leads to a transitory fall in job creation.

Bernanke and Blinder (1992) find that after a contractionary monetary policy shock there is an instant and persistent decline in the volume of bank deposits and bank assets. These results are in line with the theories of the monetary transmission mechanism that focuses on the role of credit market imperfections. Gertler and Gilchrist (1993, 1994) do similar research and find that a contractionary monetary policy shock leads to a decline in consumer and real estate loans but the commercial and industrial loans do not decline. Also, the small manufacturing loans decline more as compared to that of large manufacturing firms. From the above mentioned results, a contractionary monetary policy shock leads to different effects on the borrowing and lending activities of different agents in the economy.

Many researchers have investigated the impact of contractionary monetary policy shocks on exchange rates in economies. Examples include Cushman and Zha (1997), Kim and Roubini (1995) and Clarida and Gertler (1997). All these works find that a contractionary foreign monetary policy shock leads to a rise in the foreign exchange rate (units of foreign currency for one U.S. dollar) and also raise the differential between the foreign and domestic interest rates. This result is consistent with Eichenbaum and Evans (1995). These works also show that a contractionary monetary policy shock leads to a decline in foreign monetary aggregates and output, whereas it increases the interest rate and the price level only with a delay.

Kim and Roubini (2000) extend the structural VAR approach of Sims and Zha (1995) to an open economy in order to explain the effects of monetary policy shock on exchange rates.

They propose the use of a non-recursive identification scheme that allows for the identification of the effect of monetary policy shocks on the exchange rates. This scheme solves the various puzzles found in empirical research on monetary policy.<sup>4</sup> These puzzles are partially solved with the use of an unrestricted structural VAR approach. The identification scheme used by the authors solves the liquidity puzzle as the result shows that the price level and output falls following a contractionary monetary policy shock. Also, the exchange rate (units of foreign currency for one unit of U.S. dollar) appreciates following a monetary contraction.

The data vector used for this paper includes cross-country data for G-7 countries namely France, Germany, Japan, U.K., Italy, Canada and U.S. It includes observations of the short term interest rate, a monetary aggregate, the consumer price index, industrial production (used as a proxy for the output), the world price of oil in terms of the U.S. dollar, the federal funds rate of the U.S. and the exchange rate expressed as units of foreign currency per U.S. dollar. The world price of oil and the U.S. FFR are included to control for exogenous monetary policy changes. In reaction to a negative and inflationary supply shock, if the monetary authority tightens the monetary policy then the resulting recession and price inflation is caused not only by the monetary contraction but also by the original negative supply shock. For the identification of the component of the policymaker's feedback rule due to monetary policy alone, the authors have

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<sup>4</sup> Empirical works on the effects of monetary policy have uncovered various puzzles, namely the liquidity puzzle (when monetary policy shocks are identified as innovations in monetary aggregates, and these innovations lead to an increase in the nominal interest rate rather than a decrease), the price puzzle (when monetary policy shocks are measured as innovations in interest rates and it leads to a rise rather than fall in price level), the exchange rate puzzle (when a positive innovation in interest rate leads to an impact depreciation rather than appreciation of domestic currency, relative to the U.S. dollar) and the forward bias puzzle (according to the uncovered interest parity condition, a positive domestic interest rate relative to its foreign counterpart should lead to persistent depreciation of the domestic currency over time after the impact appreciation, whereas evidences shows that this innovation is associated with persistent appreciation of the domestic currency).

included the world oil price as a proxy for negative and inflationary supply shocks. The authors have included the FFR to control for the component of domestic monetary policy that is a reaction to the foreign monetary policy shock, (Grilli and Roubini (1995)). The nominal exchange rate is introduced to find the effects of the identified monetary shocks on the value of domestic currency.

The model used assumes that the economy is described by a structural form equation shown below:<sup>5</sup>

$$G(L)y_t = e_t , \quad (2.11)$$

Here  $G(L)$  is the matrix polynomial in the lag operator  $L$ ,  $y_t$  is a  $n \times 1$  data vector, and  $e_t$  is an  $n \times 1$  structural disturbance vector. The reduced form equation estimated (VAR) is:

$$y_t = B(L)y_t + u_t . \quad (2.12)$$

Here  $B(L)$  is a matrix polynomial (without the constant term),  $L$  is a lag operator and  $var(u_t) = \Sigma$ .

The identification scheme used by Kim and Roubini is as follows:

$$\begin{bmatrix} e_{MS} \\ e_{MD} \\ e_{CPI} \\ e_{IP} \\ e_{OPW} \\ e_{FFR} \\ e_{E(/\$)} \end{bmatrix} = \begin{bmatrix} 1 & g_{12} & 0 & 0 & g_{15} & 0 & g_{17} \\ g_{21} & 1 & g_{23} & g_{24} & 0 & 0 & 0 \\ 0 & 0 & 1 & g_{34} & g_{35} & 0 & 0 \\ 0 & 0 & 0 & 1 & g_{45} & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & g_{65} & 1 & 0 \\ g_{71} & g_{72} & g_{73} & g_{74} & g_{75} & g_{76} & 1 \end{bmatrix} \begin{bmatrix} u_R \\ u_M \\ u_{CPI} \\ u_{IP} \\ u_{OPW} \\ u_{FFR} \\ u_{E(/\$)} \end{bmatrix} ,$$

here  $e_{MS}$ ,  $e_{MD}$ ,  $e_{CPI}$ ,  $e_{IP}$ ,  $e_{OPW}$ ,  $e_{FFR}$ ,  $e_{E(/\$)}$  are the structural disturbances, that is, money supply shocks, money demand shocks, FFR shocks, and exchange rate shocks,

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<sup>5</sup> In the data vector  $R$  represents the short term interest rate,  $M$  is the monetary aggregate,  $CPI$  is the consumer price index,  $IP$  is the industrial production (used as a proxy for the output),  $OPW$  is the world price of oil in terms of the U.S. dollar,  $FFR$  is the federal funds rate of the U.S. and  $E(/\$)$  is the exchange rate expressed as units of foreign currency per U.S. dollar.

respectively, and  $u_R, u_M, u_{CPI}, u_{IP}, u_{OPW}, u_{FFR}, u_{E(/\$)}$  represent the residuals in the reduced form equations, which are the unexpected movement of each variable.

The first equation in the identification scheme is:

$$e_{ms} = u_R + g_{12}u_M + g_{15}u_{OPW} + g_{17}u_{E(/\$)} , \quad (2.13)$$

which shows that the monetary authority sets the interest rate after observing the current value of money, the exchange rate and the world oil price. This equation is based upon the monetary policy feedback rule that the price level and output are not affected by the monetary policy changes within the same period, whereas the value of money, the exchange rate and the world price of oil react to the change in monetary policy within the same period (Sims and Zha (1995)). They have not included the U.S. FFR here because they assume that within a month, the monetary authority is more concerned about the unexpected changes in the exchange rate rather than the unexpected changes in U.S. FFR. The world price of oil has been included to provide a control for the negative supply shocks and inflationary pressure. Kim and Roubini argue that G-7 countries (excluding the United States) implicitly and explicitly care about the effects of a depreciation of their currencies on their inflation rates. They also propose to identify the interest rate innovations that are true exogenous contractions in monetary policy and that should thus lead to a currency appreciation. Therefore, they have included exchange rates in the money supply equation.

The authors have assumed the usual real money demand function. The demand for real money balances depends on real income and the opportunity cost of holding money. For the rest of the equations the interest rate, the U.S. FFR, money, and the exchange rate are always assumed not to affect the level of real activity contemporaneously. They are assumed instead to have real effects only with a one period lag.

In short, the structural shocks are composed of several blocks. The first two equations are the money supply and money demand equations, representing the money market equilibrium. The next two equations describe the domestic goods market equilibrium. The next group of equations describes the exogenous shocks coming from the world economy, the U.S interest rate and oil price shocks. Finally, the last equation is the arbitrage equation explaining the exchange rate market.

Empirical results show that a money supply shock initially leads to a significant increase in the interest rate and a significant fall in the money supply in all six countries (France, Germany, Japan, U.K., Italy and Canada). This effect is statistically significant on impact and over the medium run. The impact effect of monetary contraction is an appreciation of the domestic exchange rate relative to the U.S. dollar for all six countries. With an increase in the U.S. FFR, the short-term interest rate in other countries also increases. This increase in the interest rate might occur as a precautionary measure taken by the countries to avoid the inflationary effect of the devaluation of their currencies due to a higher U.S. FFR. This increased interest rate leads to a fall in the money supply. On impact the currencies of the respective countries depreciate relative to the U.S. dollar. However, this depreciation is associated with an inflationary burst, as in all countries the depreciation is followed by a significant rise in domestic prices (except for the U.K.). The reaction of output is mixed. The depreciated exchange rate causes aggregate demand to increase and hence output should increase, whereas with the increased interest, the aggregate demand and output should decline.

Sellon (2004) presents insight into the relationship between monetary policy and market interest rates. This work shows how the monetary policy path changes market interest rates. The monetary transmission mechanism can be explained as follows. With an increase in the FFR the

other market interest rates also rise, thereby slowing the economy. Similarly, a decrease in the FFR leads to a decrease in other market interest rates, accelerating the economy. The author says that in practice the market interest rates and the FFR target loosely move with each other. Also, at times the large movements in the market interest rates are commonly related with only the economic data releases or statements by the policymakers, where there is no associated change in the FFR target.

Thus, the expectations about the path of future policy actions play a vital role in the determination of market interest rates. Therefore, it is important to understand the market's method used to derive the expected policy path. Since the policy expectations drive the interest rates, what central banks say regarding long-run goals becomes potentially more important than their actions. Hence, the communication of the central bank with the public and the financial market plays a very crucial role in the transmission mechanism and the determination of market interest rates. The paper suggests that for changes in the transmission from the FFR to longer-term rates, use of the historical relationship between the funds rate target and longer-term interest rates can be fruitful. The paper uses the expectation theory of the term structure to model the behavior of the interest rates. The expectation theory says that the interest rate associated with any security can be observed as an average of today's FFR target and the entire series of future targets expected by financial markets over the life of the security. Sellon explains the expectation theory using this example for expressing today's two-year rate as an average of today's one-year rate and the one-year rate that is expected to prevail in one year, plus a term premium:

$$2 - year\ rate = \frac{1}{2}(1 - year\ rate + expected\ 1 - year\ rate\ in\ one\ year) \\ + term\ premium$$

The paper describes three important features of the relationship between policy and interest rates. First, with the market's expectation of the funds rate target rising, the interest rates at all maturities also rise through time. This increase comes from the result of the averaging process explained by the expectations theory. Second, the anticipation of the expected changes in the target rate leads to an increase in the interest rate and often on the day of actual changes in the target rate, the interest rate does not change or changes very little. This can be an interpretation of the assumption that the Federal Reserve adjusts the funds rate target exactly as the market expects. Third, during the period in which the target rises, the short-run rates undergo much larger changes relative to that of the long-run.

Another useful approach for analyzing the relationship between the policy path and interest rates is to see the path's relation to the yield curve. The yield curve is defined as the cross-section of interest rates at each date and can be constructed by looking at the vertical distance between rates for each date. According to the expectations theory, the present structure of the market interest rates contains an implied future path for the FFR target. This particular path determines the evolution of the interest rate over time. Whenever the financial markets receive some new information regarding the economic outlook and monetary policy, they update the path accordingly. Changes in the policy path affect the market interest rates and this effect is determined by three important general factors for determining the response of market rates. First is the persistence of changes in the policy path. Persistence means the length of time a change in the path is expected to last. In general, the more persistent a change is, the larger is the effect on longer-term interest rates. The next factor is the timing of policy path changes. The further in the future a change is expected in the path, the smaller the response of the short-term rates relative to longer-term rates. The last factor is the size of policy path changes. A small initial change in the

funds rate target can be associated with large changes in market rates, even long-term rates, when the initial target change leads markets to believe that additional changes will be forthcoming. Until now the focus has been on the path and reaction to the information. How do markets get this information for the policy path? Sellon argues that to develop a policy path, markets require three types of information, namely information on the Federal Reserve's long-run objectives, an estimate of the Federal Reserve's internal economic forecast and a measurement of how fast the Federal Reserve will adjust the funds rate target if its forecast suggests that the economy will not achieve its long-run goals. An easy way to combine these three factors is to use the Taylor rule as a simplified model of central bank's behavior. It specifies the interest rate target adjustments to be made by a central bank in order to maintain price stability and full employment. A particular form of the Taylor Rule can be represented as:

$$R_t = R^* + \gamma(Y_t^e - Y^*) + \lambda(\pi_t^e - \pi^*)$$

Here,  $R_t$  is the central bank's current interest rate target,  $R^*$  is the equilibrium interest rate target,  $Y_t^e - Y^*$  is the expected output gap, and  $\pi_t^e - \pi^*$  is the expected inflation gap. Following the Taylor rule, the central bank will set its interest rate target above the equilibrium level when the output gap is positive or when the inflation gap is positive and vice-versa. The parameters  $\gamma$  and  $\lambda$  determine how fast the central bank changes the interest rate target to eliminate the output and inflation gaps. From the above equation, according to the Taylor rule, the equilibrium interest rate target  $R^*$  plays a very important role. As  $R^*$  is a nominal interest rate, it can be divided into two parts - an estimate of the long-run equilibrium real interest rate for the economy and a measure of long-run inflationary expectations. The long-run equilibrium interest rates do not change much with time. If the central bank targets a credible long-run inflation objective then the financial market's estimate of long-run inflation expectation should be equal to this inflation

objective. In this particular scenario  $R^*$  will be relatively constant. On the other hand, if the central bank's inflation objective is not well understood, then the financial market's estimate of long-run inflation expectation may change over time, thereby changing the market's estimate of  $R^*$  over time. This paper explains the process that how the short-term FFR should be targeted with the use of the Taylor rule. Sellon, explains that the expectations for the short-term FFR have a substantial impact on the market interest rate and hence financial variables. The paper also shows the transmission mechanism of the short-term interest rate into the longer-term interest rate with the help of the yield curve. We apply the ideas of Sellon in the present situation of a liquidity trap in the U.S. In particular, we focus directly on the longer-term interest rate to stabilize the economy, as we cannot lower the short-term interest rate. We do this by analyzing the macroeconomic variables responses to the unexpected changes in the bond rate in our model, which is long term rate.

# CHAPTER 3 - Empirical Analysis on the Effects of Monetary Policy Shocks on Financial Variables

## 3.1 Dataset

The data used in this paper is extracted from the database of the Federal Reserve Bank of St. Louis, Bureau of Economic Analysis, and Commodity Research Bureau Indexes. We have used quarterly data from 1959 to 2007 for conducting this analysis. The variables included are  $gdp_t$ ,  $gdpdef_t$ ,  $op_t$ ,  $hp_t$ ,  $bond_t$ ,  $hs_t$ ,  $M2_t$ ,  $crb_t$ ,  $nbrec_t$ , and  $r_t$ ; where  $gdp_t$  is the real gross domestic product (GDP) (in billions of dollars),  $gdpdef_t$  is the GDP deflator (index),  $op_t$  is the spot oil price by the West Texas Intermediate (in dollars per barrel),  $hp_t$  is the housing prices (index) (we have used the residential investment as a proxy for housing prices because we are constrained by the data availability for housing prices),  $hs_t$  is the number of new privately owned housing units started,  $M2_t$  is the money aggregate M2 (in billions of dollars),  $crb_t$  is the commodities index (a standard measure of commodity prices),  $nbrec_t$  is non-borrowed reserves of depository institutions plus term auction credit (in billions of dollars),  $r_t$  is the Federal Funds Rate (FFR) (short term rate) and  $bond_t$  is Moody's seasoned Baa corporate bond yield. Moody's drops bonds if the remaining life falls below 20 years, if the bond is susceptible to redemption, or if the rating changes.<sup>6</sup> Most of the variables are similar to what CEE (1999) use and we include  $hp_t$ ,  $hs_t$  and  $bond_t$  to analyze the effects of monetary policy shocks on the housing/financial market. Also,  $op_t$  is included to provide a control for the negative supply shock and inflationary pressure, Kim and

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<sup>6</sup> Moody's tries to include bonds with remaining maturities as close as possible to 30 years

Roubini (2000). Graphs for all the variables and their growth rate (first differences) are provided in the appendix. We use Stata software for conducting the analysis for this paper.

### 3.2 Stationarity Test

We first test for the stationarity of all the variables using augmented Dickey-Fuller test (ADF). While conducting ADF tests we need to select the lag length for each variable. We use the Akaike's information criterion (AIC) for the selection of an appropriate lag length for each variable. AIC is calculated by running a regression of dependent variable on given number of lags and each estimated model generates a different value of AIC:

$$AIC = \log \left( \frac{\varepsilon' \varepsilon}{T - k} \right) + \frac{2k}{T}$$

Here,  $\varepsilon$  is the residual vector,  $T$  is the number of observations and  $k$  is the number of parameters used in the regression model. The AIC balances the reduction of the sum of squared errors against a penalty for the number of free parameters in the regression model. Selection of lag length is done by choosing the model which minimizes the value for AIC.

We next test for stationarity. Any variable with a unit root is considered non-stationary. The ADF test is conducted by estimating the model

$$Y_t = b_0 + b_1 Y_{t-1} + b_2 Y_{t-2} + \dots + b_{k-1} Y_{t-k+1} + b_k Y_{t-k} + \varepsilon_t .$$

Here  $Y_t$  is the variable of interest. We can add and subtract  $b_k Y_{t-k+1}$  from both sides of the equation above to get:

$$Y_t = b_0 + b_1 Y_{t-1} + b_2 Y_{t-2} + \dots + (b_{k-1} + b_k) Y_{t-k+1} - b_k \Delta Y_{t-k} + \varepsilon_t ,$$

We next add and subtract  $(b_{k-1} + b_k) Y_{t-k+2}$  and keep repeating the same process to obtain:<sup>7</sup>

$$\Delta Y_t = b_0 + \delta Y_{t-1} + \sum_{i=2}^k \beta_i \Delta Y_{t-i+1} + \varepsilon_t . \quad (3.1)$$

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<sup>7</sup> We end the process by subtracting  $Y_{t-1}$  from both sides.

here:  $\delta = -(1 - \sum_{i=1}^k b_i)$ ,

$$\beta_i = - \sum_{j=i}^k b_j .$$

In equation (3.1) if  $\delta = 0$ , the equation includes only first difference terms and thus has a unit root. We test for the presence of a unit root using the Dickey-Fuller test, to decide whether to accept or reject the null hypothesis  $\delta = 0$ .

**Table 3-1. The Results of AIC and Dickey-Fuller Test for a Unit-Root.**

<b>Variable</b>		<b>Lags</b>	<b>ADF Statistics</b>	<b>5% Critical Value</b>	<b>Result</b>
<i>gdp<sub>t</sub></i>	Level	1	-1.660	-2.883	Fail to Reject H <sub>0</sub>
	First-difference	1	-6.832	-2.884	Reject H <sub>0</sub>
<i>gdpdef<sub>t</sub></i>	Level	3	0.094	-2.884	Fail to Reject H <sub>0</sub>
	First-difference	2	-2.362	-2.884	Fail to Reject H <sub>0</sub>
<i>op<sub>t</sub></i>	Level	1	-1.172	-2.883	Fail to Reject H <sub>0</sub>
	First-difference	1	-8.914	-2.884	Reject H <sub>0</sub>
<i>hp<sub>t</sub></i>	Level	2	-1.195	-2.884	Fail to Reject H <sub>0</sub>
	First-difference	1	-3.923	-2.884	Reject H <sub>0</sub>
<i>hs<sub>t</sub></i>	Level	2	-3.317	-2.884	Reject H <sub>0</sub>
	First-difference	1	-7.034	-2.884	Reject H <sub>0</sub>
<i>crb<sub>t</sub></i>	Level	1	-1.486	-2.883	Fail to Reject H <sub>0</sub>
	First-difference	1	-5.830	-2.884	Reject H <sub>0</sub>
<i>M2<sub>t</sub></i>	Level	1	-1.464	-2.883	Fail to Reject H <sub>0</sub>
	First-difference	3	-4.098	-2.884	Reject H <sub>0</sub>
<i>nbrec<sub>t</sub></i>	Level	2	-1.421	-2.883	Fail to Reject H <sub>0</sub>
	First-difference	1	-21.240	-2.884	Reject H <sub>0</sub>
<i>r<sub>t</sub></i>	Level	5	-2.946	-2.884	Reject H <sub>0</sub>
	First-difference	5	-5.270	-2.884	Reject H <sub>0</sub>
<i>bond<sub>t</sub></i>	Level	3	-2.099	-2.884	Fail to Reject H <sub>0</sub>
	First-difference	4	-5.432	-2.884	Reject H <sub>0</sub>

Source: Author's estimation based on FRED®

The above table shows the values of lags and the ADF statistics we used for testing for a unit root. We can see that all the variables are stationary or they do not have a unit-root at first-difference except for the GDP-deflator. Let us consider the case of GDP. From the table above, we use only one lag for running the Dickey-Fuller test as chosen by the AIC statistics. The equations for  $gdp_t$  for the Dickey-Fuller test can be written as:

Level:

$$\Delta gdp_t = 0.0247 \quad - 0.0021gdp_{t-1} + 0.2576681\Delta gdp_{t-1} + \varepsilon_t$$

(0.0115)                      (0.0013)                      (0.0694)

First-Difference:

$$\Delta^2 gdp_t = 0.0046 \quad - 0.5936 \Delta gdp_{t-1} \quad - 0.1578\Delta^2 gdp_{t-1} + \varepsilon_t$$

(0.0009)                      (0.08688)                      (0.0710)

The equation above shows the values for the coefficients and standard errors generating the value -1.660 and -6.832 for ADF statistics for GDP at level and first-difference respectively.

### 3.3 Baseline Model

While working with time series data, we have to detrend or separate the cyclical component of the time-series from raw data for some variables with low frequency trends in order to make the data stationary. For the isolation of the business cycle component of variables we use the Hodrick-Prescott filter (HP-filter). The HP-filter decomposes each variable into a growth (smooth component) and a cyclical component. The HP filter for a series  $y_t$  where  $t = 1, 2, 3, \dots, T$  is given by:

$$\ln y_t = g_t + c_t \tag{3.2}$$

$$\tilde{y}_t = \ln y_t - g_t = c_t$$

$$\min_{g_t, c_t} \sum_{t=1}^T c_t^2 + \lambda \sum_{t=3}^T [(1 - L^2)g_t]^2 \tag{3.3}$$

Here,  $c_t$  and  $g_t$  are the cyclical and growth components, respectively. The first part of the equation penalizes the variations in the cyclical component, and the second part penalizes the variations in the growth component. In equation (3.3)  $\lambda$  provides the control for the smoothness of the growth component. The higher the value of  $\lambda$ , the smoother the series, (King and Rebelo (1993)). We use Prescott's estimation recommendation of  $\lambda = 1600$  for a quarterly time-series

dataset. We filter  $gdp_t$ ,  $crb_t$ ,  $M2_t$ ,  $nbrec_t$ ,  $hs_t$ , and use the resulting cyclical component of the filtered series for further analysis. We filter  $gdp_t$ ,  $M2_t$ ,  $nbrec_t$ ,  $hs_t$  variables because this is the standard approach to filter these real variables and use the first differences for prices. But we also filter  $crb_t$  because CEE (1999) also use the filtered component for the commodity prices. The filtered series for these five variables are shown in the graphs in appendix. The figure below shows the first-difference and cyclical component for GDP. The figures below show that the HP-filter removes the low frequency trends from the data series.

Figure 3.1: First Difference of Real GDP

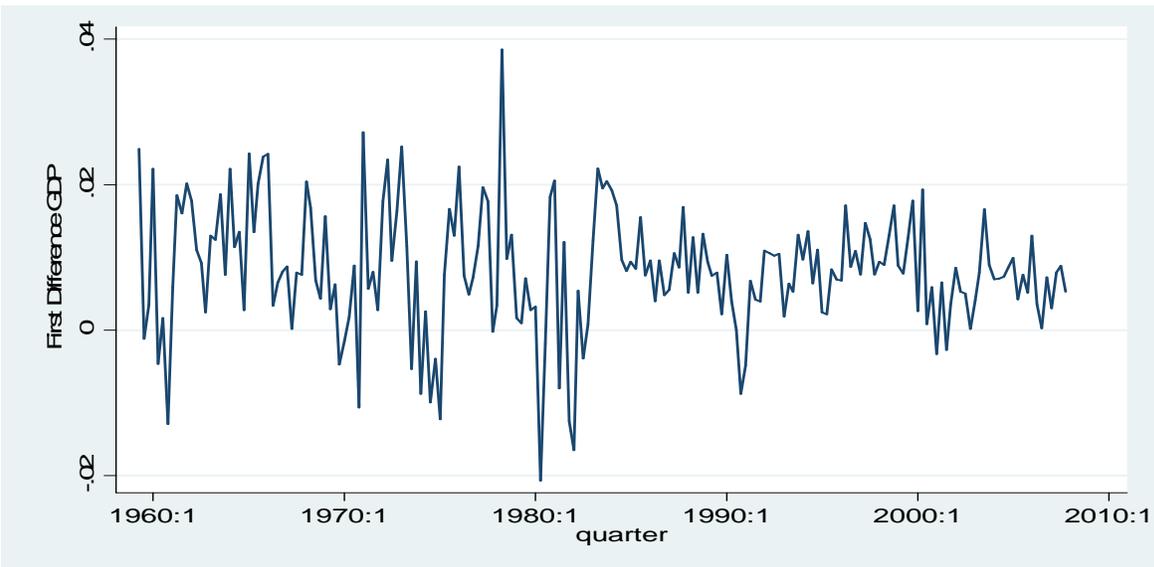
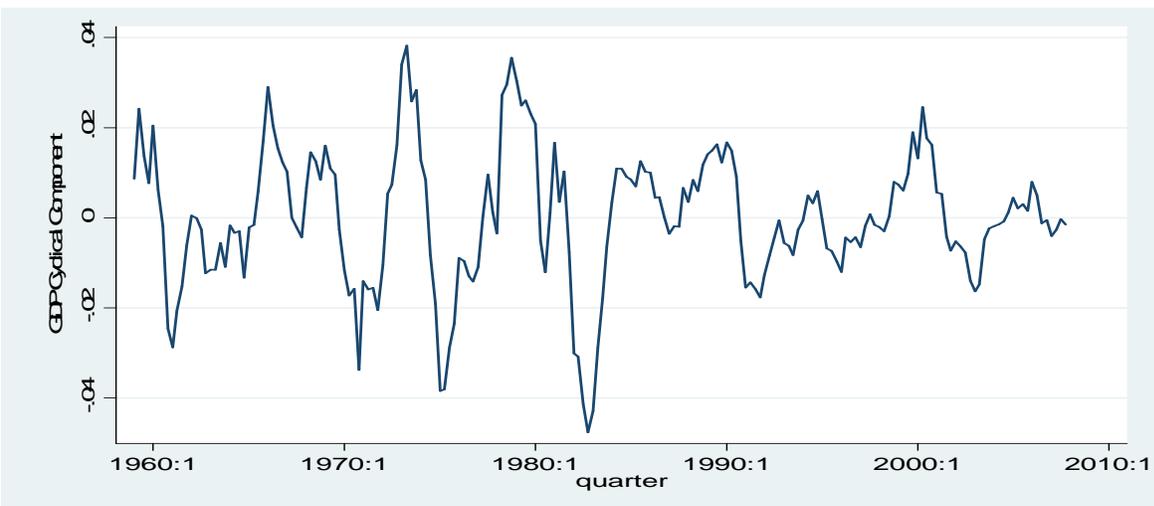
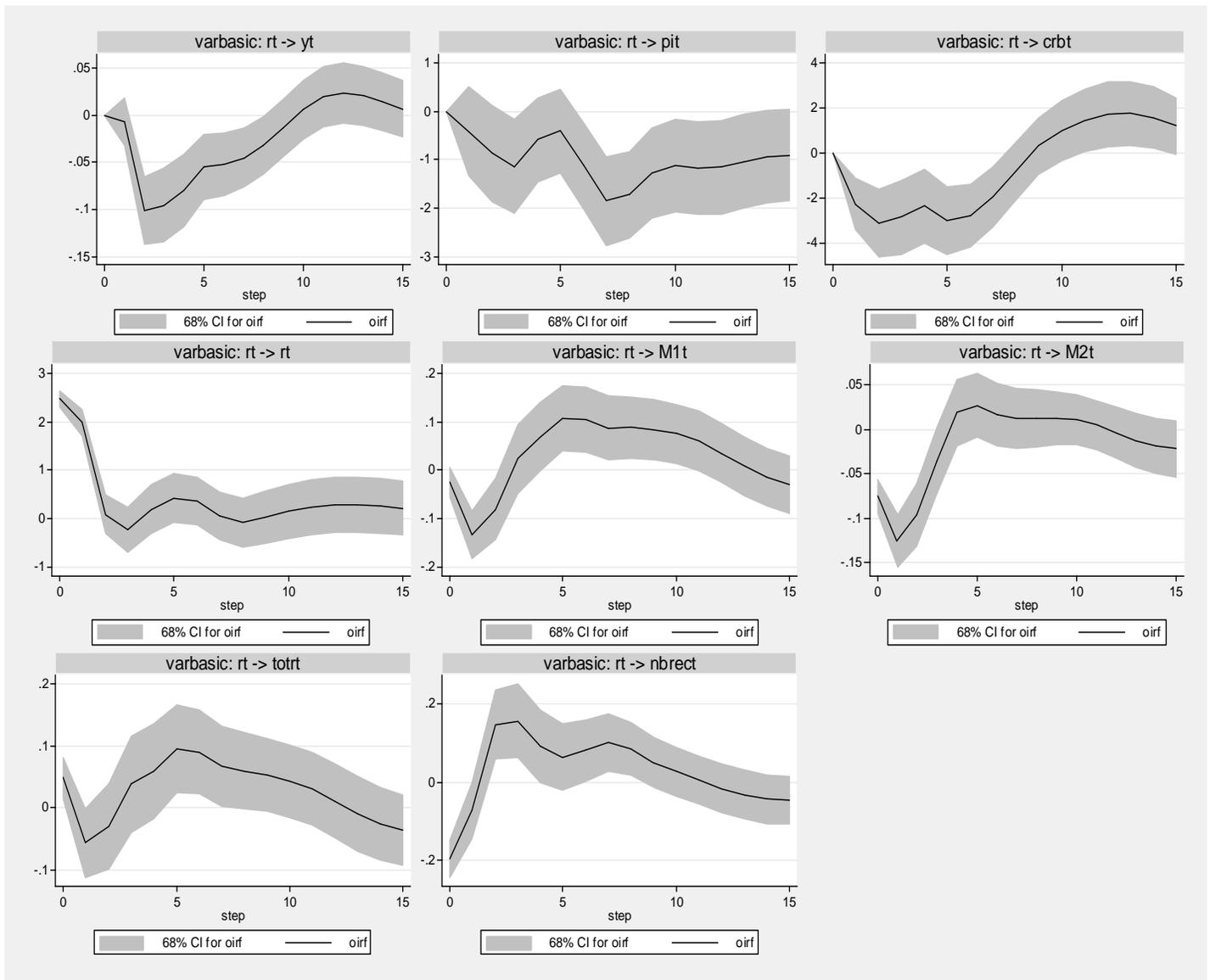


Figure 3.2: Cyclical Component of GDP after HP-filter



We begin with a replication of CEE to review our methodology for conducting the empirical analysis. For the most part, we use the same dataset as CEE except for the GDP deflator and the commodity prices index. This variation in the data set leads to IRFs that are slightly different from CEE. To complete our dataset and replicate CEE, we use the identical series for both the missing variables of commodity prices and the GDP deflator as in the independent research that follows. The IRFs generated are shown below:

Figure 3.3: IRFs for the Contractionary Monetary Policy Shock  $-r_t$  (for CEE dataset)



For running the VAR for the CEE dataset, we use four lags for the quarterly dataset from 1965 to 1994; the following subsection provides a detailed explanation for the VAR for our

dataset. The figure above shows that with an increase in the federal funds rate ( $r_t$ ), output ( $y_t$ ) declines showing a hump shaped pattern. The inflation ( $pi$ ) and the commodity price index ( $crb_t$ ) falls. Non-borrowed reserves decline, money supply M1 and M2 ( $M1_t$  and  $M2_t$ ), total reserves ( $totr_t$ ) decline. Also, the total reserves and M1 show almost the same qualitative pattern after the shock. These responses show that in short-run the monetary contraction leads to a decline in aggregate demand pushing the price level and output downwards.

Next we conduct the same analysis using a different set of variables. We use four lags for the quarterly dataset. The data vector  $Y_t$  for the VAR is

$$\{y_t, gdpdef_t, crb_t, hp_t, hs_t, op_t, bond_t, r_t, nbrec_t, M2_t\}.$$

Here we have used the annualized cyclical component for all the variables except for  $r_t$ ,  $hp_t$ ,  $bond_t$ ,  $op_t$  and  $gdpdef_t$ . The logged first difference of the  $hp_t$ ,  $op_t$  and  $gdpdef_t$  is used in  $Y_t$ . The VAR equation used for this paper is given by:

$$Y_t = A_c + A_1 Y_{t-1} + A_2 Y_{t-2} + \dots + A_p Y_{t-p} + u_t, \quad (3.4)$$

$$B_0 Y_t = B_c + B_1 Y_{t-1} + B_2 Y_{t-2} + \dots + B_p Y_{t-p} + e_t, \quad (3.5)$$

$$Y_t = B_0^{-1} B_c + B_0^{-1} B_1 Y_{t-1} + B_0^{-1} B_2 Y_{t-2} + \dots + B_0^{-1} B_p Y_{t-p} + B_0^{-1} e_t, \quad (3.6)$$

$$cov(u_t) = \Omega, \quad (3.7)$$

$$cov(e_t) = I, \quad (3.8)$$

$$\Omega = B_0^{-1} B_0^{-1'}. \quad (3.9)$$

In the above equation,  $p = 4$  as we are using four lags,  $u_t$  is the reduced form errors vector not the structural shocks. To convert these into structural shock we define  $u_t = B_0^{-1} e_t$  or  $e_t = B_0 u_t$ . Here,  $e_t$  represents the structural shocks with covariance I and  $e_t \sim (0, I)$ .<sup>8</sup> There are an infinite numbers of solutions for  $\Omega$ . In order to indentify a unique solution we need to impose some restrictions, for which we use recursiveness assumption. It imposes the restriction by making the matrix  $B_0$  a lower triangular matrix using the Choleski Decomposition method. The identified monetary policy shock responds to all variables except  $nbrec_t$  and  $M2_t$  contemporaneously and affects some variables with a lag. This restriction implies that the policymakers see elements ordered before the identified shock in the data vector/information set,

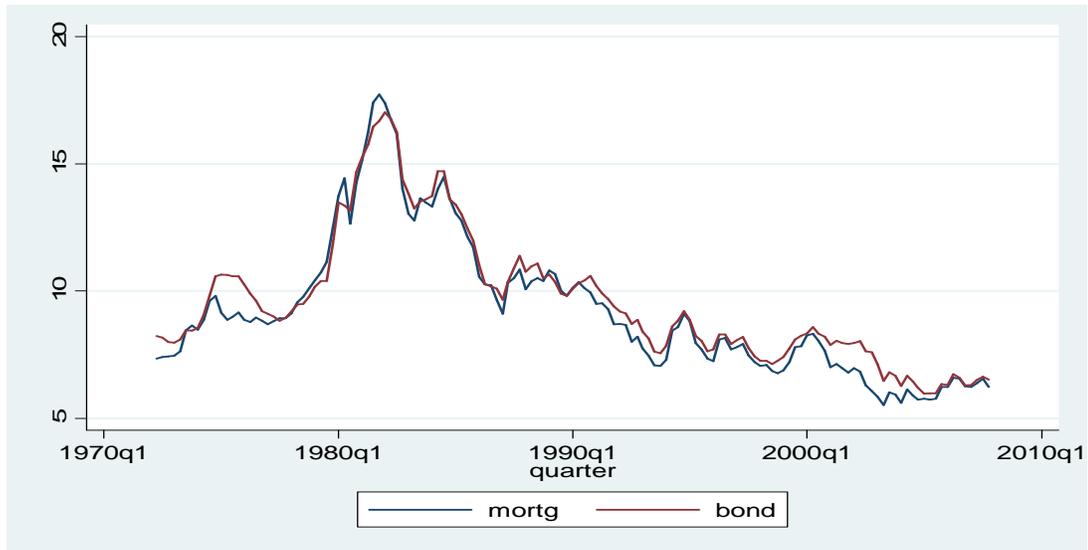
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<sup>8</sup> In the introduction section we have defined  $u_t = B e_t$  and  $e_t = B^{-1} u_t$ .

but they do not see the elements ordered after the identified shock. For instance, in our data vector, policy makers do not consider  $nbrec_t$  and  $M2_t$  while setting  $r_t$  and vice-versa. Also, the dynamic response of the monetary policy shock is invariant to the ordering of the variables before it in the dataset (see CEE (1999)).

As mentioned earlier this paper explains four different scenarios by analyzing the dynamic responses of financial variables to monetary policy shocks. The expansionary shock is measured as a decline in FFR, an increase in the money supply, an increase in non-borrowed reserves or a decrease in longer term rate (bond rate). We include the bond rate to analyze the situation in which the economy is in a liquidity trap with a very low federal funds rate, the monetary authority targets the longer term rate instead of the short-term interest rate (FFR). The figure below compares the values of the bond rate and the mortgage rate for the last 36 years; it shows that both the variables track each other closely.<sup>9</sup>

Figure 3.4: Longer-Term Bond Rate and Mortgage Rate



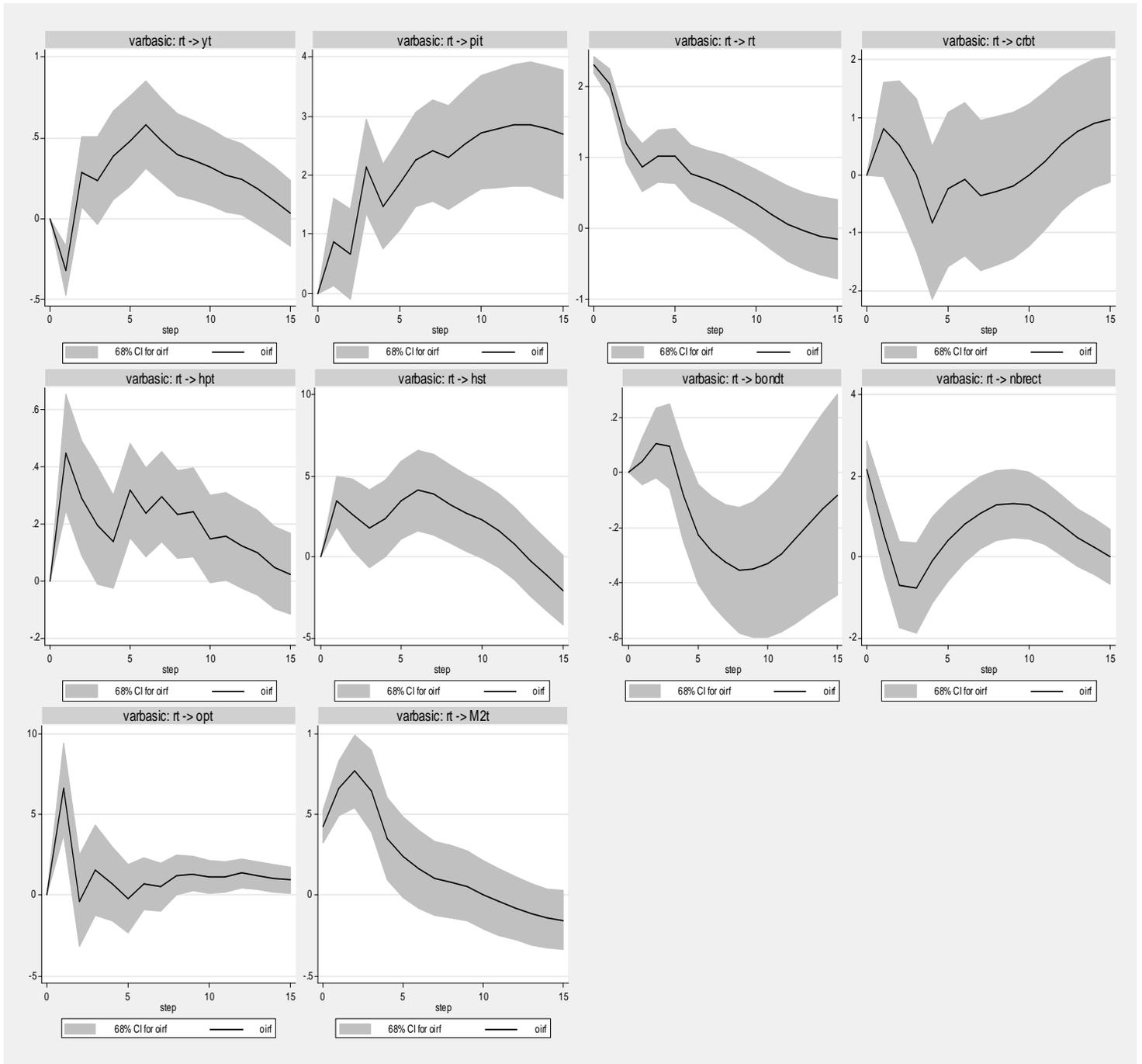
Source: St. Louis Fed, FRED®

The next section focuses on the dynamic responses of the variables in the data vector to the four different structural shocks.

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<sup>9</sup> Initially we wanted to use the mortgage rate in our model as we have included the housing market variables for analysis, but data for the mortgage rate only starts in 1970. We want to analyze a longer time-series, so we replaced the mortgage rate with the longer-term bond rate.

Figure 3.5: IRFs for Expansionary Monetary Policy Shock – negative  $r_t$



We shock the negative value of the interest rate. This shock results in a rise in output, prices, money supply and inflation as shown in figure 3.5 above. It is in line with the basic IS-LM framework which implies that at lower interest rate businesses and consumers spend more.

This fall in  $r_t$  is accomplished by an increase in money. We observe a rise in both output and prices. The housing market expands after the shock as housing prices and new housing units started increase after the effect. This provides evidence for recent situation in the U.S. when the constant decline in the FFR leads to a huge growth of the housing market. Also, the magnitude of the change in housing prices is less than compared to the other variables because we have used just the annualized first difference without multiplying it by hundred for housing prices and the commodity prices indexes. The non-borrowed reserves decline and the oil price rises after the shock. The shock shows the transmission mechanism of the short-term rate into the long-term rate as the bond rate declines after the decline in the FFR, (Sellon (2004)).

Figure 3.6 shows the IRFs generated by an expansionary monetary policy shock, where the shock comes from a surprise increase in the money supply ( $M2_t$ ). The responses show that output increases after an expansionary monetary policy shock. This is because the expansionary monetary policy shock (increase in  $M2_t$ ), leads to an increase in investment. This increase in investment increases aggregate demand, and thus output. The increased aggregate demand shifts prices upward. Hence, this shock results in inflation. The longer-term bond rate follows a hump shape pattern, as it declines in first two quarters, then increases for few quarters and declines again. Housing prices rise after the shock and the number of housing units started decline. Like other prices, the oil price also rises after the shock. The non-borrowed reserves decline for first few quarters and then increase. Also, both short-term and long-term interest rates rise, which is the liquidity puzzle (Kim and Roubini (2000)). This increase of the interest rate after an increase in the money supply implies that this shock reflects the money demand shocks as well. However, we are interested in analyzing the effects of only the increase in the money supply or the supply shock. Eichenbaum (1992) suggests that non-borrowed reserves are a better measure for implementing an expansionary monetary policy shock rather than  $M2$ , because they reflect the true exogenous shocks to monetary policy, whereas the latter primarily reflects the money demand shocks. Following Eichenbaum, we shock the non-borrowed reserves.

Figure 3.6: IRFs for the Expansionary Monetary Policy Shock –  $M2_t$

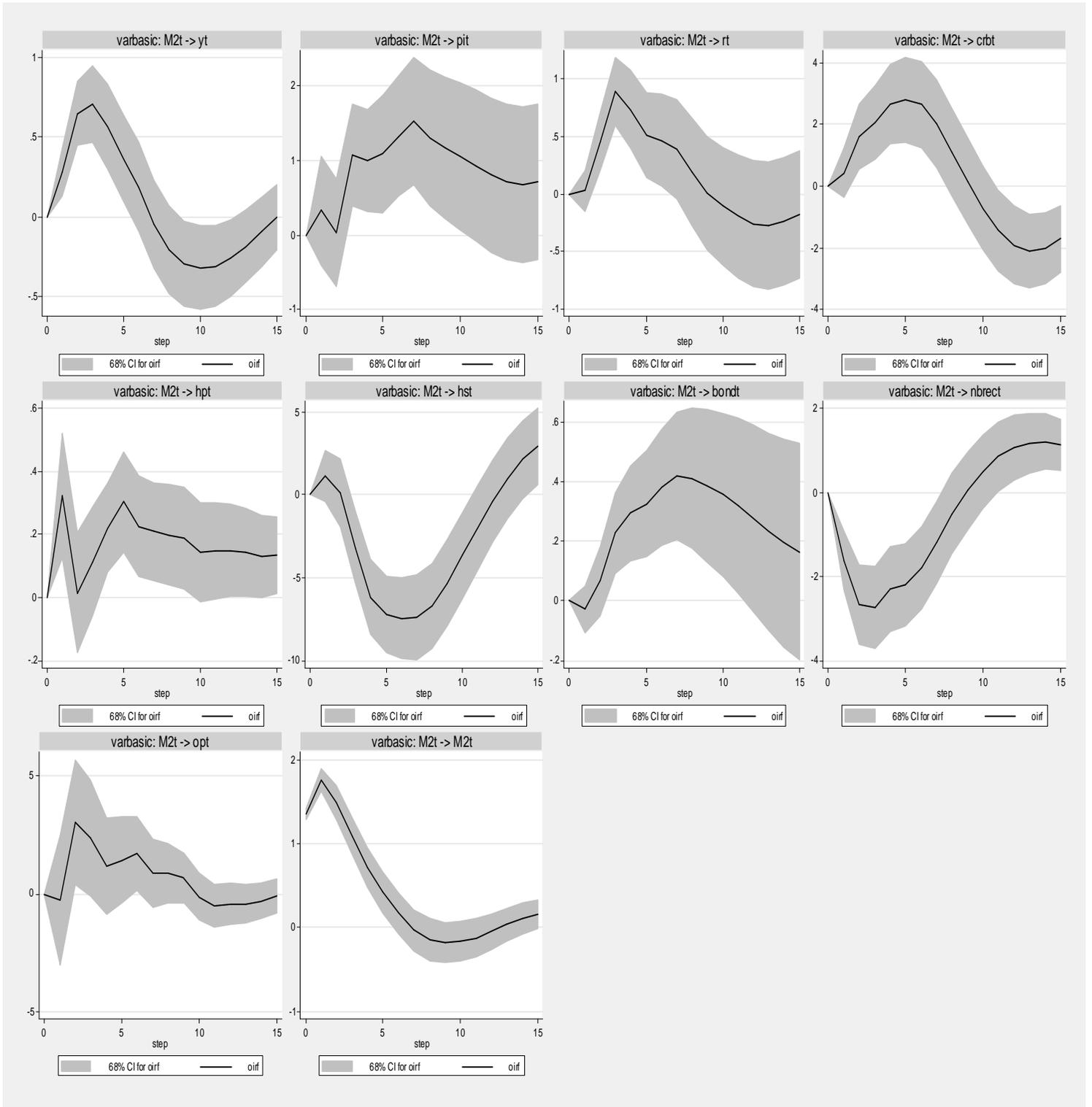
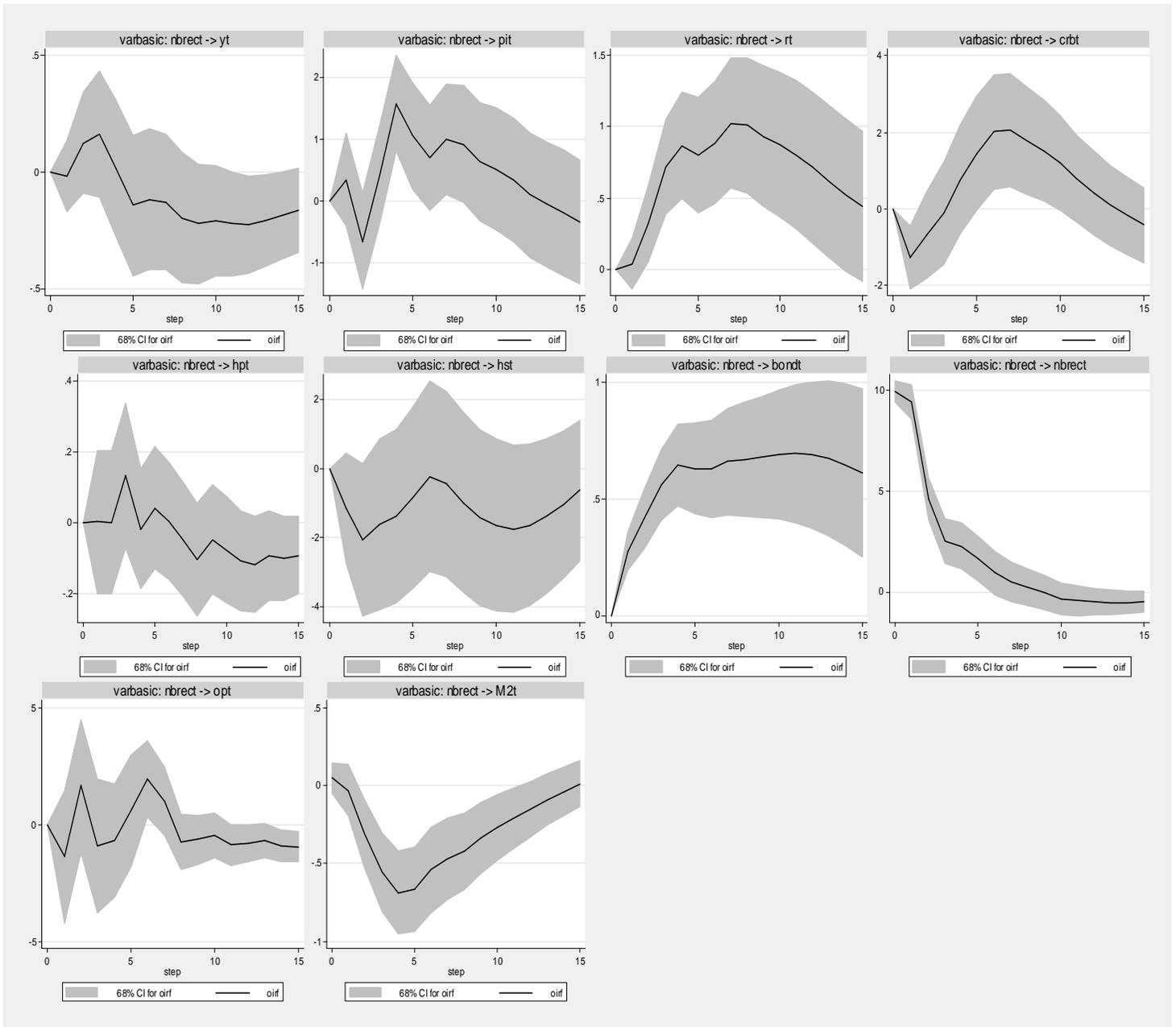


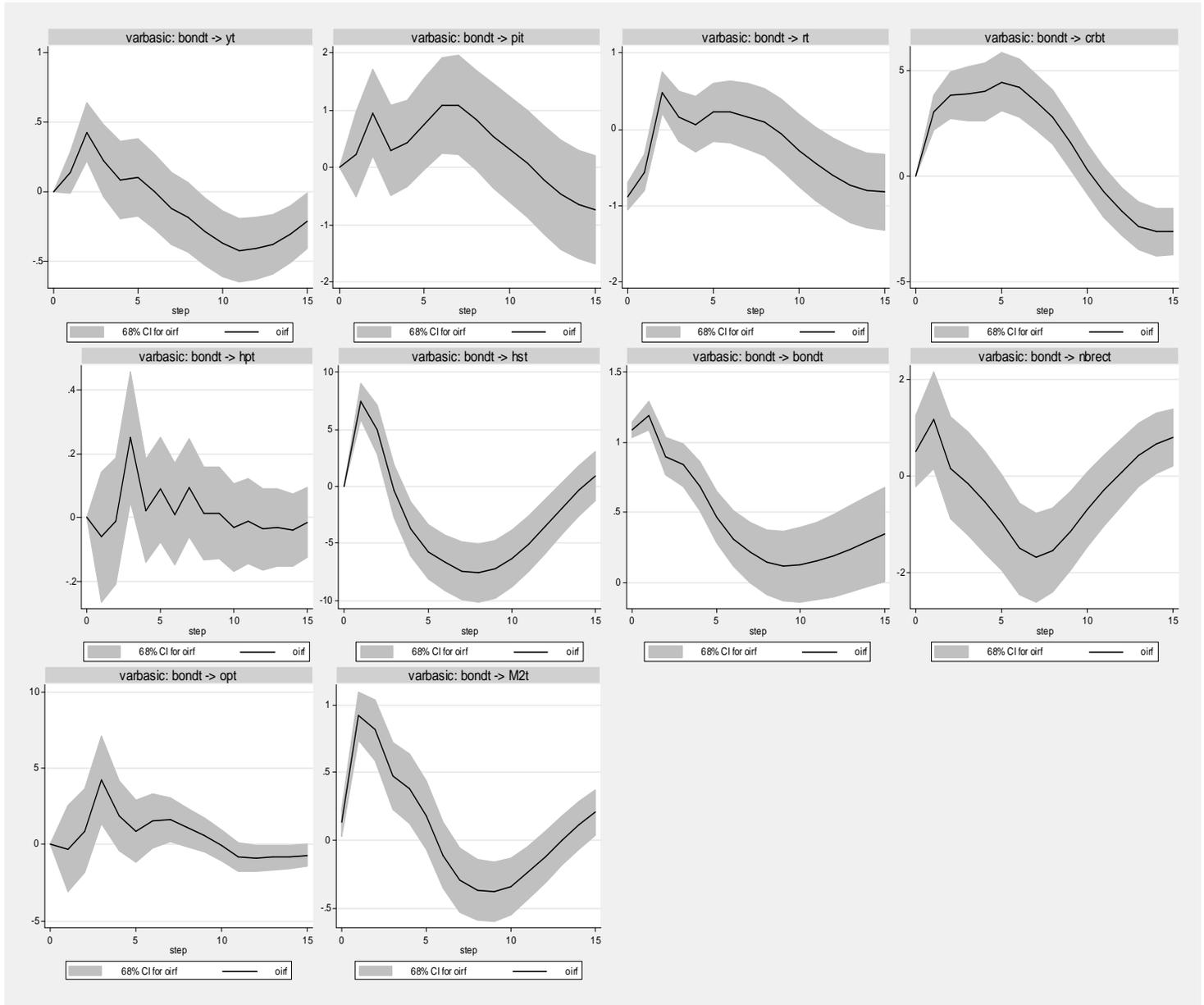
Figure 3.7: IRFs for the Expansionary Monetary Policy Shock –  $nbrec_t$



The increase in non-borrowed reserves increases output, commodity prices and inflation. This is consistent with theoretical traditional Keynesian models (i.e. the IS-LM model). This shock still results in a liquidity puzzle like the one we see in the case of  $M2_t$  shock, which implies that the interest rate and the long term bond rate increase rather than decrease after an expansionary monetary policy shock. Therefore, it also potentially reflects the money demand

shock. Housing prices react to the shock with a lag of two to three quarters, and the money supply declines with a humped shape pattern.

Figure 3.8: IRFs for Expansionary Monetary Policy Shock –  $bond_t$



As mentioned earlier, the U.S. economy is facing a liquidity trap. In such a situation the standard monetary policy measures cannot be used for implementing the policy shocks. As the FFR is at a lower bound and increasing the money supply does not help because with a very low opportunity cost for holding money people tend to hold more money than required for day to day

transactions. Moreover, we realize that both  $M2_t$  and non-borrowed reserves policy shocks do not distinguish between the money demand and money supply shocks. Even in a liquidity trap, however, the monetary authority can still target the long-term rate, which is not a lower bound. Therefore, we shock the longer-term interest rate and analyze the dynamic responses of the variables to a negative longer-term interest rate shock. This shock follows the same initial story as explained for  $M2_t$  and non-borrowed reserves shock. Figure 3.8 shows that after this expansionary shock, output increases for the first four quarters, the inflation rate rises and prices rise. The number of the housing units started and money supply both rises initially and then decline, showing the same kind of a pattern. The non-borrowed reserves decline during the first few quarters but after that rise again. This shock shows a positive impact only in the short-run and then it potentially overheats the economy leading to a decline in output. It implies that the monetary authority should be careful while implementing such an unexpected change in policy.

We have analyzed the reaction of the macro variables to the changes in the short term rate. But we also want to see that whether the interest rate responds to the variation in these variables or not. For this let us consider the structural VAR for  $r_t$  for our model, it can be shown as:

$$r_t = A_{cr} + A_{1r}Y_{t-1} + A_{2r}Y_{t-2} + \dots + A_{pr}Y_{t-p} + B_{0r}^{-1}e_t^r \quad , \quad (3.10)$$

$$A_{jr} = \text{row corresponding to the } r_t \text{ equation, } j = 0, 1, \dots, p \quad . \quad (3.11)$$

$$B_0^r = \text{row corresponding to the } r_t \text{ equation in error coefficient matrix.}$$

This  $r_t$  equation is only one row of the matrix system. In the above equation,  $e_t^r$  is the monetary policy shock. It represents the Taylor rule or feedback rule for our purpose as we assume that this is how the monetary authority sets the interest rate. Next we conduct the chi-square test for testing for the significance of certain variables in the interest rate equation. The table below reports the values for the chi-square test, jointly testing the significance of all four lags for some of the selected variables in the  $r_t$  equation. The reason for separately testing these variables is that these are the new financial variables we have introduced in the model.<sup>10</sup>

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<sup>10</sup> Also the eigenvalues for all the variables lie within unity, satisfying the VAR stability condition. The modulus of the highest eigenvalues produced is 0.9785.

**Table 3-2. The Results for Chi-Square Test.**

<i>Variable</i>	$\chi^2/\chi^2 - \text{value}$	<i>p - value</i>
$\sum_{i=1}^4 \beta_{ir} r_{t-i}, H_0: \beta_{ir} = 0 \forall i$	$\chi^2(4) = 598.73$	0.00
$\sum_{i=1}^4 \beta_{ic} crb_{t-i}, H_0: \beta_{ic} = 0 \forall i$	$\chi^2(4) = 16.28$	0.002
$\sum_{i=1}^4 \beta_{ih} hs_{t-i}, H_0: \beta_{ih} = 0 \forall i$	$\chi^2(4) = 24.15$	0.00
$\sum_{i=1}^4 \beta_{ih} hp_{t-i}, H_0: \beta_{ih} = 0 \forall i$	$\chi^2(4) = 0.68$	0.953
$\sum_{i=1}^4 \beta_{io} op_{t-i}, H_0: \beta_{io} = 0 \forall i$	$\chi^2(4) = 2.62$	0.623
$\sum_{i=1}^4 \beta_{ib} bond_{t-i}, H_0: \beta_{ib} = 0 \forall i$	$\chi^2(4) = 18.21$	0.00

*Source: Author's estimation based on FRED®*

The null hypothesis is that the FFR does not depend on all these variables. The result shows that the FFR responds to the variations in most variables in the data vector, with the exception housing and oil prices. The results provide an evidence for the Federal Reserve Bank's response to the housing market bubble. For example in 2003-04 the housing prices were growing at a very high rate and this was considered as a housing bubble. But the monetary authority did not increase the FFR to decline the abnormal growth in housing prices. The Federal Reserve Bank's chairperson Ben Bernanke argues that the monetary did use a contractionary monetary policy shock (by increasing FFR), but the rise required to constraint the housing bubble could have hampered the growth rate for the economy which was still recovering from the recession of 2001.

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The standard Taylor rule equation is represented as  $r_t = \pi_t + r_t^* + a_\pi (\pi_t - \pi_t^*) + a_y (y_t - y_t^*)$ , Here  $\pi_t - \pi_t^*$  is the inflation gap,  $y_t - y_t^*$  output gap,  $r_t^*$  is the current federal funds rate,  $\pi_t$  is the current inflation rate,  $\pi_t^*$  is the target inflation rate and  $r_t$  is the target federal funds rate.

## **CHAPTER 4 - Conclusion**

This thesis analyzes the effects of expansionary monetary policy shocks on financial and the housing market variables. We have analyzed these effects by using four different scenarios. We find that after a surprise decline in the federal funds rate output, inflation, money supply, and various prices increase. It also leads to an expansion of the housing market by increasing housing prices and the number of new housing units started. Similar dynamic responses are observed when we shock the money supply and the non-borrowed reserves. But these shocks lead to a liquidity puzzle, as we see a rise in the short-term interest rate after an increase in the money supply in the economy. Also, the U.S. economy is in a liquidity trap, which implies that neither the FFR shock nor the money supply shock can stimulate the economy. Therefore, we investigate an expansionary monetary policy shock by targeting the longer-term bond rate. This shock leads to an increase in output, the inflation rate, prices, housing units, the money supply and non-borrowed reserves in the short-run. We also investigate that whether the FFR responds to the variations in all these variables in the data vector and find evidence that it responds to all except for housing prices and oil prices.

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# Appendix

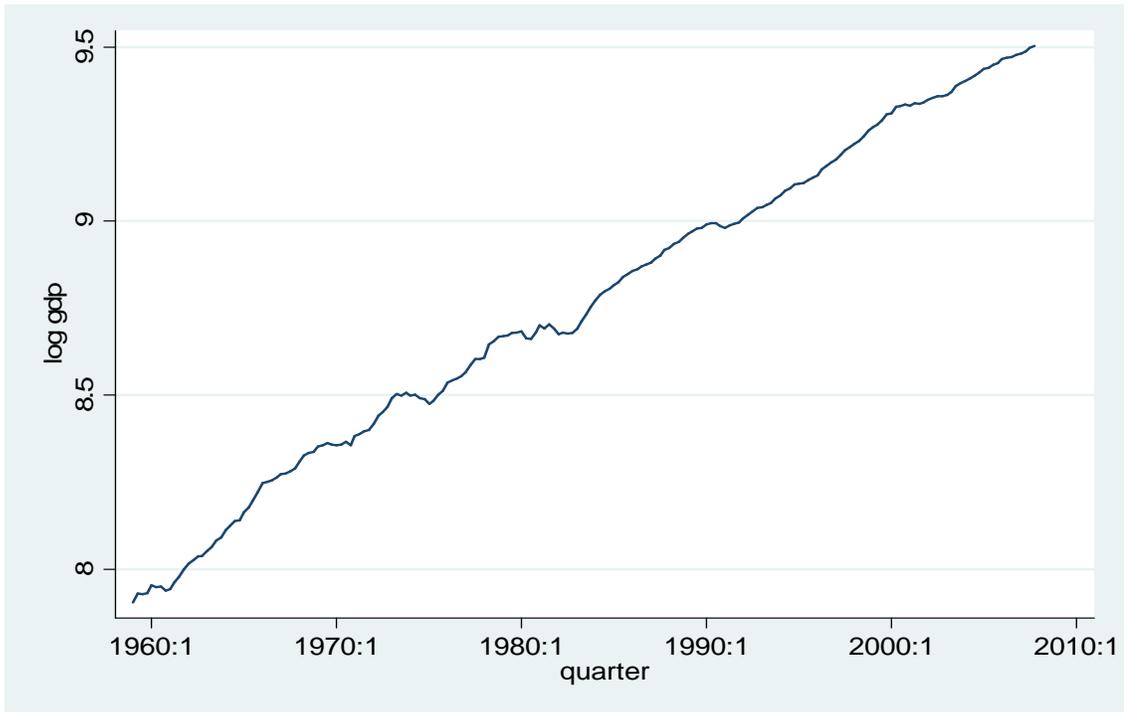


Figure A.1: Real GDP, 1959:Q1 - 2007: Q4

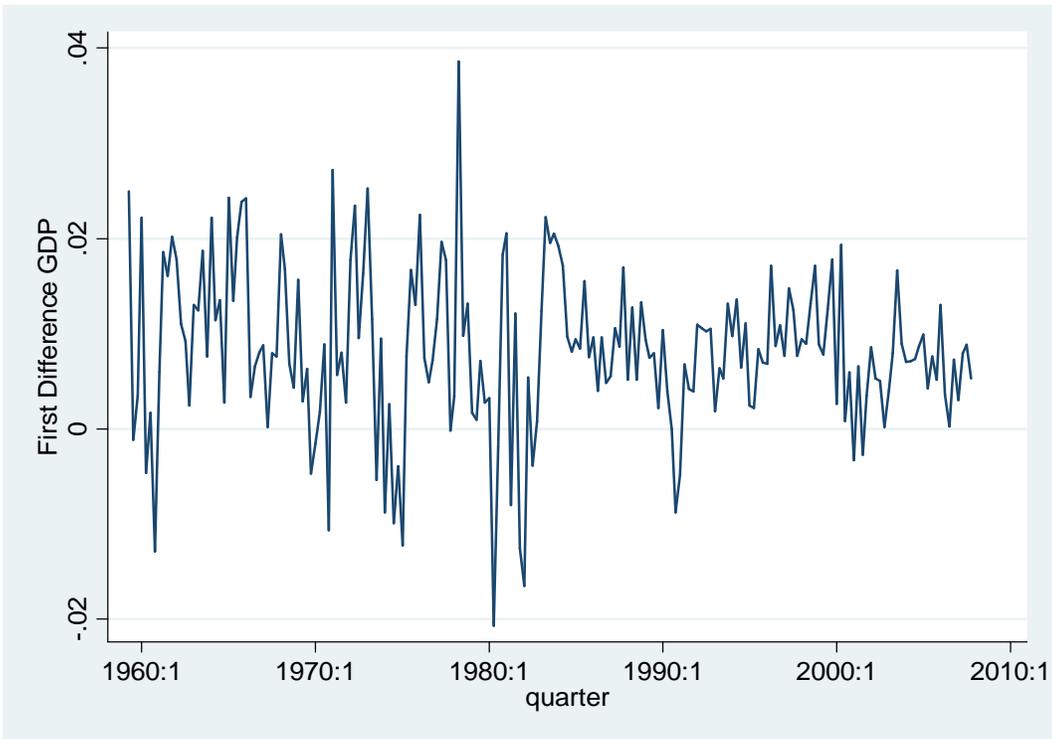


Figure A.2: First Difference of Real GDP, 1959:Q1 - 2007:Q4

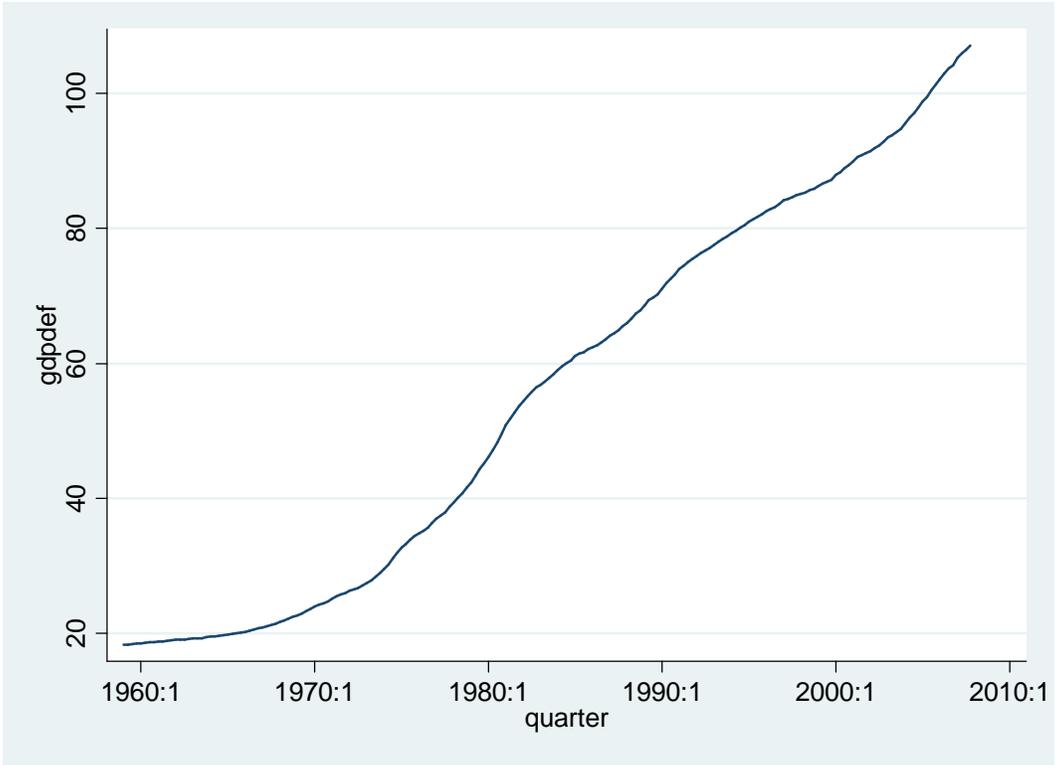


Figure A.3: GDP Deflator, 1959:Q1 - 2007:Q4

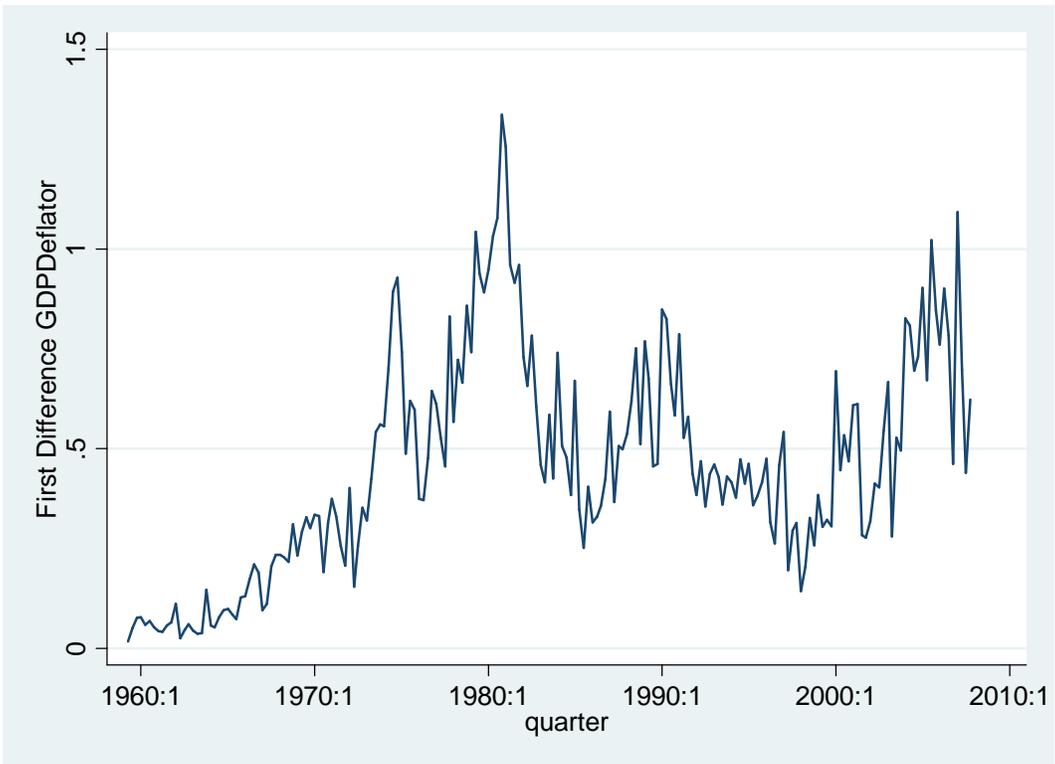


Figure A.4: First Difference of GDP Deflator, 1959:Q1 - 2007:Q4

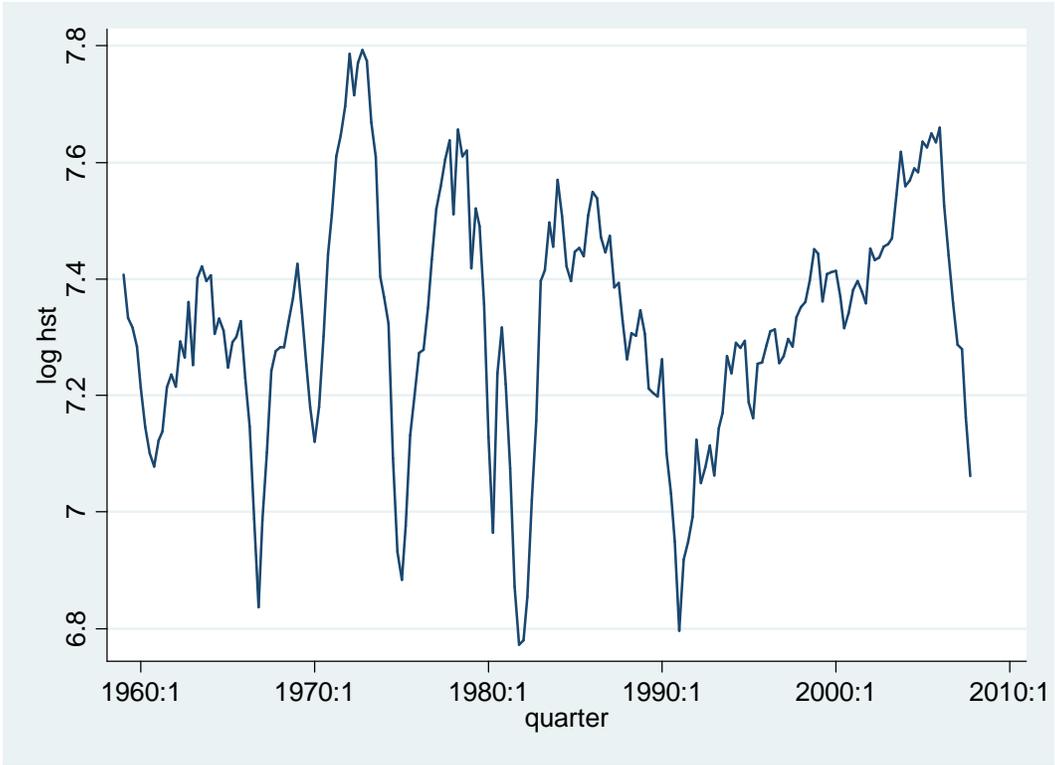


Figure A.5: Privately Owned Housing Units Started, 1959:Q1 - 2007:Q4

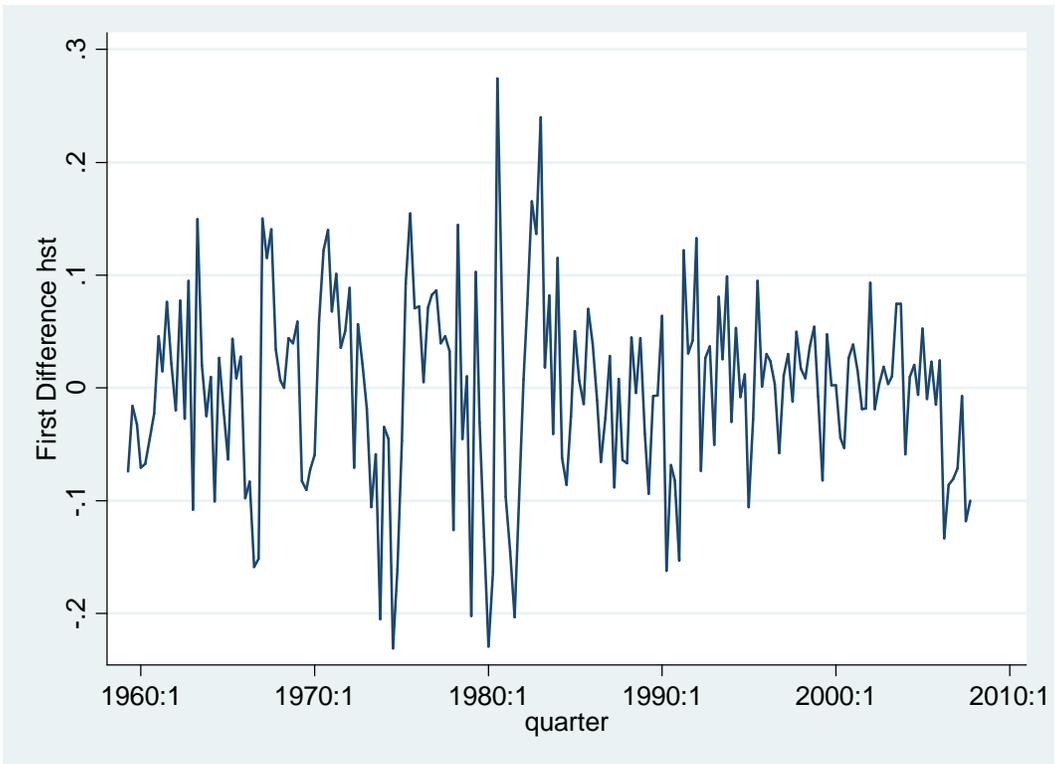


Figure A.6: First Difference of Privately Owned Housing Units, 1959:Q1 - 2007:Q4

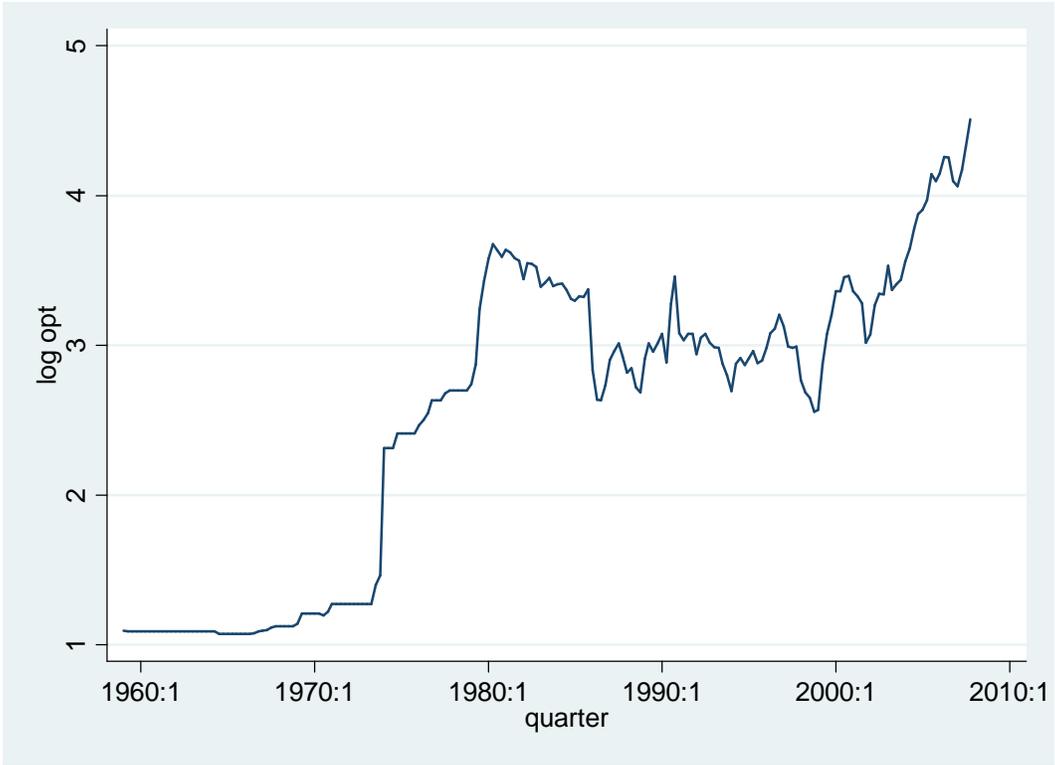


Figure A.7: Oil Prices, 1959:Q1 - 2007:Q4

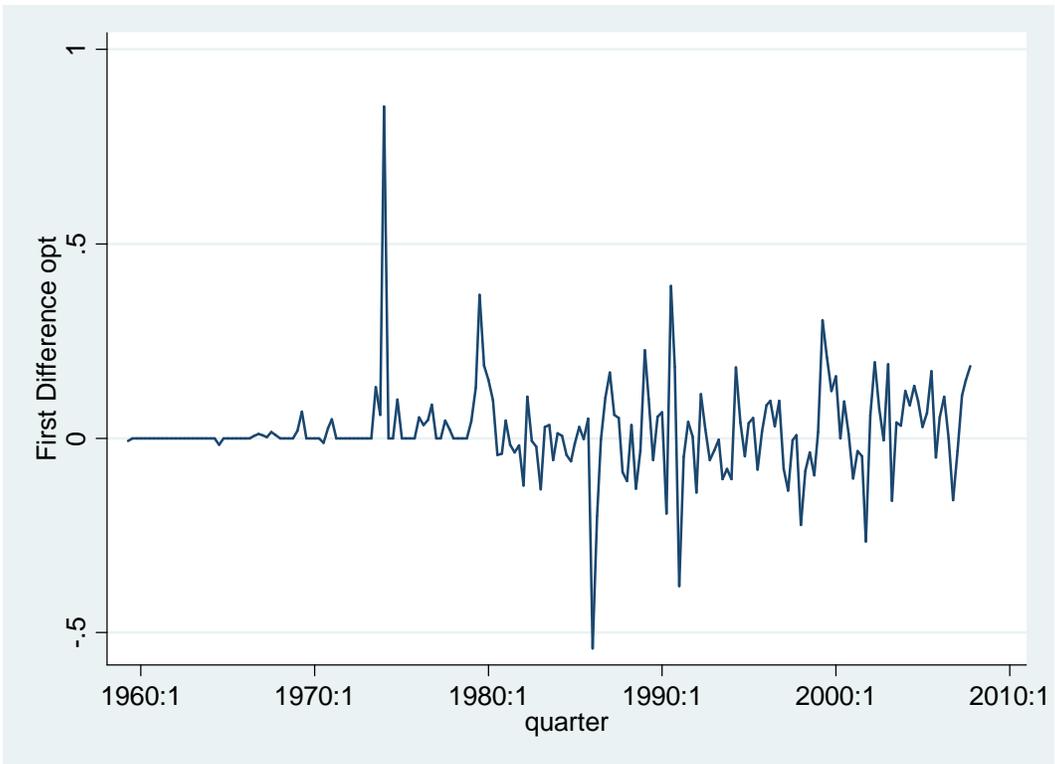


Figure A.8: First Difference of Oil Price, 1959:Q1 - 2007:Q4

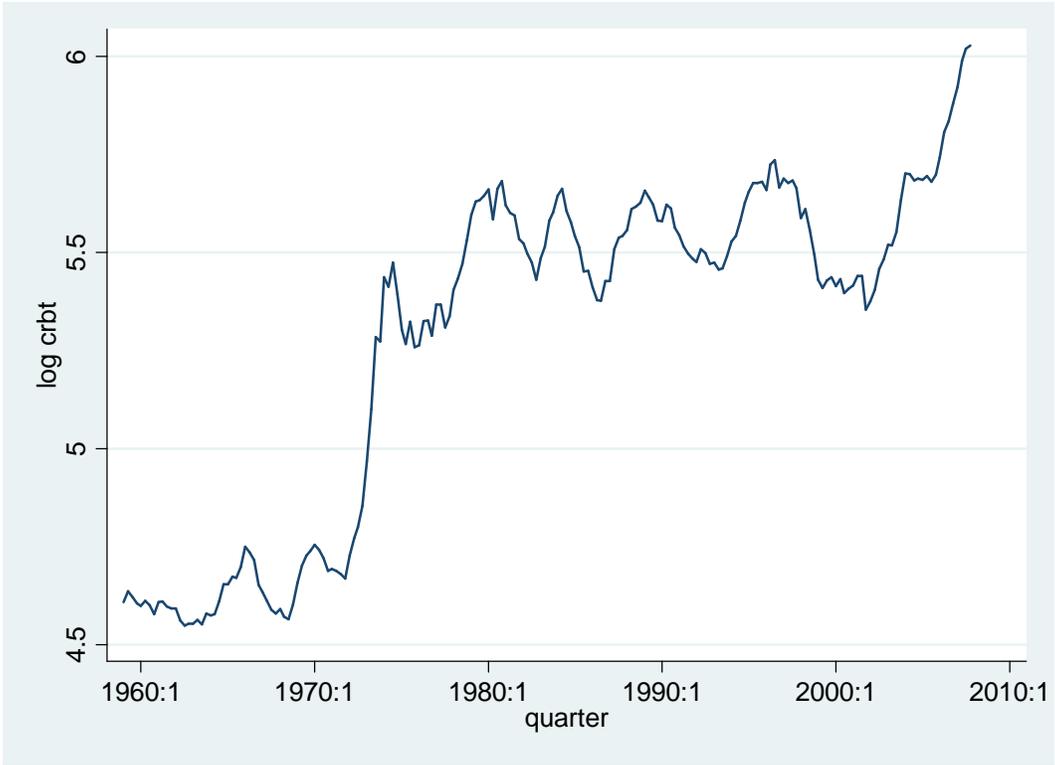


Figure A.9: Commodity Price Index, 1959:Q1 - 2007:Q4

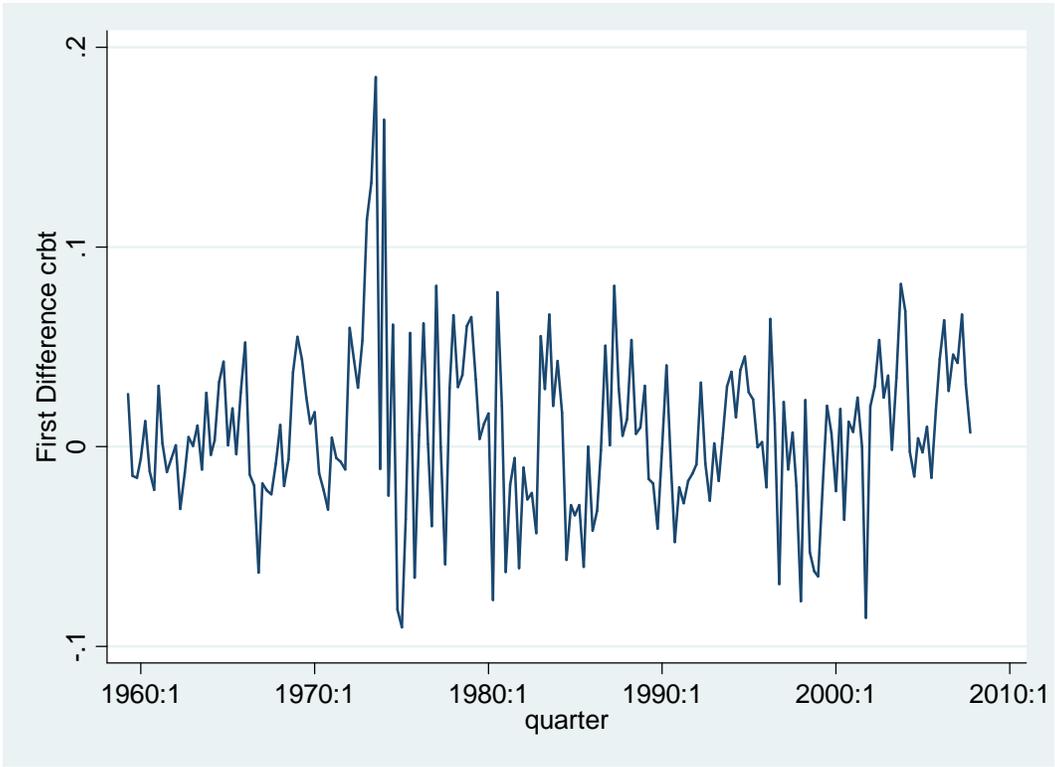


Figure A.10: First Difference of the Commodity Price Index, 1959:Q1 - 2007:Q4

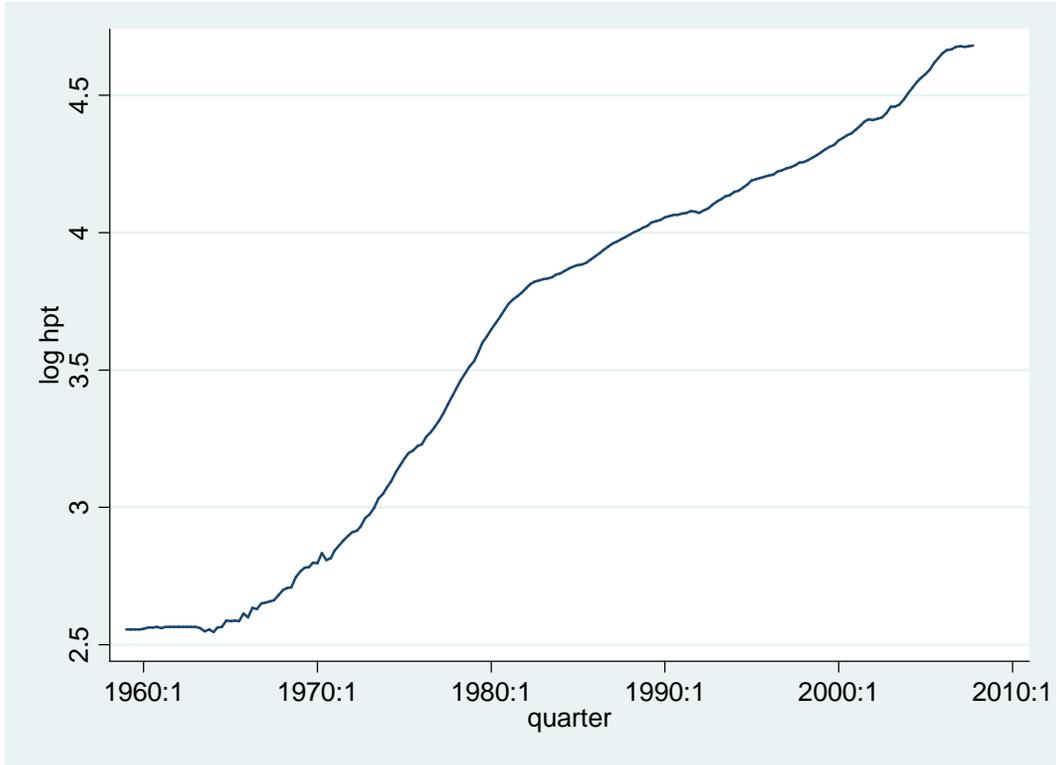


Figure A.11: Housing Prices, 1959:Q1 - 2007:Q4

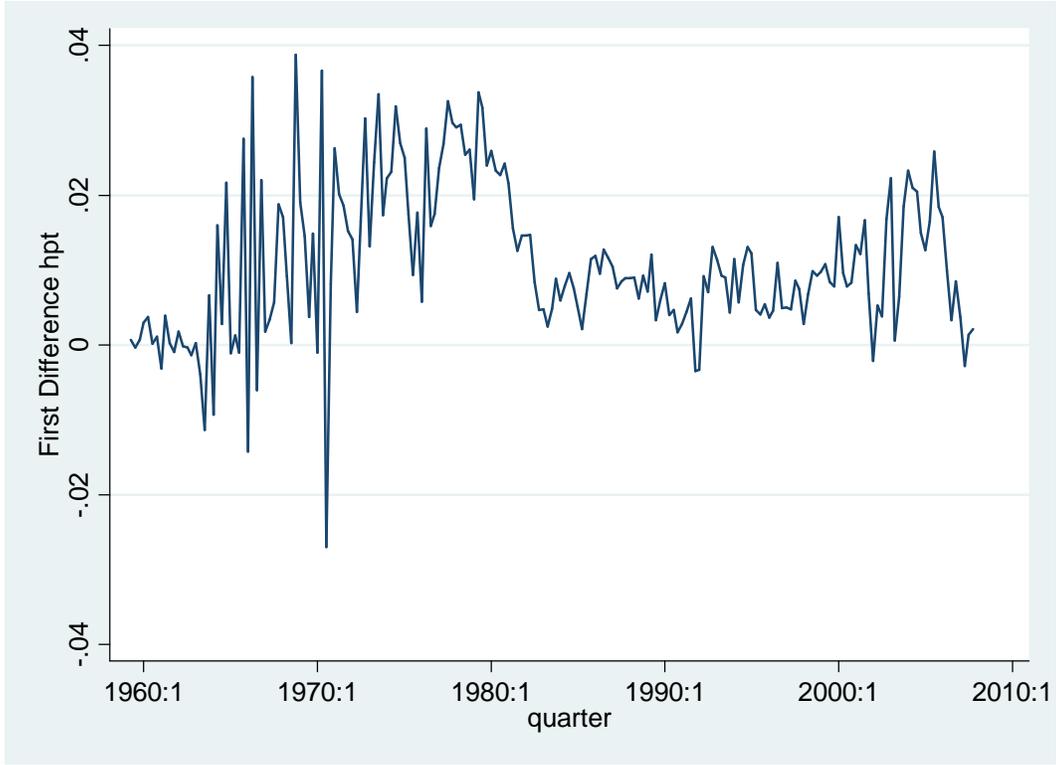


Figure A.12: First Difference of Housing Prices, 1959:Q1 - 2007:Q4

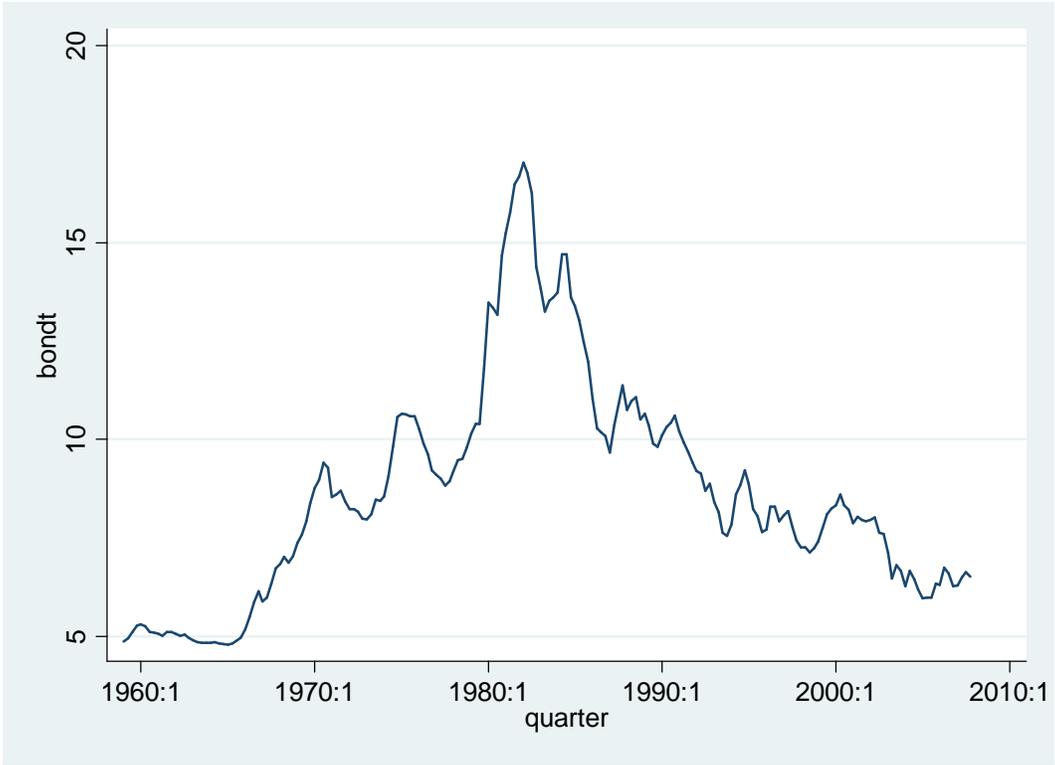


Figure A.13: Bond Rate, 1959:Q1 - 2007:Q4

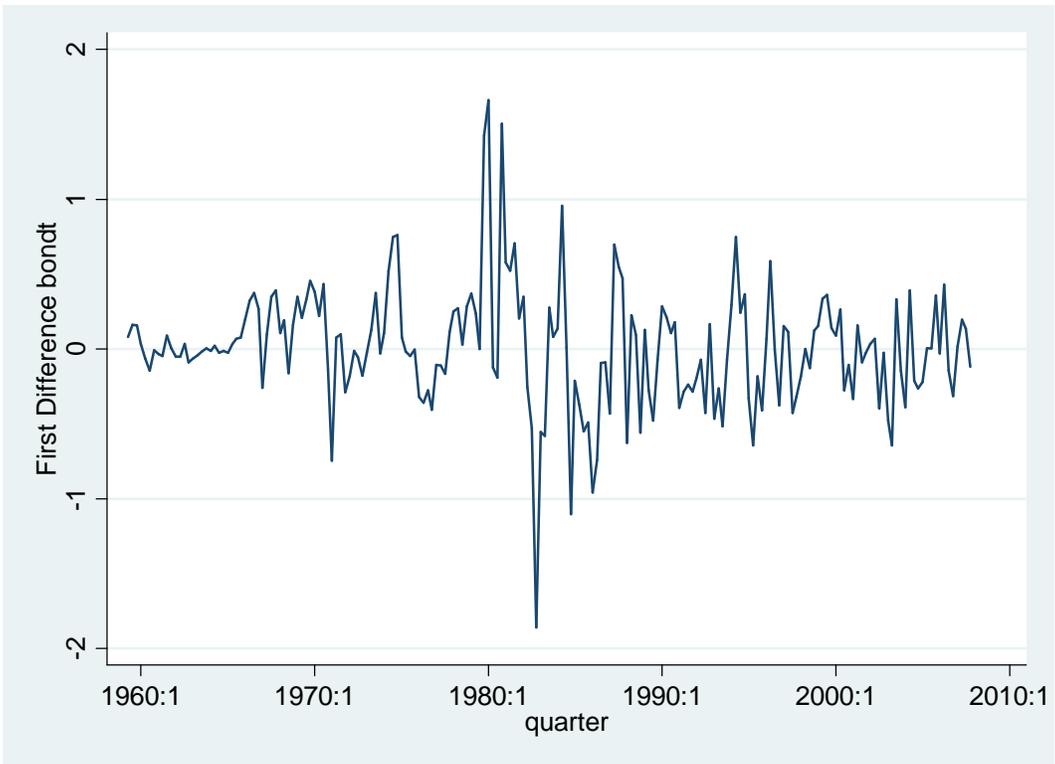


Figure A.14: First Difference of Bond Rate, 1959:Q1 - 2007:Q4

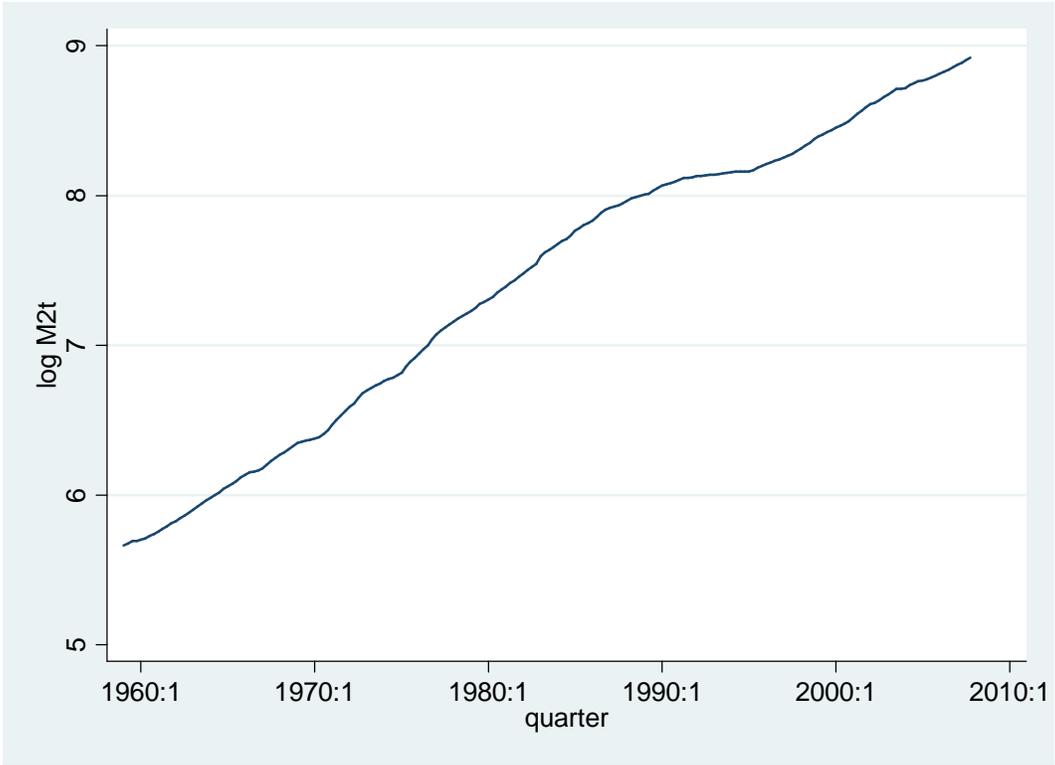


Figure A.15: Money Supply, 1959:Q1 - 2007:Q4

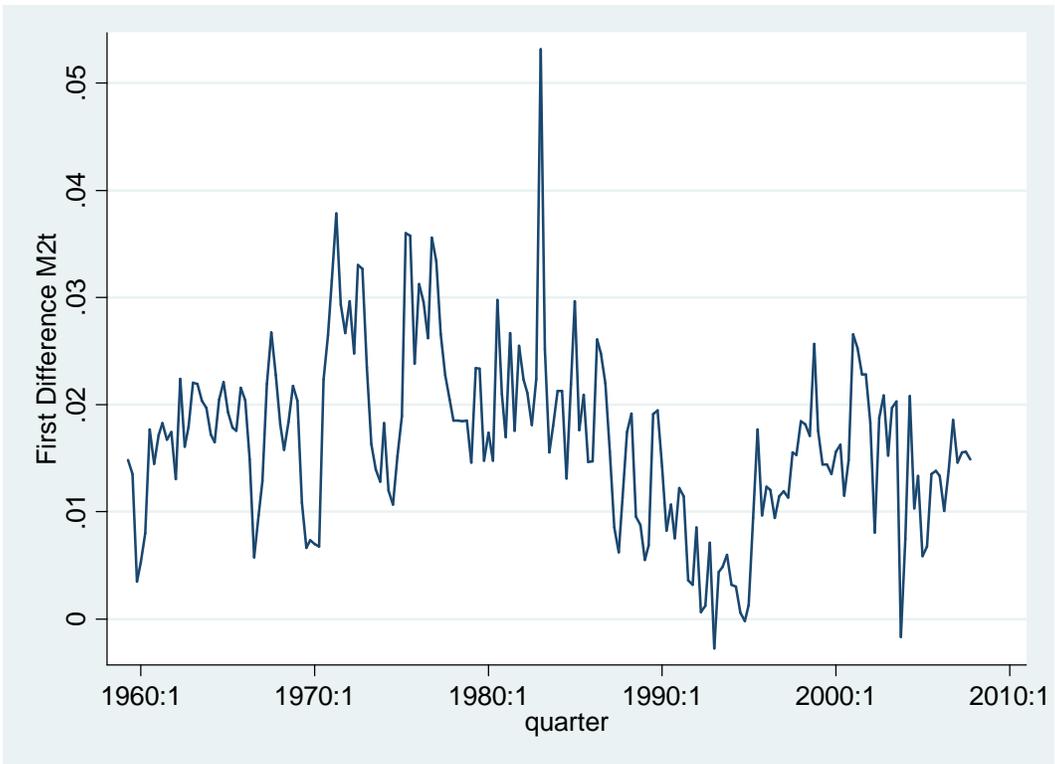


Figure A.16: First Difference of Money Supply, 1959:Q1 - 2007:Q4

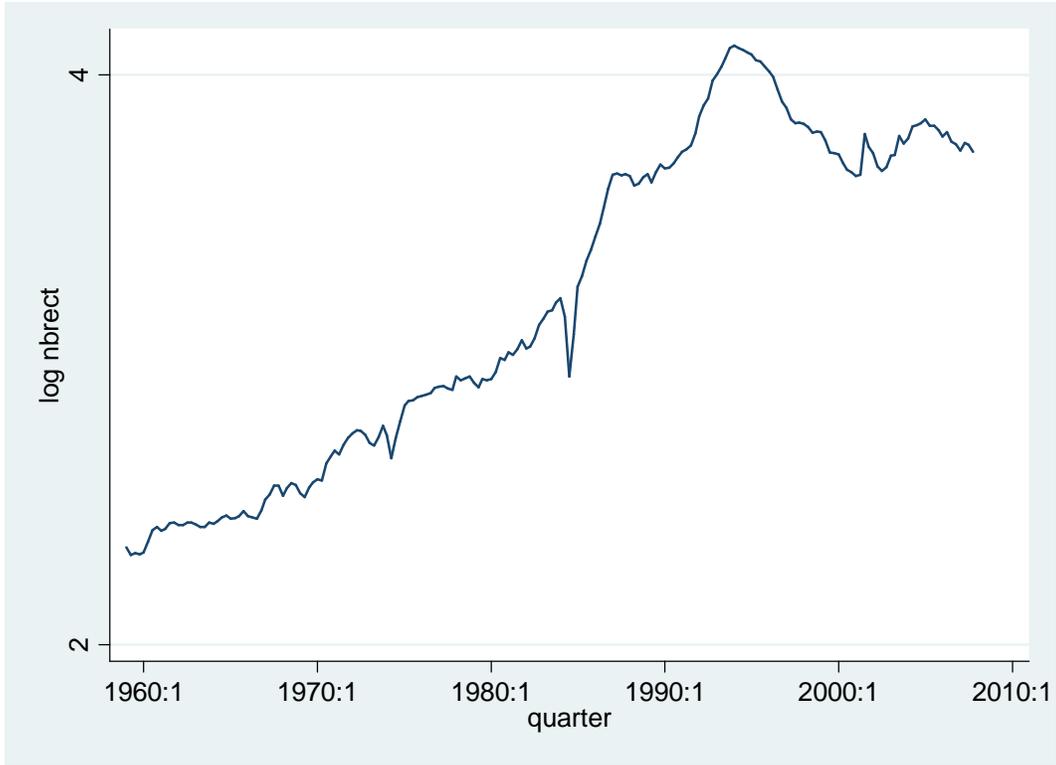


Figure A.17: Non-borrowed Reserves, 1959:Q1 - 2007:Q4

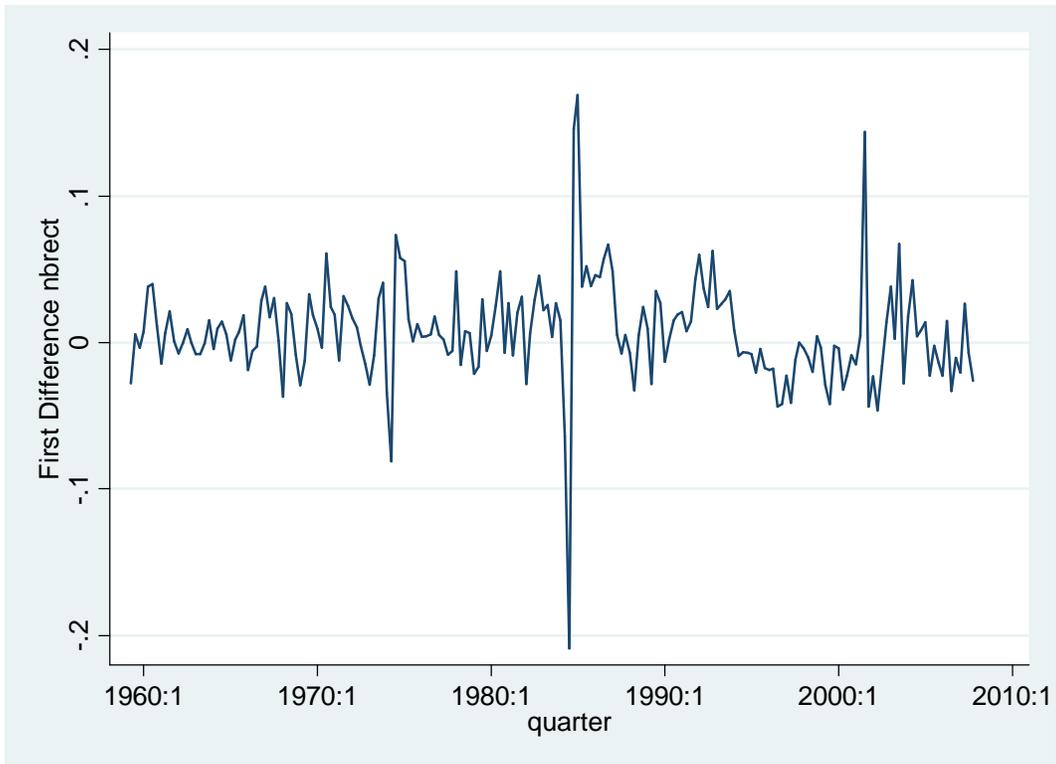


Figure A.18: First Difference of Non-borrowed Reserves, 1959:Q1 - 2007:Q4

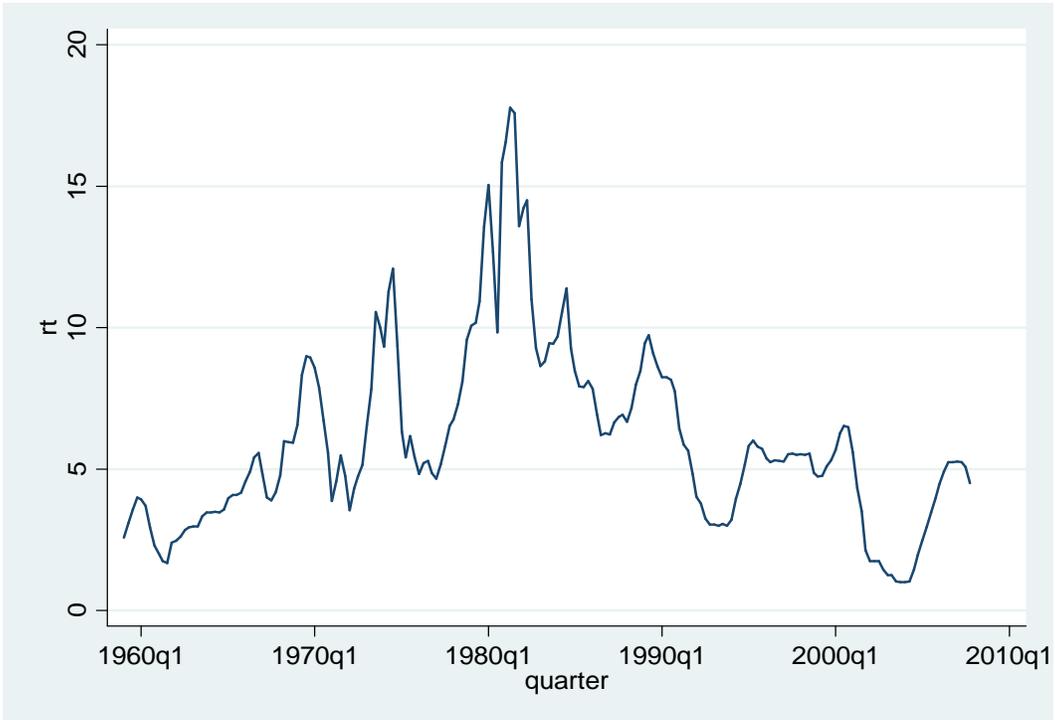


Figure A.19: Federal Funds Rate, 1959:Q1 - 2007:Q4

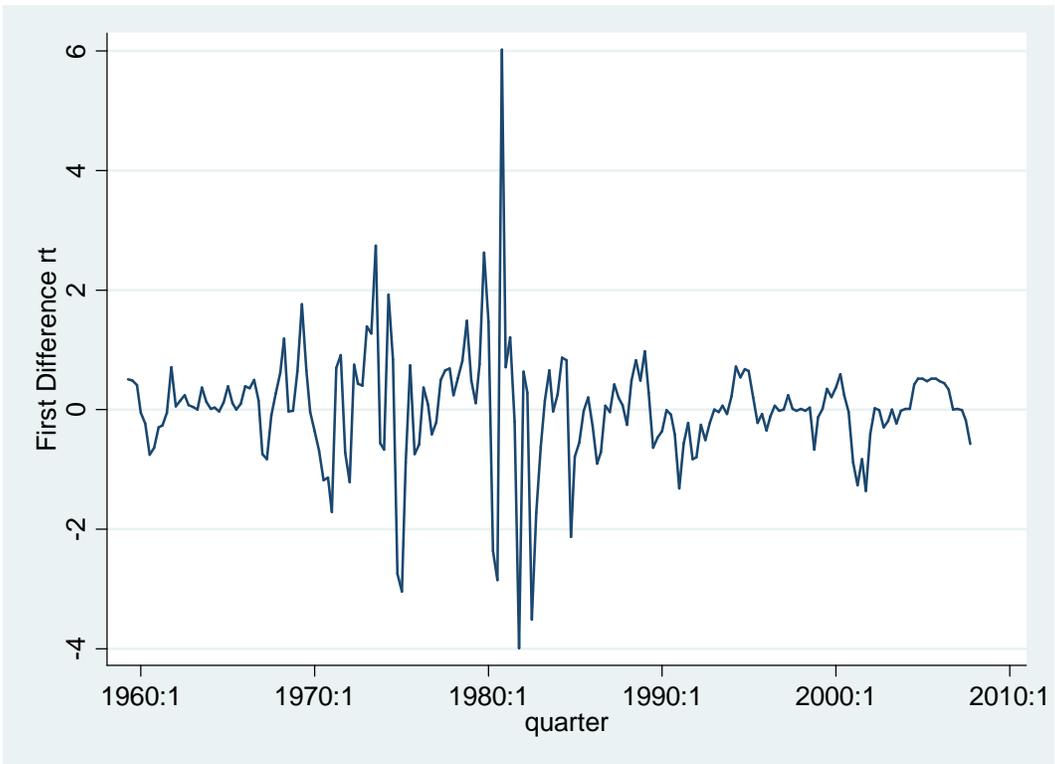


Figure A.20: First Difference of Federal Funds Rate, 1959:Q1 - 2007:Q4

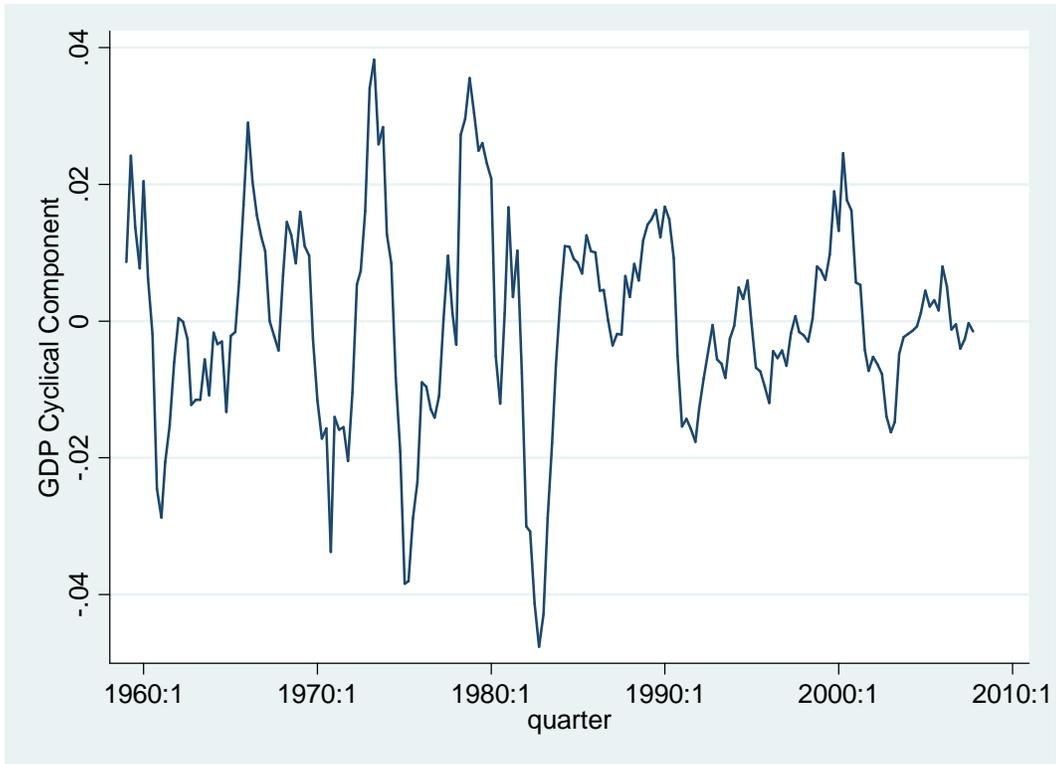


Figure A.21: Cyclical Component of GDP after HP-filter

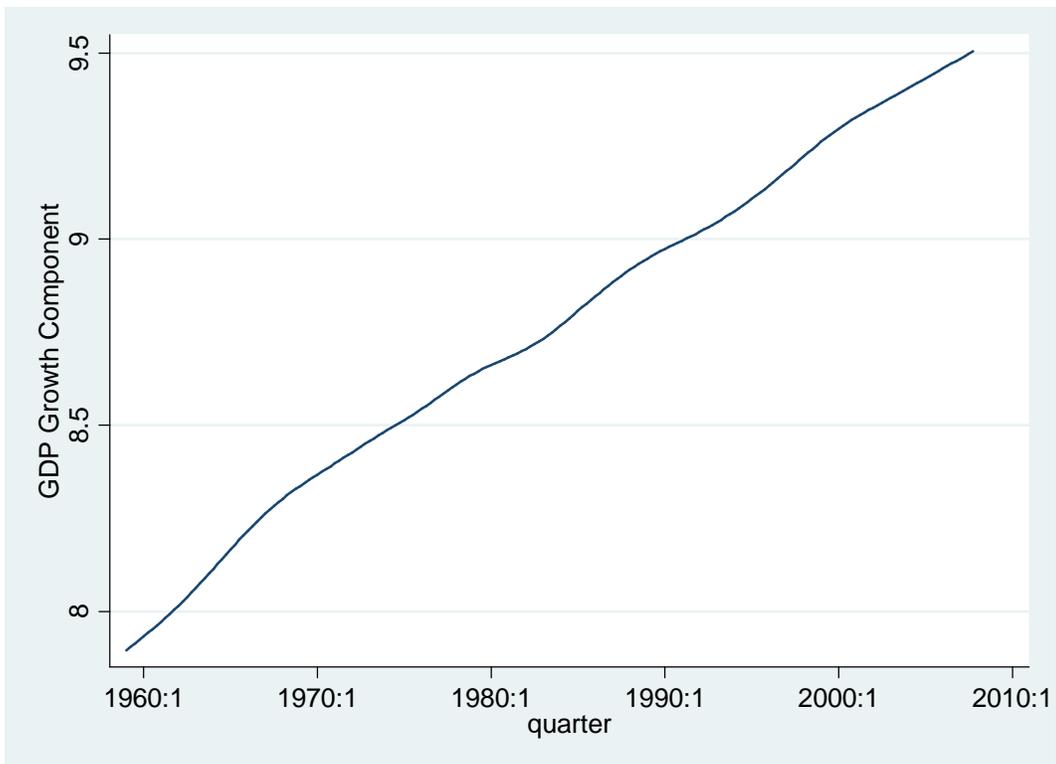


Figure A.22: Growth (Smooth) Component of GDP after HP-filter

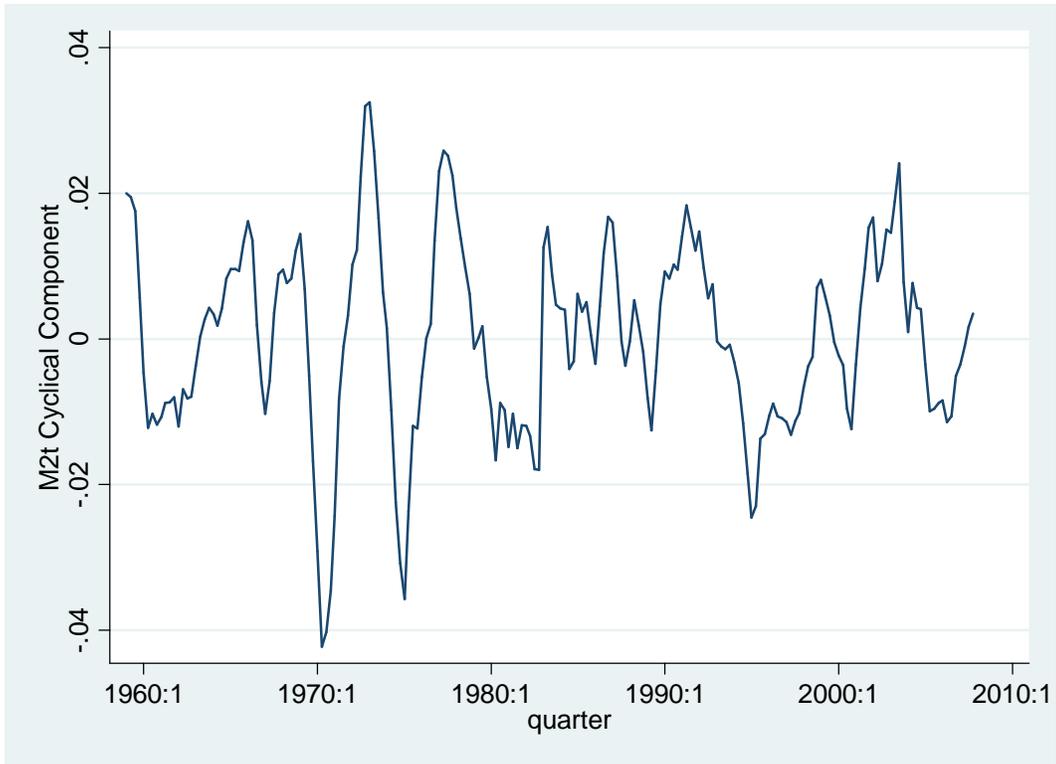


Figure A.23: Cyclical Component of Money Supply after HP-filter

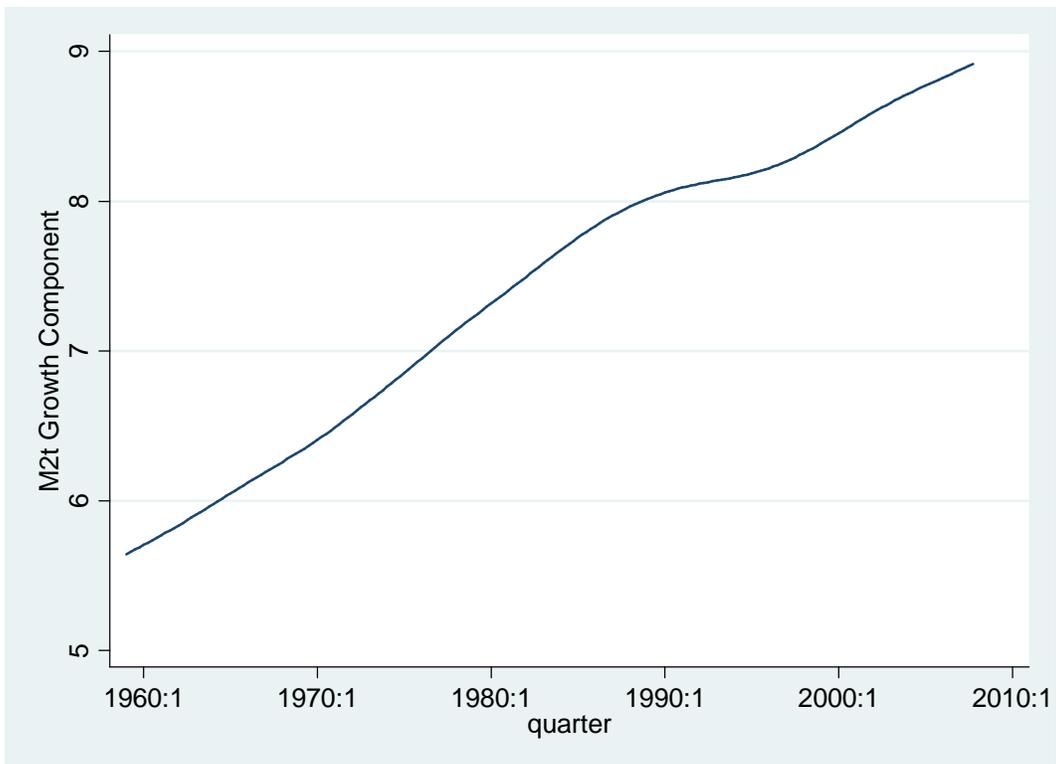


Figure A.24: Growth (Smooth) Component of Money Supply after HP-filter

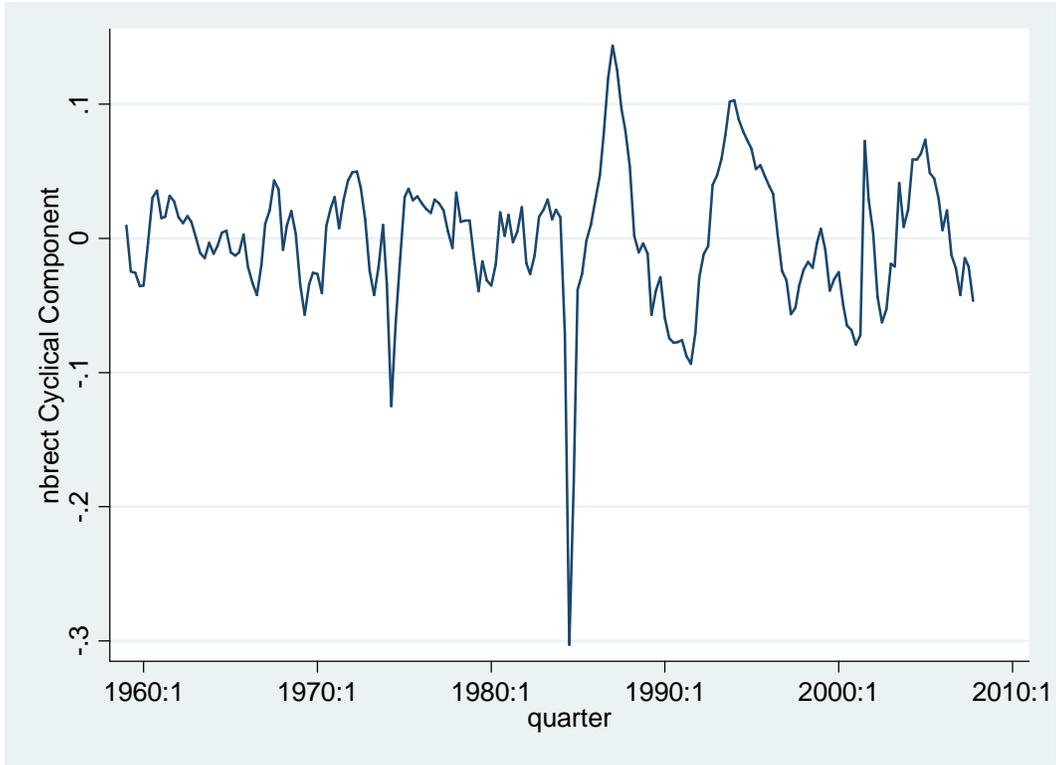


Figure A.25: Cyclical Component of Non-Borrowed Reserves after HP-filter

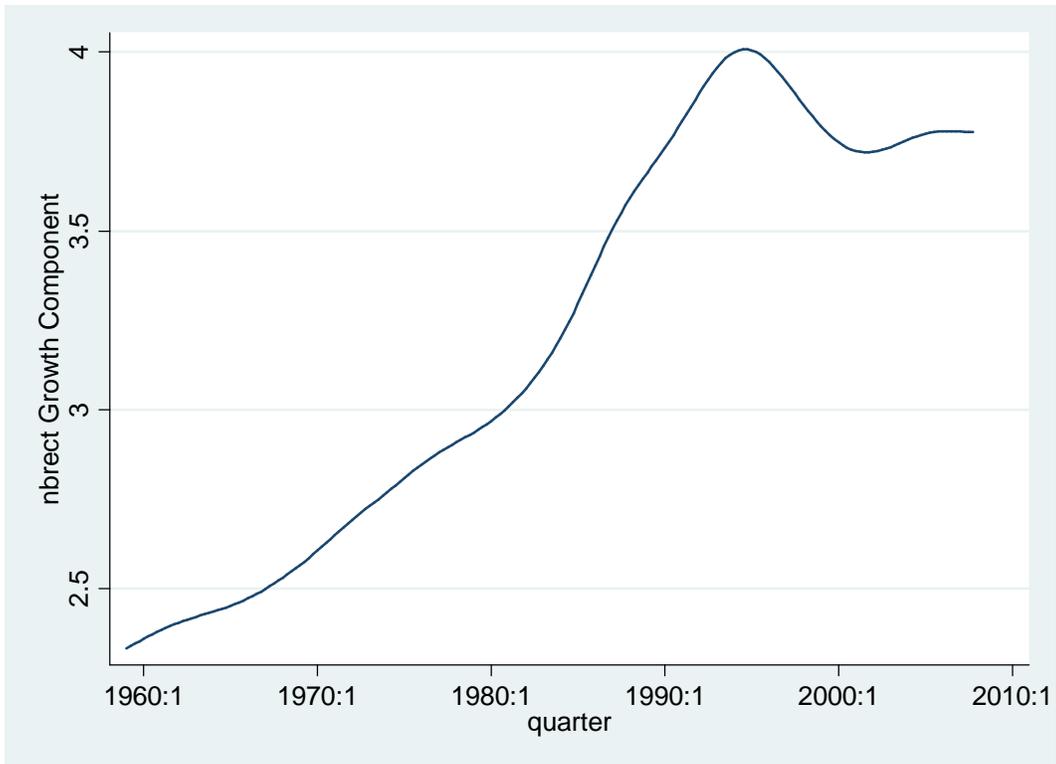


Figure A.26: Growth Component (Smooth) of Non-Borrowed Reserves after HP-filter

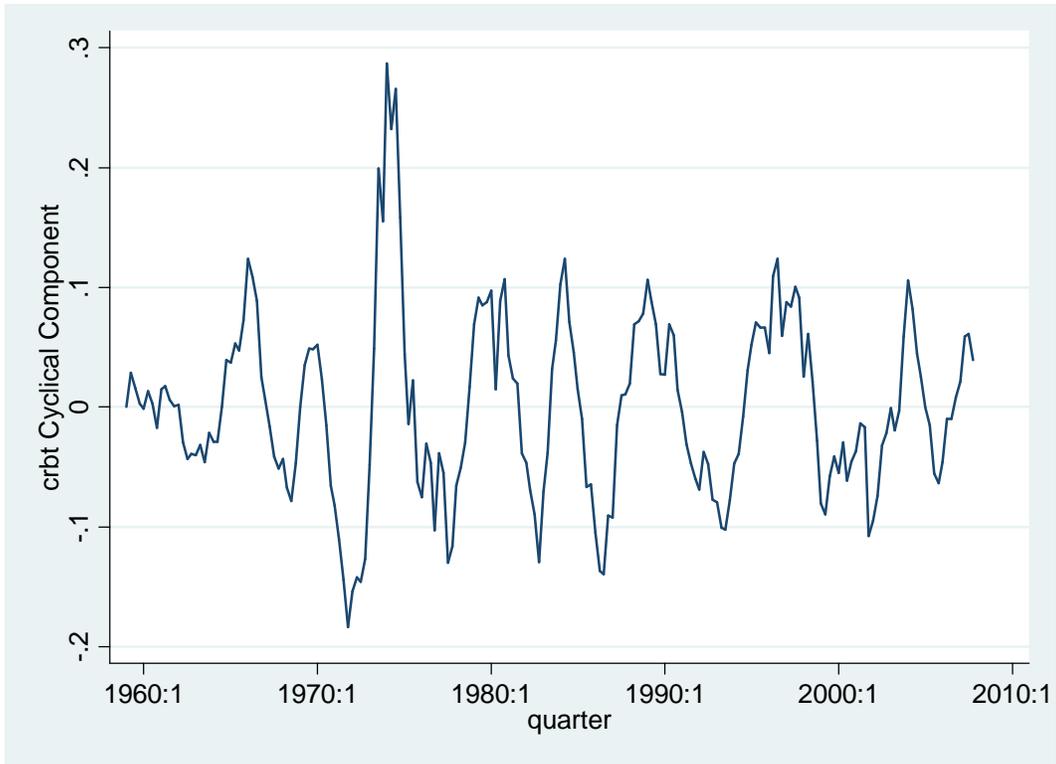


Figure A.27: Cyclical Component of Commodity Price Index after HP-filter

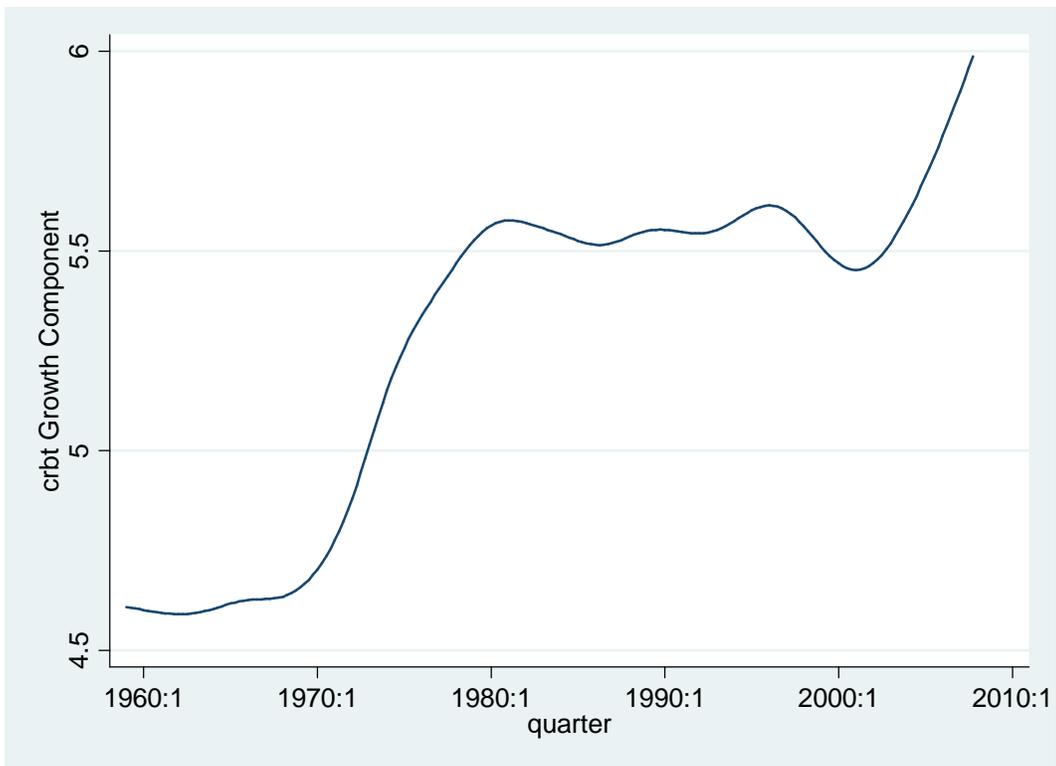


Figure A.28: Growth Component (Smooth) of Commodity Price Index after HP-filter

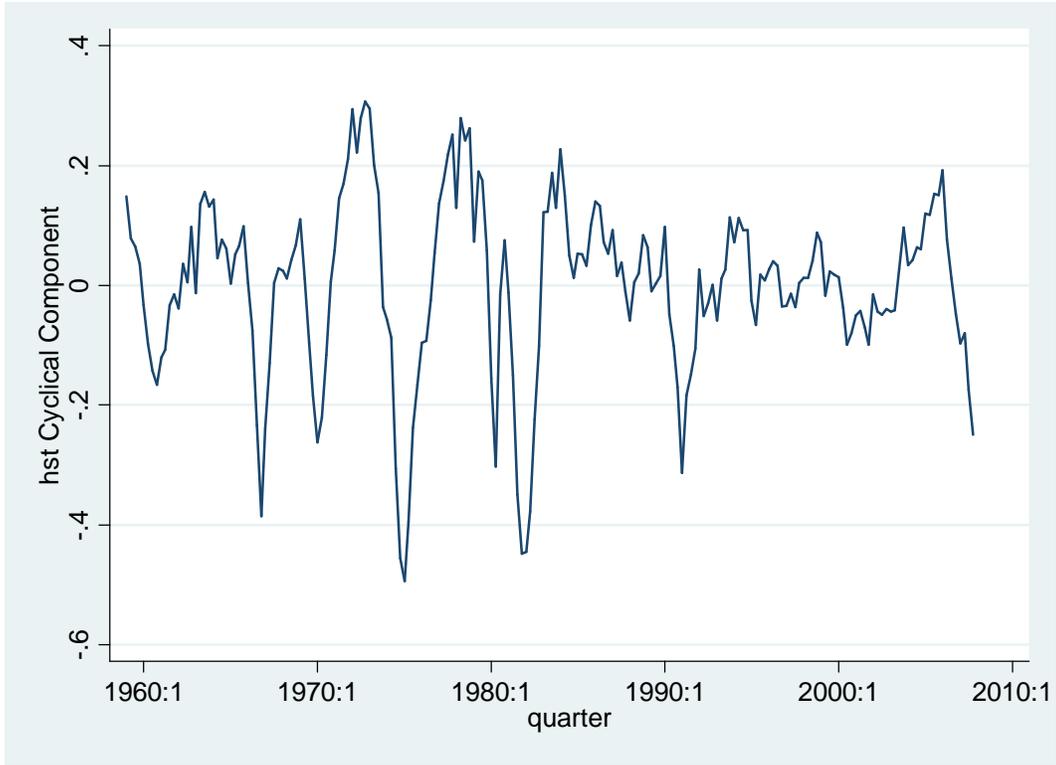


Figure A.29: Cyclical Component of Newly Started Housing Units after HP-filter

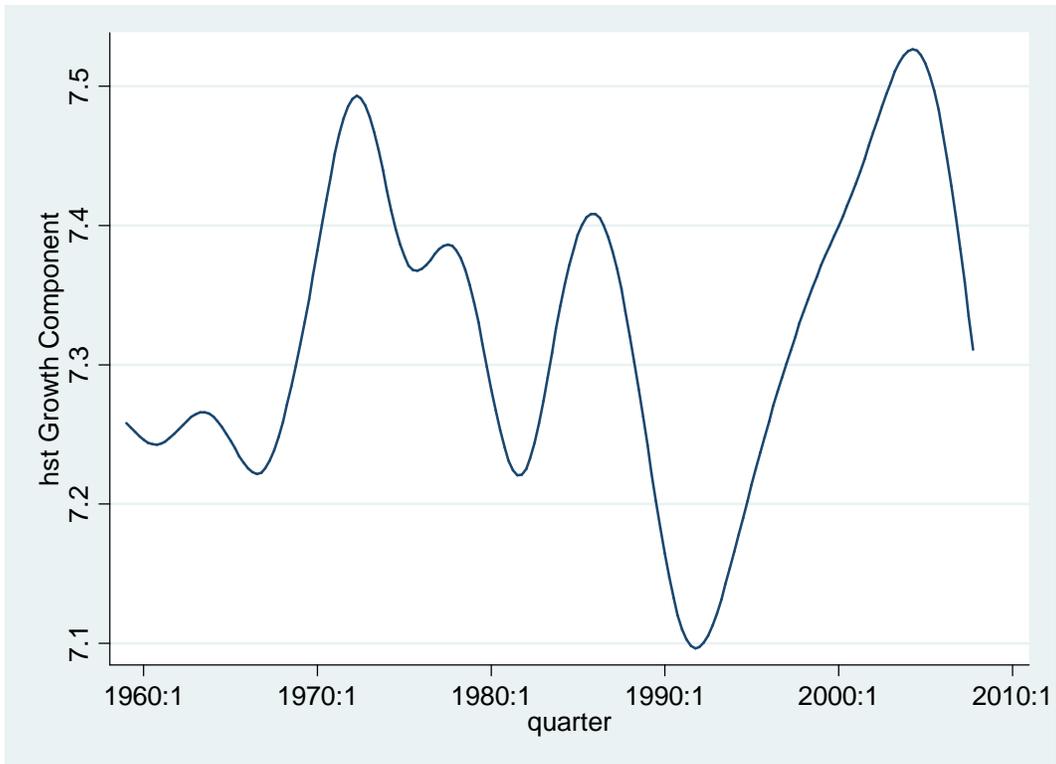


Figure A.30: Growth Component (Smooth) of Newly Started Housing Units after HP-filter

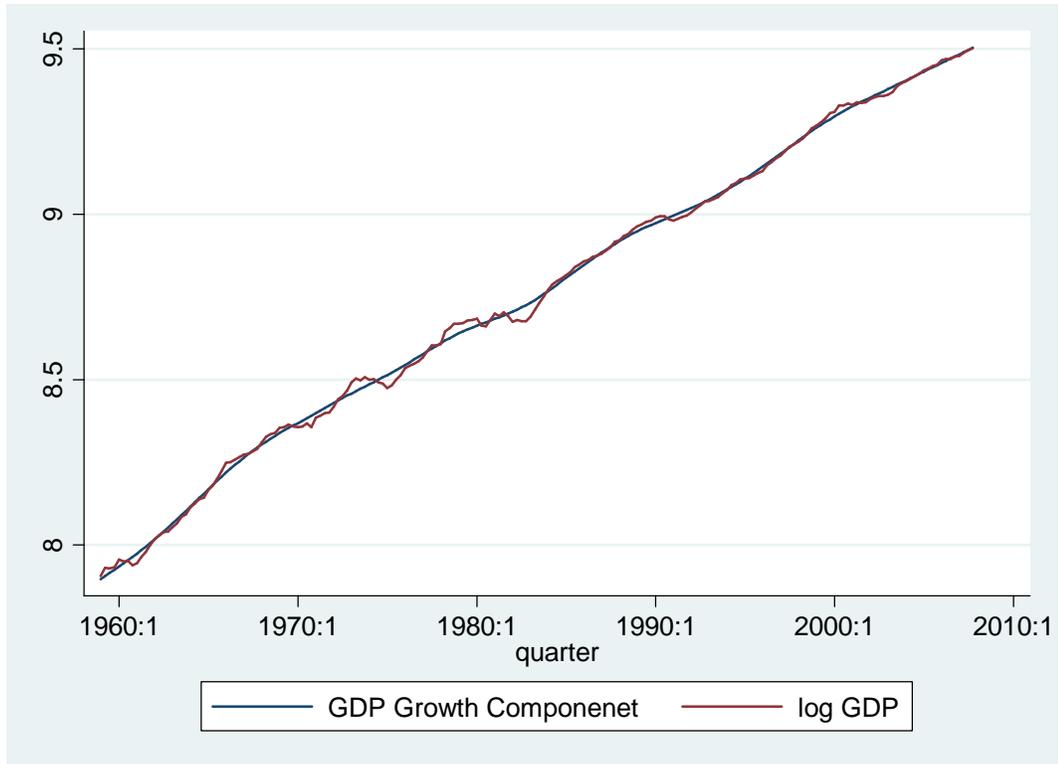


Figure A.31: Gross Domestic Product and Growth Component

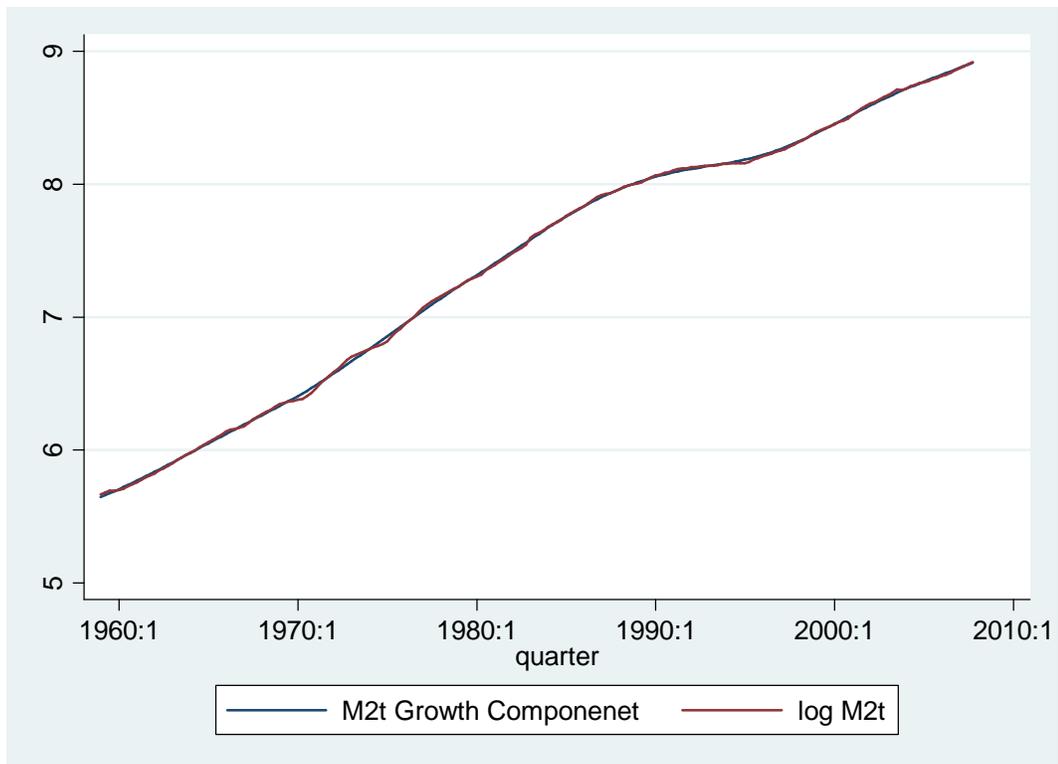


Figure A.32: Money Supply and Growth Component

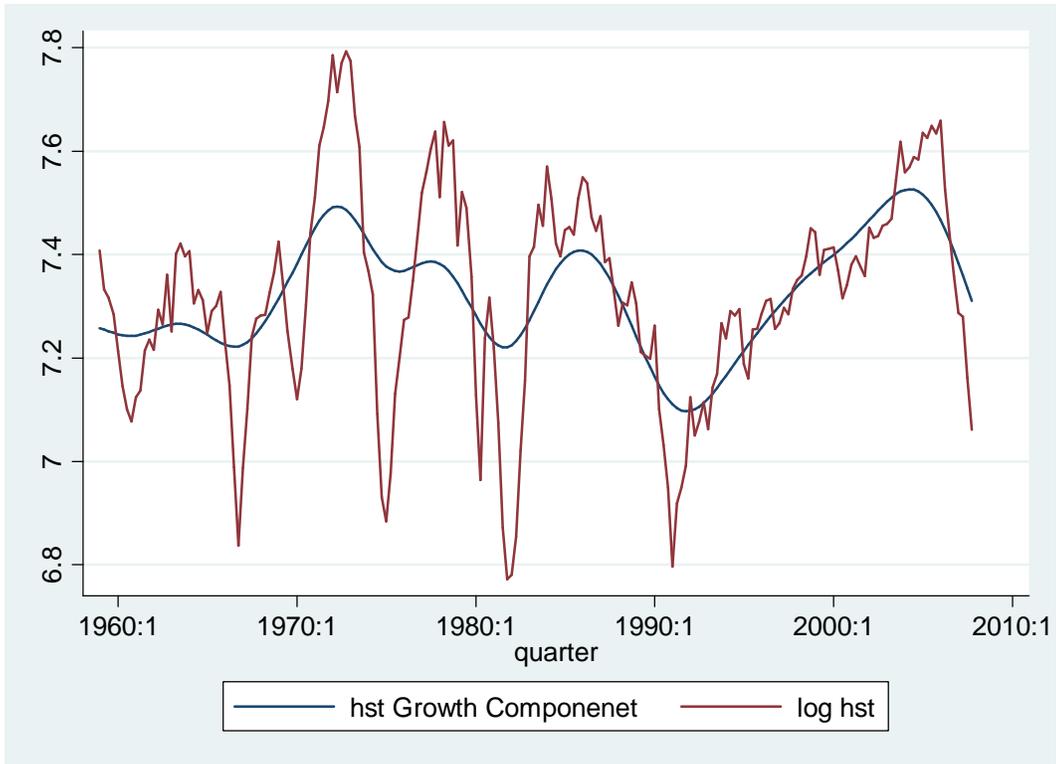


Figure A.33: Newly Started Housing Units and Growth Component

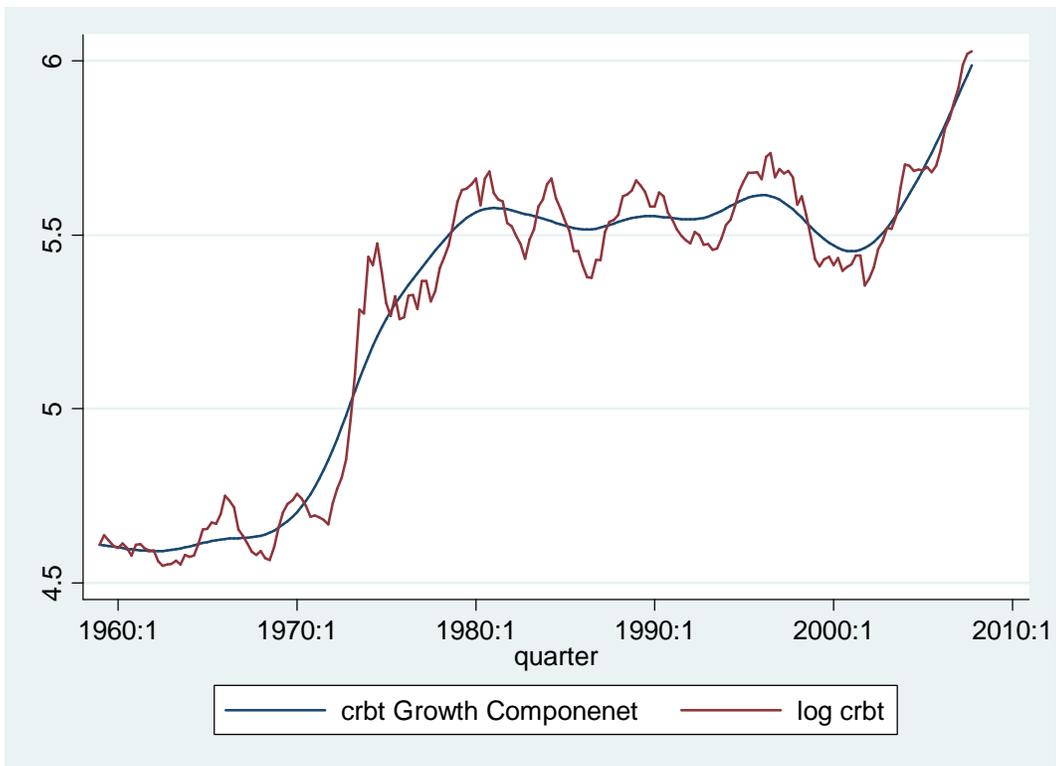


Figure A.34: Commodity Price Index and Growth Component

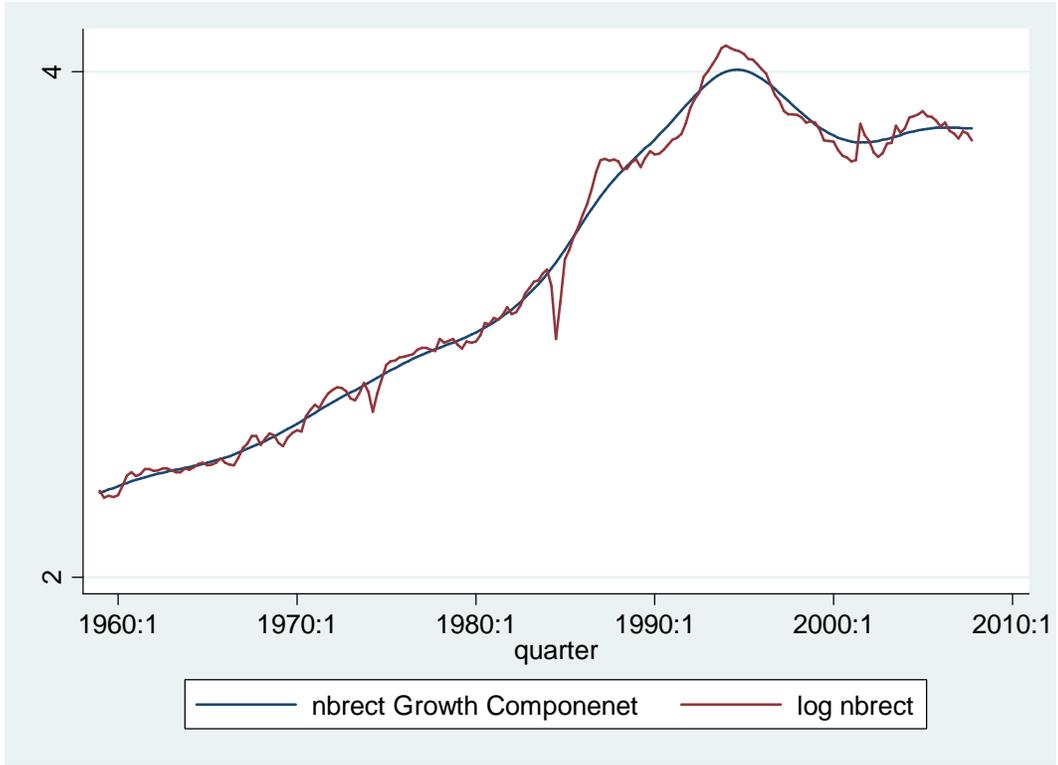


Figure A.35: Non-borrowed Reserves and Growth Component

Figure A.36: IRFs for Contractionary Monetary Policy Shock ( $r_t$ )

