Monetary Shocks and the Bond Market's Reaction: Evidence from the Narrative Approach to Shock Identification

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Abstract

This paper studies the effect of monetary policy on bond yields using the narrative shocks derived from the work of Romer and Romer (AER, 2004). Monetary shocks are orthogonalized against authorities' forward-looking behaviors, thereby capturing the true monetary effect on the economy. The challenge in empirical studies examining monetary policy is how to develop a measure that can accurately distinguish the endogenous policy movements from the exogenous monetary shocks.

By employing the monetary shocks derived from the work of Romer and Romer (AER, 2004), this study confirms that an exogenous shock has a stronger impact on the bond yields than an endogenous policy action does. Although monetary effect on the bond yields is transitory, its influences on the bond yields can last longer than previous studies have argued. Empirical evidence also indicates that (1) a negative (expansionary) shock has a stronger effect on the bond yields than a positive (contractionary) shock does; (2) a larger shock has a greater influence on the bond yield than a smaller shock does; and (3) a shock during a recession carries more weight than a shock during expansions. These results support the arguments put forth in interest rate channel of monetary policy and financial accelerator theory.

JEL classifications: E43; G12

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1 Introduction

The recent financial crisis has reminded us of the close relationship between monetary policy and financial markets. Schwartz (2008) argued that it was the long expansive monetary policy from 2001 to 2004 setting for the housing price boom. The housing price boom together with the adoption of innovated financial instruments lead to the emergence of the recent financial crisis. It is true that the power of monetary policy to macroeconomy builds on its abilities to move financial markets that matter (Blinder, (1998)). Therefore, understanding the link between the financial markets and monetary policy news is crucial in accessing the dynamic of monetary transmission mechanism and policy effect.

However, it is often difficult for policy makers and market participants to fully understand the effect of a specific monetary action. A policy action usually contains both policy makers' responses to future development in the economy and the exogenous shocks policy makers want to create[1]. The former is referred to as the endogenous actions while the latter is called the exogenous movements of monetary policy. The challenge in empirical studies examining monetary policy is how to develop a measure that can accurately distinguish the endogenous policy movements from the exogenous monetary shocks. However, disentangling the exogenous monetary shocks from the endogenous monetary action is complicated. When making policy decisions, the Federal Reserve considers a huge amount of information, probably including some private information, about current and likely future movements of economic variables. An ideal model for estimating policy effect should include most of the information the Federal Reserve uses in setting a policy while simultaneously being able to adjust to the changes of Federal Reserve's preferences over time. The fact that asymmetric information exists between the Federal Reserve and market participants usually makes it very difficult to separate the exogenous monetary actions from the endogenous ones. Although previous studies (Edelberg and Marshall (1996), Bernanke and Mihov (1998), Evans

[1] Christiano, Eichenbaum, and Evans (1994, 1998), Ellingsen and Söderström (2001), Peersman (2002), and ect.

and Marshall (1998), Kuttner (2001), Wu (2001), Jordà and Salyer (2003), Rigobon and Sack (2004), etc.) have contributed to the dynamics between monetary policy and financial markets using different econometric methods, their approaches in extracting monetary shocks have been subjected to some criticisms due to the model's structural limitations or data problems. Therefore, searching for a more effective measure of monetary policy is still an ongoing research focus in monetary economics.

The term structure of interest rates, which contains significant and invaluable information, is often considered as the ideal candidate for analyzing monetary transmission. According to the expectations hypothesis, the long rate is the average of expected future short rates plus a term premium. That is,

$$y_t^n = \frac{1}{n}\sum_{j=0}^{n-1} E_t[i_{t+j}] + TP_n, \tag{1}$$

where y_t^n is the n-period yield, i_t are expected future yields on one-period bonds over the next n periods, and TP_n is the excess yield that compensates investors to hold a long term bond instead of a series of short term bonds. Therefore, the transmission of monetary policy works from the short term interest rate monitored by central banks to the long term interest rate that aggregate demand depends upon. Since the long term rate is the average of expected future short rates plus a term premium, authorities' changes in the current short term interest rate will affect the market's expectations on future short rates, and consequently, the level of the longer term rate. On the other hand, the long term rate, which contains a premium for expected inflation, has also been proven to be an useful indicator of the market's expectations on future economic growth and a main determinant of aggregate consumption and investment decisions (Goodfriend (1992)). Thus, examining monetary effect through the lenses of the term structure of interest rate is expected to yield some implications for conducting policy.

In this paper, I adopt the narrative monetary shock series derived from the work of Romer and Romer (2004) as the measure of monetary shock to estimate the influence of monetary policy actions on bond yields. This study extends previous research in several ways. First, this paper is the first to evaluate the impact of policy on the bond market using the shocks generated from the internal operation and meetings records as well as the Federal Reserve's in-house Greenbook forecast. This forecast is prepared by the research staff at the Board of Governors before each Federal Open Market Committee (FOMC) meeting and contains most of the information available to the Federal Reserve at the time the decision was about to be made. The adoption of internal narrative meeting records as well as quantitative operation records in analyses overcomes previous data and structural problems in the sense that this approach studies policy effect using the same data set that the Federal Reserve was looking at. Moreover, narrative approach has no predeterminated structural functions. It adapts to the changes of policy stances and parameters on a monthly basis. As this narrative approach to shock derivation is new to the literature, narrative shocks have the potential to shed fresh insights on the current understanding of monetary effect.

Second, theories like information processing and credit channel of monetary policy suggest that financial series should react to macroeconomic news asymmetrically, depending on the states of the economy or the nature of policy action. This strand of literature[2] tends to focus on the following aspects of asymmetry: (1) asymmetry about the direction of the policy action, i.e. whether a positive (contractionary) or a negative (expansionary) shock affects financial series differently ; (2) asymmetry about the magnitude of the policy action, i.e. whether a relatively large or small shock causes different responses on financial series; and (3) asymmetry about the states of business condition, i.e. whether a shock in expansion or recession periods has the same effects on financial series. Previous studies either focus on how to derive an exogenous monetary effect or how a change in policy affects markets asymmetrically. The current study intends to integrate these two perspectives together.

This paper is organized as follows. Section 2 discusses monetary shock identification,

[2] Cover (1992), Jensen, Mercer, and Johnson (1996), Choi (1999), Weise (1999), Peersman and Smets (2001), Garcia and Schaller (2002), Kaufmann (2002), Lo and Piger (2003), Christie-David et al. (2003), Andersen et al. (2007), Knif et al. (2008) and etc.

while Section 3 presents the empirical analysis, Section 4 discusses the empirical results; and Section 5 provides concluding remarks.

2 Shock identification

Why don't we simply estimate the effect of monetary policy using monetary authorities' target instruments, for example, the Federal funds rate? The literature has shown that the setting of short-term interest rate involves some sort of feedback rule. A standard feedback rule is the Taylor-type of rule that describes the fluctuation of interest rate target as a function of output, inflation, and error term. Therefore, a policy action contains both policy makers' responses to future output and inflation expectations as well as the exogenous shocks that policy makers want to create to the economy[3]. It is the authorities' forwarding-looking behavior in setting short term interest rate that causes problems in estimating policy effects. For example, if the expected macro data indicate the possibility of a future recession, the Federal Reserve will react to such future forecasts with a cut in its target Federal funds rate. In such circumstance, the output may or may not rise in response to such a rate cut even though monetary policy has proven to have a stimulative and short-term effect on the output. Such countercyclical actions, therefore, lead problems in executing regressions (Romer and Romer (2004)). Kuttner (2001) found that failing to separate endogenous from exogenous actions caused Cook and Hahn (1989) to document little policy effect on the market interest rates from 1980s to 1990s.

To avoid such estimation problems, one needs to start with shocks identification. Since monetary shocks, by definition, have no correlation to current and future events, their effects on macro variables or financial markets are not contaminated by any countercyclical action, therefore, reflecting the true monetary effects.

[3]Christiano, Eichenbaum, and Evans (1994, 1998), Ellingsen and Söderström (2001), Peersman (2002), and ect.

2.1 Previous approaches

Previous methods like vector autoregression (VAR) models or event studies have been criticized on many grounds. The following discussion explains the fundamentals of these traditional approaches and why they have been subjected to many criticisms.

2.1.1 VAR identification

The VAR approach was first introduced by Sims (1980). Since then, the VAR model has become a classical approach for documenting monetary effect. For example, Cochrane (1994) proposed different possibilities of feedback rules to estimate monetary effects under the VAR framework. Edelberg and Marshall (1996) examined the relationship between monetary policy and long term bond yields using a VAR model, while Bernanke and Mihov (1998) employed a "semi-structural" VAR model to measure innovations in monetary policy. Evans and Marshall (1998) explored how exogenous monetary shocks influence the yield curves with three different VAR settings. Wu (2001) studied the effects of exogenous monetary shocks on the movements of the slope factor in the term structure of nominal interest rates using a six-variable VAR model. Jordà and Salyer (2003) explored the responses of the term structure to monetary policy uncertainty using a GARCH-SVAR approach.

In general, the VAR model is a system of linear equations. In the reduced form, each variable in the system can be expressed as a function of its own lags and the lags of other variables. That is

$$Y_t = C_0 + C_1 Y_{t-1} + C_2 Y_{t-2} + \cdots + C_j Y_{t-j} + u_t, \tag{2}$$

where J denotes the number of lags, Y_t is an $m \times 1$ vector of variables, C_j are coefficient matrices of size $m \times m$ and u_t is the one-step ahead prediction error with variance-covariance matrix Σ. The m fundamental innovations are assumed to be mutually and serially uncorrelated and normalized to be of unit variance, i.e. $E\left[vv'\right] = I_m$. To identify innovations in vector v, one need to find a matrix A such that $u_t = Av_t$. The variance-covariance matrix Σ contains $(m^2 + m)/2$ distinct elements and can be written as

$$\Sigma = E\left[u_t u_u^{'}\right] = AE\left[u_t u_u^{'}\right]A^{'} = AA^{'}. \tag{3}$$

Since there are m^2 unknowns and $(m^2 + m)/2$ relationships in the system, identifications can be achieved by imposing additional $(m^2 - m)/2$ restrictions on the structural model to map the reduced form shocks to structural shocks[4].

The identification restrictions can emerge from selecting the policy instrument targeted by the Fed, specifying a functional form of the feedback rule, and choosing the macro variables on which the Fed's decision usually depends (Christiano, Eichenbaum, and Evans (1996a, 1996b, 1998), Bluedorn and Bowdler (2005)). By setting these identification assumptions, market participants remove the anticipated change from the Fed's policy action. The residual in this feedback rule is thus the exogenous shock.

Popular empirical identification strategies include (1) setting A to be a Cholesky factor of Σ and assuming a recursive restriction of the variables as in Sims (1986) or Christiano, Eichenbaum, and Evans (1996a, 1996b); (2) applying *a priori* information or economic analysis to set some structural relationships among the structural shocks as in Sims and Zha (1995), or Bernanke and Mihov (1998); (3) separating temporary from permanent components as in Blanchard and Quah (1989); and (4) combining both short run and long run restrictions on A as in Gali (1992).

Although the VAR model provides a simple and straightforward way to identify policy effect without specifying a complete structural model of the economy, it suffers from several shortcomings due to its structural fragility and simplicity. The VAR system relies on a restricted information set and specific identification assumptions to extract exogenous monetary shock from underlying macro data. The choices of model parameters and the Fed's feedback are subjective rather than objective. Moreover, unless the VAR system includes the

[4]The discussion of the VAR model herein draws from Favero (2001), Enders (2004), and Uhlig (2005).

exact information that the Fed considers, the identification strategies will fail to eliminate the endogenous policy actions (Bluedorn and Bowdler (2005)).

Rudebush (1998) also criticized that the linear, time-invariant structure of feedback rule in monetary VAR is misspecified because it ignores the Fed's changing attitudes and preferences. The adoption of revised data in monetary VAR casts another estimation error given that the authorities use real-time data instead of revised data in making the decisions. Therefore, Rudebush (1998) suggested that further improvements in the structural approach are necessary to better describe the dynamics of the economic variables. Uhlig (2005) also argued that the VAR forecasts are heavily influenced by economists' *a priori* theory and it is hard to distinguish if one is testing the assumptions or the conclusions.

2.1.2 Futures market identification

Owing to the estimation difficulties associated with the structural model, monetary economists have recently attempted to construct monetary shocks from forward-looking financial data, such as 30-Day Fed funds futures contracts (Krueger and Kuttner (1996), Rudebusch (1998), Söderström (2001), Kuttner (2001), Gürkaynak (2005), Bernanke and Kuttner (2005),Gürkaynak ,Sack, and Swanson (2005), and Wang (2008) and etc.).

Unlike the VAR model that adopts the Fed funds rate as the benchmark to generate monetary shocks, this approach derives the shocks from the Fed funds futures contracts. The Fed's expectations are not directly observable by the public, however, the Fed funds futures prices are an ideal proxy for the market's expectations of the Fed's future movements. The Fed funds futures was first traded at the Chicago Board of Trade (CBOT) in October 1988. The price is quoted as 100 minus the average daily Fed funds overnight rate for the delivery month. The underlying interest rate is the average daily effective Fed funds rate, rounded to the nearest one-tenth of one basis point, for the delivery month.[5]

Assume FFF_t is the Fed funds futures, then FFF_t can be expressed as

[5] The specifications of the 30 day Fed funds futures are described at http://www.cbot.com.

$$FFF_{t+i} = E_t\overline{FF}_{t+i} + \alpha_i, \tag{4}$$

where FFF_{t+i} is the i-month ahead futures rate; $\overline{FF}_{t+i}$ is the average effective Fed funds rate ; and α_i is a bias term (Robertson and Thornton (1997)). Kuttner (2001) and Bernanke and Kuttner (2005) demonstrated that a monetary shock is the difference between the Fed funds target rate and the one-month futures contract on the last day of previous month[6]. That is, month t surprise Δi_t^u can be expressed as

$$\Delta i_t^u = \frac{1}{D}\sum_{D=1}^{D} i_{t,d} - f_{t-1,D}^1, \tag{5}$$

where $i_{t,d}$ is the Fed funds rate target on day d of month t, and $f_{t-1,D}^1$ is the one-month futures contract on the last day(Dth) of month t. Gürkaynak ,Sack, and Swanson (2005) further extended these lines of study by using high-frequency data from the Fed funds futures to decompose the information from the FOMC announcement into two factors, surprise in the Fed funds target rate and surprise about the future path of policy, to estimate monetary effect.

Although adopting the Fed funds futures in gauging monetary effect overcomes the VAR's rigidity problem, one still needs to deal with data mismatch issue. The underlying asset for the Fed funds futures is the average effective Fed funds rate instead of the average Fed funds target rate. Figure 1 plots the dynamics of these two rates over time. Although the average effective Fed funds rate and the average Fed funds target rate are generally close to each other, causal observations show that sometimes the spreads are too large to be ignored. Robertson and Thornton (1997) argued that such differences could cause identification problems which lead to biased estimations.

[6] According to Bernanke and Kuttner (2005), for an event taking place on day d of month m, monetary shock is derived from the change in the rate implied by the current month future contract. Since the contract is settled against the average daily fed funds overnight rate, the shock term on day d of month m has to be scaled up by the appropriate percentage.

2.1.3 Narrative identification

Unlike the models previously discussed, the narrative approach to shock identification offers economists a new way to study the monetary transmission mechanism. In the spirit of the work of Friedeman and Schwartz (1963), Romer and Romer (1989) piorneered a so-called narrative method to identify monetary policy shock. The core idea of the narrative approach is that it combines monetary authorities' internal records and forecasts along with usual macroeconometric techniques to wash out the anticipated and endogenous parts of monetary actions.

In their influential paper, Romer and Romer (2004) further advanced this line of studies. Their methodology is described as follows. First, the Romers began by deriving a series of the Fed's intentions regarding targeted change for the Fed funds rate around the FOMC meetings for the period of 1969 to 1996. To derive this intended series, the Romers adopted the information from the narrative records of the FOMC meetings and the Weekly Report of the Manager of Open Market Operations, a quantitative internal memo about the expected federal funds rate. This operation report contains the detailed information about the open market desk's timing of move and the range of target movements for a specific date.

Second, this intention series was regressed on the Fed's Greenbook forecast of future output, inflation, and unemployment to filter out the monetary actions taken as the results of Fed's forward-looking behaviors. The Greenbook forecast is prepared by the research staff at the Board of Governors before each FOMC meeting. It contains the in house's projections about the state of future economy. The equation the Romers estimated was:

$$\begin{aligned} \triangle ff_m &= \alpha + \beta ffb_m + \sum_{i=-1}^{2} \gamma_i \widetilde{\triangle y}_{mi} + \sum_{i=-1}^{2} \lambda_i (\widetilde{\triangle y}_{mi} - \widetilde{\triangle y}_{m-1,i}) \\ &\quad + \sum_{i=-1}^{2} \varphi_i \tilde{\pi}_{mi} + \sum_{i=-1}^{2} \theta_i (\tilde{\pi}_{mi} - \tilde{\pi}_{m-1,i}) + \rho \tilde{u}_{m0} + \epsilon_m \end{aligned} \quad (6)$$

,where $\triangle ff_m$ is the change in the intended funds rate around FOMC meeting m. ffb_m is the level of the intended funds rate before any changes associated with meeting m. $\widetilde{\triangle y}$, $\tilde{\pi}$, and $\tilde{u}$ are the real output growth, the forecasts of inflation, and the unemployment rate, respectively. Since the residuals of this regression are the movements not made in response to forecasts of future economic variables, ϵ_m is considered to be an exogenous monetary shock.

Using this new measure, Romer and Romer (2004) analyzed and compared the responses of output and inflation to monetary policy using the actual funds rate and the intended series derived. They found that their new measure causes a stronger effect on output and stronger and more rapid responses on price than conventional VAR estimations, where the actual Federal funds rate are the policy measure. This result indicats that the existence of an endogeneity problem in VAR models may lead to biased estimations.

Why is the narrative measure of shocks a competitive measure for identifying shocks? The narrative approach overcomes previous identification problem by using monetary authorities' internal memos and meeting minutes to remove endogenous actions made in response to other macro data. The narrative approach certainly does not require specifying the Fed's feedback rule. The adoption of in house Greenbook forecasts to control endogenous and anticipated movements from exogenous actions mimics the Fed estimating behaviors. Cochrane (2004) praised the construction of the Fed's intention series in Romer and Romer (2004) as a significant innovation because it considers all real time information up to dates before each FOMC meeting, thereby providing the maximum data available to forecast. Faust and Wright (2007) argued that the Greenbook forecast is the best real world forecast given it is based on a wider range of information than most large time series models. Sims (2002) considered the Greenbook forecast to be the most vintage data in evaluating the current state of the economy. Cover (2008) found that the Romers' shock series passed two specification tests, i.e. (1) shocks have no long run influence on output and (2) shocks are eventually completely reversed. Therefore, it is safe to assert that the shocks derived by Romer and Romer (2004) are reasonable exogenous shocks. Given that the Romers' shock series is new to the literature, this series of shock is anticipated to provide economists with several new insights about the dynamic of monetary policy and economic variables.

3 Empirical analysis

3.1 Data

This paper examined monthly data from January 1970 to December 1996, with the initial lagged value starting in January 1969. The zero coupon bond yields for January 1969 to February 1991 come from McCulloch and Kwon (1993) while those for March 1991 to December 1996 from Robert Bliss (1994)[7]. All interest rates are on a continuous compounding basis and are given as percentage per annum. The macro variables are taken from the Federal Reserve Economic Data (FRED) of Federal Reserve Bank of St. Louis and the Board of Governors of the Federal Reserve System. Monetary shock is a generated series from the work of Romer and Romer (2004). Table 1 presents the unit root tests of the series studied in this paper, while Table 2 summarize the sample statistics. Figure 2 graphs the long-term bond yield, short term bond yield, and yield spread over the period from 1969 to 1996. Figure 3 depicts the change of the Fed funds target rate and the Romer and Romer (2004) shock series over the period from 1969 to 1996.

3.2 Baseline regression

3.2.1 Cook and Hahn-style analysis

The analysis begins with Cook and Hahn-style model by regressing the changes in the bond yields on the expected (endogenous) and unexpected (exogenous) componets of the target rate changes. Thie type of equation has been used in many existing works, including Cook and Hahn (1989), Kuttner (2001), Bernanke and Kuttner (2005), and Gürkaynak et al.

[7] Professor Gregory R. Duffee from University of California at Berkeley has consolidated these two datasets and made then available at his homepage http://www.haas.berkeley.edu/~duffee/.

(2005). The equation estimated is

$$\Delta R_t^i = \alpha + \beta_1^i \Delta r_t^e + \beta_2^i \Delta r_t^u + \epsilon_t^i, \tag{7}$$

where ΔR_t denotes the change in the i-month bond yield, Δr_t^e denotes expected change of target rate, Δr_t^u is the monetary shock derived from Romer and Romer (2004)'s narrative approach[8], and ϵ_t is a stochastic error term. Table 3 reports the empirical results for equation (7).

3.2.2 Autoregressive distributed lag analysis

Woodford (2003) and Evans and Marshall (2007) suggest that incorporating the interest rate smoothing feature in the estimation is more efficient in describing the dynamic relationship between policy movements and interest rates than a simple regression. Therefore, I estimate a "smoothing" version of the equation as

$$\Delta y_t = \mu + \sum_{j=0}^{12} \alpha_j \triangle y_{t-j} + \sum_{j=0}^{12} \beta_j s_{t-j} + \epsilon_t, \tag{8}$$

where Δy_t denotes the log change in a bond yield, s_t denotes monetary shocks derived from Romer and Romer (2004)'s narrative approach, and ϵ_t is a stochastic error term that captures the impacts of other factors on the change in the bond yield. Equation (8) is an autoregressive distributed lag (ARDL) representation where it can be written more compactly as

$$C(L)\Delta y_t = \mu + B(L)s_t + \epsilon_t \tag{9}$$

by defining polynomials in the lag operator,

[8]The change of target rate can be decomposed into the expected rate change and the unexpected rate change. That is,

$$\Delta r_t = \Delta r_t^e + \Delta r_t^u.$$

$$C(L) = 1 - \alpha_1 L - \alpha_2 L^2 - \cdots \alpha_{12} L^{12}$$

and

$$B(L) = \beta_0 + \beta_1 L + \beta_2 L^2 \cdots + \beta_{12} L^{12}.$$

Therefore,

$$\Delta y_t = \frac{\mu}{1 - \alpha_1 - \alpha_2 - \cdots - \alpha_{12}} + \sum_{j=0}^{\infty} \gamma_j s_{t-j} + \sum_{l=0}^{\infty} \theta_l \epsilon_{t-l}. \qquad (10)$$

The coefficients on s_t, $s_{t-1}, \cdots$ in equation (10) are the ratios of polynomials $\frac{B(L)}{C(L)}$. Table 4 presents the empirical results for equation (10).

3.2.3 Impulse responses

The conventional approach to illustrating a policy effect is through a set of impulse response graphs, which provide many insights in an easily readable format[9]. To demonstrate the impulse responses of bond yields to a monetary shock, the VAR framework analyzed in Christiano et al. (1996a, 1996b) and extended by Edelberg and Marshall (1996) and Evans and Marshall (1998, 2001) was estimated. Instead of using the Fed funds rate as the policy instrument, this estimate follows Romer ad Romer (2004) and Bluedorn and Bowdler (2005) in adopting the accumulated narrative shock series derived in the work of Romer and Romer (2004) to measure monetary policy. The VAR estimated herein is

$$\begin{bmatrix} a & 0 \\ c & 1 \end{bmatrix} \begin{bmatrix} Z_t \\ R_t^j \end{bmatrix} = \begin{bmatrix} A(L) & 0 \\ B(L) & C(L) \end{bmatrix} \begin{bmatrix} Z_{t-1} \\ Y_{t-1}^j \end{bmatrix} + \widetilde{\sigma} \begin{bmatrix} \epsilon_t^z \\ \gamma_t^j \end{bmatrix} \qquad (11)$$

where $A(L)$, $B(L)$, $C(L)$ are matrix polynomials in the lag operator L; 0 is the zero matrix with appropriate dimensions; a is a square matrix with ones on the diagonal and c is a row

[9] It is the structure of the VAR system that causes biased measure of shocks. The VAR system itself is still an useful statistical method for illustrating the dynamics of the policy effect.

vector. The process $\left\{ \begin{array}{cc} \epsilon_t^z & \gamma_t^j \end{array} \right\}'$ is an i.i.d. vector of mutually and serially uncorrected structural shocks whose variance is the identity matrix; and $\widetilde{\sigma}$ is a diagonal matrix. The data vector Z_t is given by

$$Z_t = (Y_t, P_t, PCOM_t, RR_t, NBRX_t)',$$

where Y_t is the logarithm of nonfarm payroll employment; P_t is the logarithm of personal consumption expenditures deflator; $PCOM_t$ is the logarithm of an index of sensitive materials prices; RR_t is the cumulated Romer and Romer (2004) shock series; and $NBRX_t$ is the logarithm of the ratio of non-borrowed reserves plus extended credit to total reserve. R_t^j is the yield vector consisting of zero coupon bond yields of different maturities. As discussed by Sims (1992), including an index of commodity price $PCOM_t$ and a $NBRX_t$ ratio in the regression will eliminate the price puzzle in which price rises in response to a contractionary monetary shock. Following this convention, 12 lagged values are included and a recursive identification strategy is assumed —namely, variables only respond contemporaneously to those placed higher in the VAR specification— in the estimation[10]. Figure 3 demonstrates the impulse responses of bond yields to a monetary shock.

In addition to examining bond yields, the current analysis runs the same equation with respect to the shape of a yield curve. Litterman and Scheinkman (1991) suggested that most of the variations in fixed-income securities can be explained in terms of three factors: level, slope, and curvature. To derive the yield factors, the definitions specified in Diebold et al. (2003) are followed: the level of the yield curve is the equally weighted average of the 3-month, 24-month, and 120-month yields; the slope is the difference between the 120-month yield and the 3-month yield; and the measure of curvature is twice the 24-month yield minus the sum of the 3-month and 120-month yields. Figure 4 presents the impulse responses of

[10]Evans and Marshall (1998) compared the effects of monetary policy on the term structure of interest rates using three alternative identification strategies and documented that no significantly different responses emerged among these different settings. The three identification strategies estimated by Evans and Marshall (1998) are: (1) a recursive strategy by Christiano, Eichenbaum, and Evans (1996a, 1996b); (2) a nonrecursive strategy by Sims and Zha (1995); and (3) a mixture of long and short term identification by Gali (1992).

bond yields to a monetary shock.

3.3 Asymmetric properties of bond reactions

Although a large body of empirical works has modeled the consequence of an exogenous monetary shock on bond yields by assuming symmetrical responses of bond yields, another strand of studies indicate that economic variables and financial assets should respond asymmetrically to unexpected macroeconomic news depending on the nature of policy actions and states of business condition[11]. For example, Jensen, Mercer, and Johnson (1996) found that security returns vary across monetary environments. Christie-David, Chaudhry, and Lindley (2003) demonstrated that debt markets respond differently with respect to different size and potential effect of an exogenous monetary shock. Anderson et al. (2002) showed that the asymmetric responses in financial markets relate to investors' price discovery process. Knif, Kolari, and Pynnönen (2008) documented that depending on the economic state, positive and negative inflation shocks can induce a variety of stock market responses; the cause for such differentiation lies in whether investors perceived a shock as good or bad news in different economic regimes.

Several reasons contribute to the observed asymmetric properties of bond reactions. First, the rigidity of financial prices can cause asymmetric responses in the bond yield upon the arrival of a shock. Literature on monetary transmission has documented that financial prices are more rigid in adjusting downward rather than upward (Lo and Piger (2003), Ball and Mankiw (1994), and Senda (2001)). Therefore, a contractionary shock should be anticipated to work differently than an expansionary shock on bond yields. Second, Bernanke and Gertler (1995) demostrated that monetary policy has a direct effect through interest rate channel as well as an indirect effect through credit channel. The changes of credit conditions contribute to the asymmetric market reactions.

[11]Related studies include Cover (1992), Garcia and Schaller (2002), Kaufmann (2002), Peersman and Smets (2001), Lo and Piger (2003), Choi (1999), Weise (1999), Jensen, Mercer, and Johnson (1996), Christie-David, Chaudhry, and Lindley (2003), Anderson et al. (2002), Knif, Kolari, and Pynnönen (2008), Wang et al. (2008), etc.

Third, the asymmetry of bond responses may stem from the changes in policy parameters. Choi (1999) demonstrated the properties of state-dependent responses of interest rates using a model economy. Fourth, from the investors' point of view, the asymmetric responses come from investors' price discovery process. As many studies[12] have suggested, the effect of a macro shock is conditional on whether investors perceive it as a good or bad news in different economic regimes. Investors' responses to macro news represent their expectations about the future course of market conditions. Bad news during economically promisinng times tends to cause greater impacts on financial assets than bad news in economically unstable times as the former indicates the possibility of an eventual economic slow down while the latter has usually been anticipated by investors.

3.3.1 The models

To capture the asymmetric responses to monetary shocks in bond yields, the analysis herein categorizes monetary shocks according to the states of shock sign, shock size, and business conditions when shocks occur. To determine whether an expansionary shock has the same impact as a contractionary shock on bond yields, the following equation is estimated:

$$y_{i,t} = \alpha + \beta_i^+ s_t^+ + \beta_i^- s_t^- + \epsilon_{i,t} \tag{12}$$

where $y_{i,t}$ is the vector for log changes of zero coupon bond yield i; s_t^+ is a vector taking on the value of the contractionary shock (positive shock) and a zero otherwise; s_t^- is a vector taking on the value of the expansionary shock (negative shock) and a zero otherwise. The sample period under study includes115 contractionary shocks and 114 expansionary shocks.

Asymmetric responses in bond yields may also come from the magnitude of a shock. In other words, a larger shock may have a stronger impact on bond yields than a smaller shock. To determine if the intensity of a shock matters, the following equation is estimated:

[12] Knif, Kolari, and Pynnönen (2008), Wang, Yang, and Simpon (2008), Andersen, Bollerslev, Diebold and Vega (2003), and etc.

$$y_{i,t} = \alpha + \beta_i^L s_t^L + \beta_i^S s_t^S + \epsilon_{i,t} \tag{13}$$

where $y_{i,t}$ is the vector for log changes of zero coupon bond yield i; s_t^L is a vector taking on the value of the large shock and a zero otherwise; s_t^S is a vector taking on the value of the small shock and a zero otherwise. A shock is considered to be a small shock if it falls in the inter quantile of the sample; otherwise, it is considered to be a large shock.

Another possible cause for asymmetric responses suggested by the literature is that a monetary shock in good times (expansionary period) may have different influences than that in a bad time (recession period). To explore if a monetary shock works differently in different states of business conditions, the following equation is estimated:

$$y_{i,t} = \alpha + \beta_i^E s_t^E + \beta_i^R s_t^R + \epsilon_{i,t} \tag{14}$$

where $y_{i,t}$ is the vector for log changes of zero coupon bond yield i; s_t^E is a vector taking on the value of the shock when the economy is in expansion and a zero otherwise; s_t^R is a vector taking on the value of the shock when the economy is in recession and a zero otherwise. Following the dates designated by the National Bureau of Economic Research (NBER), 274 observations in the sample period are considered expansion periods, while 62 occur during recession periods[13].

3.3.2 Cross asymmetries

To account for the presence of cross asymmetries, the following equations are estimated:

$$y_{i,t} = \alpha + \beta_i^{+E} s_t^+ s_t^E + +\beta_i^{+R} s_t^+ s_t^R + \beta_i^{-E} s_t^- s_t^E + \beta_i^{-R} s_t^- s_t^R + \epsilon_{i,t}, \tag{15}$$

[13]According to the dates designated by NBER, there are five peaks (Dec 1969, Nov. 1973, Jan. 1980, July 1981, July 1990, Mar. 2001) and five throughs (Nov. 1970, Mar. 1975, July 1980, Nov. 1982, Mar. 1991) over the sample period.

$$y_{i,t} = \alpha + \beta_i^{EL} s_t^E s_t^L + +\beta_i^{ES} s_t^E s_t^S + \beta_i^{RL} s_t^R s_t^L + \beta_i^{RS} s_t^R s_t^S + \epsilon_{i,t}, \tag{16}$$

and

$$y_{i,t} = \alpha + \beta_i^{+L} s_t^+ s_t^L + +\beta_i^{+S} s_t^+ s_t^S + \beta_i^{-L} s_t^- s_t^L + \beta_i^{-S} s_t^- s_t^S + \epsilon_{i,t}. \tag{17}$$

4 Empirical results

4.1 Interest rate channel of monetary effect

4.1.1 The results

With regards to bond yields, Table 3 presents the results of the Cook and Hahn-style analysis while Table 4 demonstrates the results of baseline regression combined with the interest rate smoothing feature. From Table 3, the yield on 3-month bill rises by 93 basis points in response to an exogenous one percentage point increase in the target rate, while the yield on 3-month bill rises only by 32 basis points in response to an endogenous one percentage point increase in the target rate. For all maturities, bond yields respond about 3 or 4 times stronger to the exogenous changes in the target rates than the endogenous changes in the target rates. The impacts of endogenous and exogenous changes diminish as the maturities increase. The yield on 10-year bond rises by only 15 basis points in response to an exogenous one percentage point increase in the target rate and by 6 basis points in response to an endogenous one percentage point increase in the target rate. The empirical results from table 3 support the argument that bond yields respond much stronger to an exogenous change in the target rate and the argument from Efficient Market Hypothesis (EMH).

In the baseline regression with interest rate smoothing feature, an unit of contractionary monetary shock induces an 8.88 percent increase in the log change of the three-month bond yield in the period when the shock occurs. The three-month rate continues to rise over the next month before subsequently falling. For bond yields with longer maturities, they follow the similar patterns as the three-month yield except the impacts of a shock diminish as the maturities increase. For the five-year bond, an unit of monetary shock causes 2.54 percent increase in the log change of five-year bond yield.

The impulse responses demonstrated in Figure 4 replicate the stylized facts documented in Christiano, Eichenbaum, and Evans (1996a, 1996b)[14]. With one-standard-error confidence bands, Figure 4 indicates that the output level initially rises slightly before dropping thereafter. The output returns to its original level after approximately 48 months. The price level remains around the same for 10 months before falling. NBRX, the ratio of non-borrowed reserves plus extended credit to total reserve, drops after a tightening monetary action. These responses are in line with Friedman (1961)'s arguments that monetary policy affects output and price level with a long lag and monetary policy has no long run influence on output levels (Cover (2008)). Generally speaking, a contractionary shock induces immediate positive effects on bond yields, and the intensity of such an initial impact decreases as the maturity of the bonds increases from 3-month to 10-year.

In regards to the shape of the yield curve, a monetary shock lifts the level of the yield curve and lowers the level of slope factor. The level of curvature, on the other hand, is reduced. Since a contractionary shock causes positive impacts on bonds of all maturities, as indicated earlier, it is not surprising that the level of the bond yield is raised accordingly. The drop of the slope factor represents the fact that monetary policy has a stronger influence on the near term bond yields than bonds with rear terms. This evidence also indirectly rejects the pure expectation hypothesis.

[14]Christiano, Eichenbaum, and Evans (1996a, 1996b) documented several stylized facts about monetary shocks on macro variables. First, a contractionary monetary policy should raise the level of short-term interest rate and lower the output level. Second, the price level should stay about the same for one year before falling.

4.1.2 Monetary policy and term structure dynamics

Figure 4, Figure 5, and Table 4 all support the idea that monetary policy has transitory rather than permanent effects on bond yields. A contractionary shock raises bond yields temporarily. The high levels of interest rates, then, reduce investors' future inflation expectations. After about 10 months, the bond yields overshoot to the negative side as investors have adjusted to the lower level of inflation expectations, bond yields have to be lower than their original levels.

The empirical results in this paper also support the presence of liquidity effect in which interest rates react negatively to money growth. This liquidity effect can stem from two sources. First, the asymmetric information between market participants and policy makers. Since the Federal Reserve possesses much information that is not known by the public, a contractionary shock will cause market participants to interpret it as unfavorable private information about the future course of inflation behavior. Market participants consequently adjust their expectations of inflation upward, which leads interest rates at both the short and long horizons to rise (Romer and Romer (2000), Peersman (2002)). Second, market frictions and the rigidity of price adjustment. The limited participation model suggests that an incomplete financial market prohibits agents from immediately reacting to a shock. The precommitments made by households and firms to banks impose costs for immediate response. Therefore, the liquidity effect exists. The persistence of the liquidity effect, thus, depends on how soon households and firms can price the monetary news into their assets. Once the news has been fully digested into the price, the liquidity effect disappears [15].

If the narrative shocks derived by Romer and Romer (2004) are relatively free of anticipatory and endogenous movement compared to previous estimation methods, narrative shocks should cause stronger and longer effects not only on output and price levels as the Romers claimed in their original studies, but also on the term structure of interest rates.

[15] See Lucas (1990), Fuerst (1992), Christiano, Eichenbaum, and Evans (1996), and Einarsson and Marquis (2002).

Figure 6 plots the shocks derived from the VAR and Romer and Romer (2004) frameworks. Figure 7 shows the impulse responses on bond yields using VAR shocks. Table 9 presents the statistics for both narrative and VAR shocks.

Empirical evidence suggests that a VAR shock increases the 3-month rate by 25 basis points in the period when the shock occurs. The influence of a VAR shock decreases as maturities increase. For the 10-year rate, a VAR shock causes only a 6 basis points increase. The impacts of a VAR shock drop to around zero in five months. On the other hand, a narrative shock induces a 20 basis points increase in the 3-month rate in the period when the shock occurs. Although the initial impact of a narrative shock on bond yields is slightly smaller than a VAR shock, the impacts of a narrative shock remain positive for one year. For longer maturities bonds, the impacts of a narrative shock remain positive for about 16 months. The persistent impacts of a narrative shock imply that monetary effect can cause longer influences on bond yields than previously thought. In other words, VAR shocks may still contain some anticipatory and endogenous policy movements which have led to underestimates of monetary effect. (Romer and Romer (2004))

4.2 The asymmetric properties of bond reactions

Many monetary economists agree that interest rate channel is not the only way that monetary policy affects the economy. Recent literature has focused on the credit channel of monetary transmission (Walsh (2003)). Market frictions such as information asymmetries and contract enforcement problems cause the imperfect credit market. Therefore, a wedge exists between the cost of internal and external financing. This wedge is called the external finance premium. A recession or a negative demand shock that worsens borrowers' balance sheet strength makes it diffiuclt for borrowers to raise capital internally. However, the cost of external financing tends to increase under this circumstance as the balance sheet strength is an important indicator for lenders to evaluate borrowers' default risks. Therefore, the external finance premium moves in the inverse direction to the balance sheet strength and is expected to be larger in recession than in expansion periods. The amplification of initial shock due to the change of market credit conditions is refer to as the mechanism of financial accelerator (Bernanke and Gertler (1995), Bernake et al. (1996), Mody and Taylor (2004), Fidrmuc et al. (2008)). As predicted by the credit channel of monetary transmission, Table 5 shows that the responses of bond yields depend on the prevailing market conditions: a shock in the recession causes a greater influence on bond yields than a shock in the expansion. For all maturities, a negative (expansionary) shock has a stronger effect than a positive (contractionary) shock. Regarding to the size of the shock, a larger shock has a greater influence on the bond yield than a smaller shock, ceteris paribus. Table 6, Table 7, and Table 8 demonstrate the estimations for cross asymmetries. Of twelve states examined, a negative shock in the expansion period shows the strongest effect on the short term bond yields, which confirms the fact that bad news in good time causes the greatest impacts on financail assets as investors perceive this information as the indicator of future economic slow down.

5 Conclusions

Estimating the effect of monetary policy has been a core issue in monetary economics. Central bankers are interested in this topic because they need to know how a change in policy rates will transmit to the economy. Market participants, on the other hand, are also looking for a way to evaluate a given policy action in order to price financial assets accurately.

However, a change in policy rates represents both monetary authorities' responses to future economic developments and the shocks that the authorities want to create. The countercyclical reactions tend to cause estimation errors. Monetary shocks, on the other hand, have no correlation to current and future events; their effects on macro variables or financial markets are not contaminated by any countercyclical action. Therefore, monetary shocks are the perfect candidates for analyzing policy effect. The conventional approach for solving this endogenous problem has been to adopt a VAR model or an event study to extract the exogenous shocks. Unfortunately, these approaches have suffered from severe criticisms due to its data, structure, and assumptions weaknesses.

In response to the obstacles previous models face, Romer and Romer (2004) proposed a new measure called the narrative approach. The basic idea of the narrative approach is to use authorities' internal forecastings and operating records, combined with statistical analyses, to remove the endogenous monetary actions from a policy rate change. The residuals of this estimation are the monetary actions not made in response to future economic developments. That is, monetary shocks. Romer and Romer (2004) 's method offers several advantages over conventional techniques. The adoption of authorities' internal records in extracting policy shocks is an innovative approach in the sense that it considers all real time information up to dates before each FOMC meeting, thereby providing the maximum data available for forecasts. Meanwhile, the narrative approach to analyzing policy actions is also relatively free from the biases caused by the change of policy regimes over time. Since this narrative approach to shock derivation is new to the literature, the approach is expected to shed new insights on our current understanding of monetary effects.

Adopting the narrative shocks derived in Romer and Romer (2004), this study confirms the stylized effects found in previous studies that monetary policy affects output and price level with a long lag and output eventually returns to its original level. With regards to the bond yields, the empirical results illustrate several important messages : (1) an exogenous monetary shock has a stronger impact on the bond yields that an endogenous monetary movement; (2) although monetary effect is transitory, its influences on bond yields can last for at least one year; (3) narrative shocks have longer influences on the bond yields than shocks identified from the VAR structure, indicating the possible under-estimation of policy effect ; and (4) monetary effects are subjected to the state of business conditions and the nature of policy action. Therefore, when an economy is in a recession, likes the current state of the economy, monetary authorities have their best shot of generating the maximum influences on the economy given that the external finance premium has been enlarged to its greatest extent. A large, neagative (expansionary), exogenous shock, according to the emprical results in this research, is the best strategy to implement.

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Figure 1: Effective Fed funds rate and Fed funds target rate for 1988-2008.

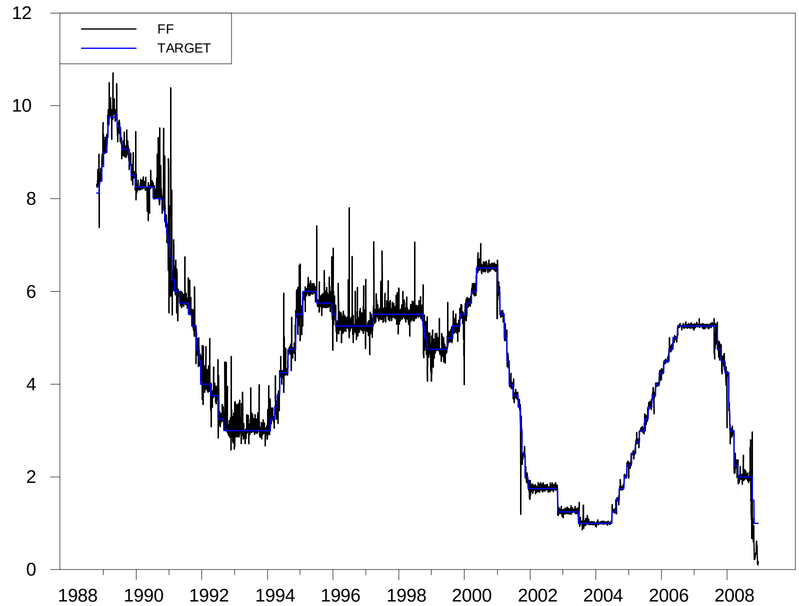

Figure 2: Long-term bond yields, short-term bond yields, and yield spread.

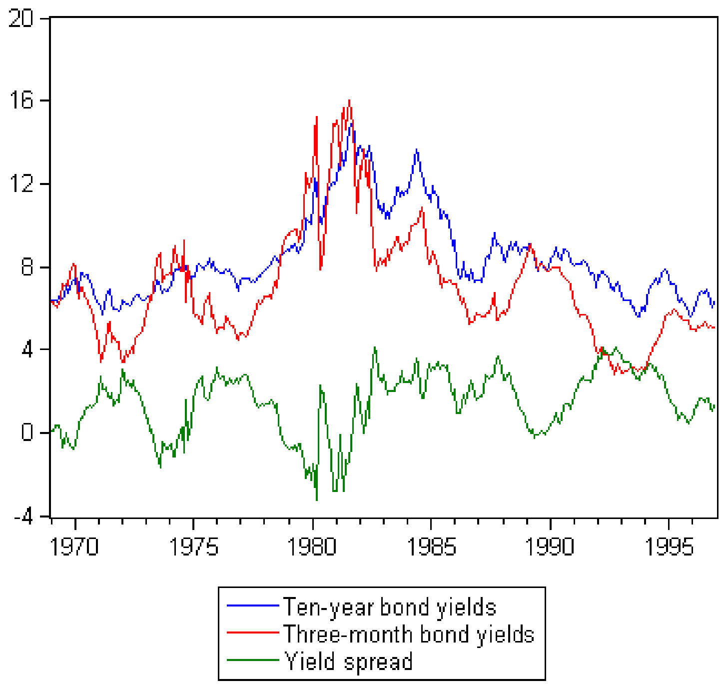

Figure 3: The total change in the target rate and the unexpected change in the target rate. (DFF stands for the change in the Fed funds target rate and Shock represnts for the unanticipated (exogenous) component of the change of the Fed funds target rate.)

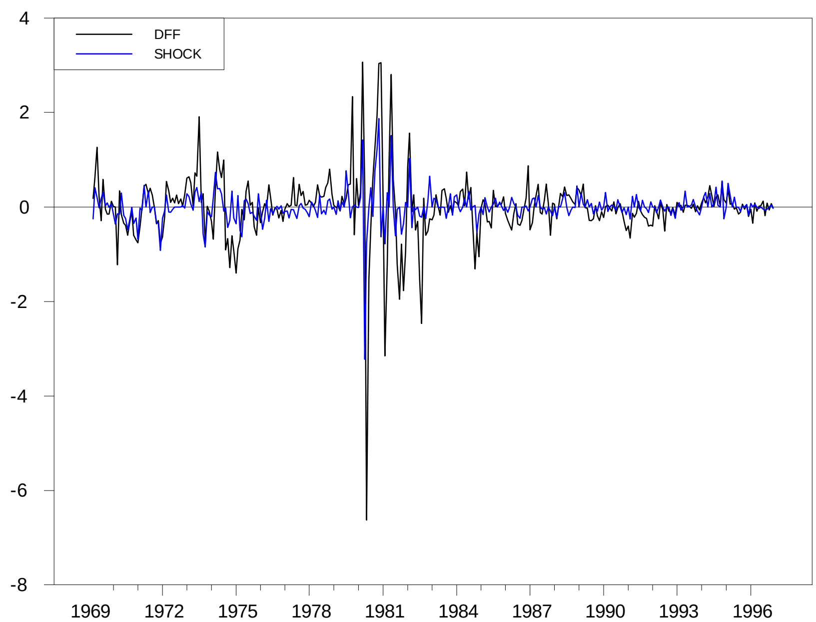

Figure 4: Impulse responses of narrative shocks on the nominal bond yields.

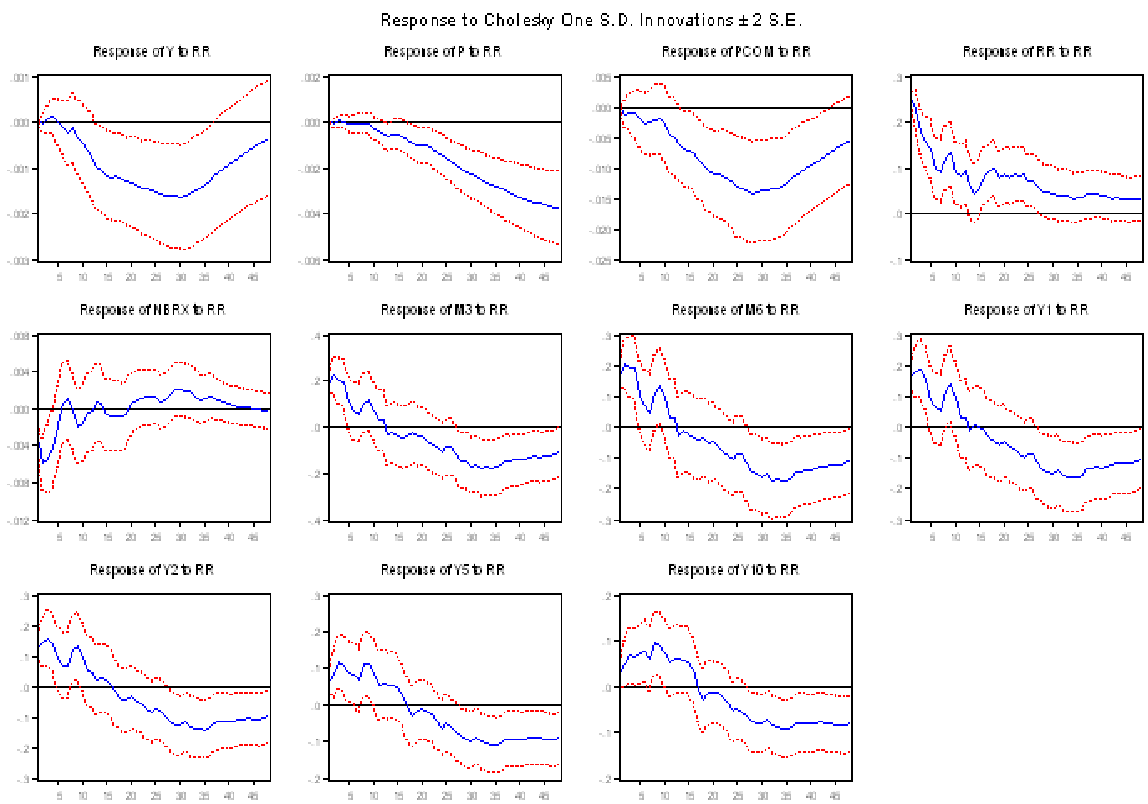

Figure 5: Impulse responses of yield factors.

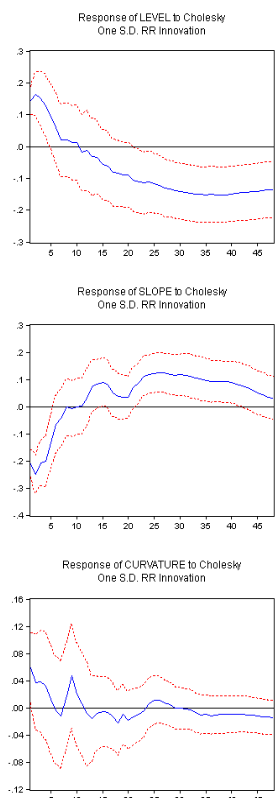

Figure 6: VAR shocks and RR narrative shocks.

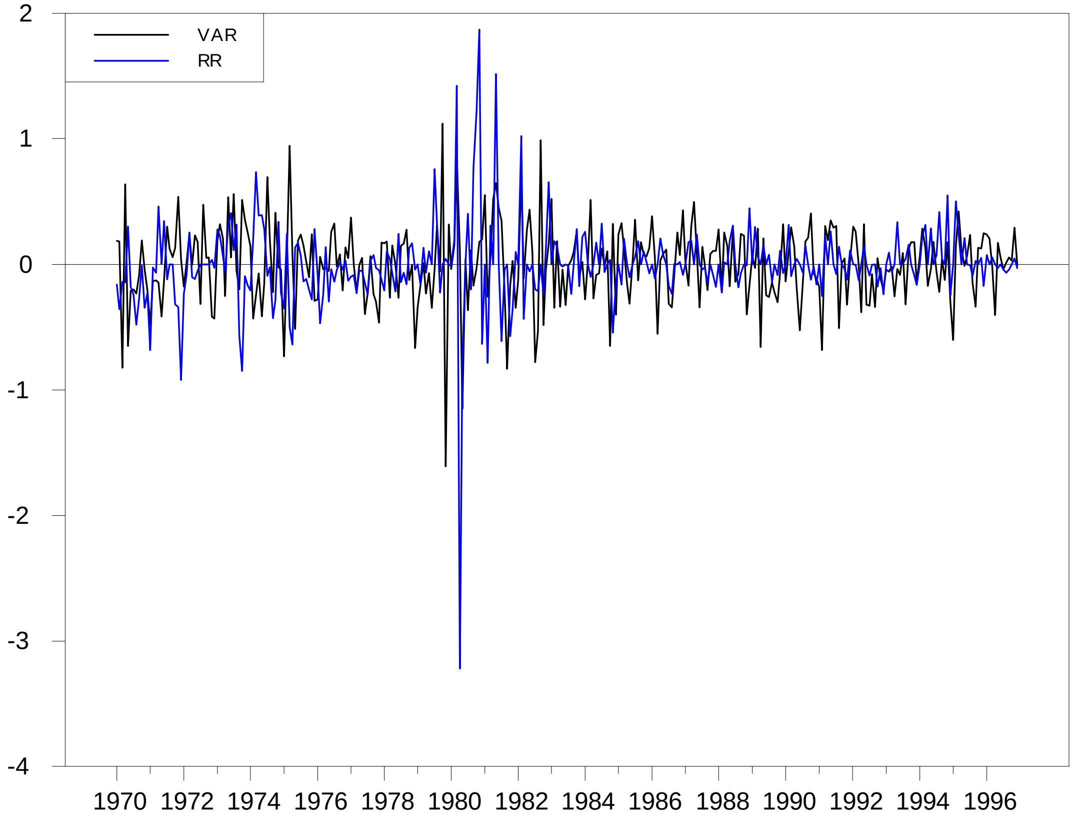

Table 1: Unit Root Tests

Variable	ADF	PP
Δm3	-16.22	-16.13
Δm6	-15.58	-15.43
Δy1	-15.49	-15.33
Δy2	-13.78	-15.28
Δy5	-16.29	-16.19
Δy10	-16.38	-16.31

*ADF and PP are Augmented Dickey-Fuller and Phillips-Perron test statistics, respectively.
**The null hypothesis is the series has a unit root. The critical values for ADF tests are -3.44967 for 1%, -2.86995 for 5%, and -2.57132 for 10%.

Table 2: Summary Statistics of Data

	3-Month	6-Month	1-Year	2-Year	5-Year	10-Year
Mean	6.9831	7.2427	7.4836	7.7748	8.1713	8.4351
Max	15.9990	16.5110	16.3450	16.1450	15.6960	15.0650
Min	2.7800	2.8780	3.0900	3.8030	4.8130	5.6150
Std. Dev.	2.7185	2.7328	2.6629	2.4930	2.2590	2.0898

Table 3: The responses of bond yields to expected and unexpected target rate changes.

Maturity	Intercept	Response to target change: Endogenous	Response to target change: Exogenous	R^2	SE	DW
3-month	-0.0021	0.3290	0.9391	0.3268	0.5410	2.4156
	(-0.0723)	(7.2538)	(10.6498)			
6-month	-0.0023	0.3099	0.9315	0.3178	0.5395	2.2720
	(-0.0780)	(6.8532)	(10.5923)			
1-year	-0.0017	0.2425	0.8252	0.2510	0.5454	2.1384
	(-0.0599)	(5.3044)	(9.2823)			
2-year	-0.0009	0.1603	0.6087	0.1629	0.5155	2.0152
	(-0.0337)	(3.7109)	(7.2439)			
5-year	-0.0001	0.0971	0.2719	0.0595	0.4365	1.9750
	(-0.0050)	(2.6546)	(3.8224)			
10-year	0.0002	0.0650	0.1552	0.0326	0.3610	1.9113
	(0.0106)	(2.1494)	(2.6380)			

Notes: Parentheses contain t-statistics.

Table 4: Baseline regression with interest rate smoothing feature.

$$\Delta y_t = \mu + \sum_{j=0}^{12} \alpha_j \triangle y_{t-j} + \sum_{j=0}^{12} \beta_j s_{t-j} + \epsilon_t$$

Shock Lag	3-Month	6-Month	1-Year	2-Year	5-Year	10-Year
0	0.0888	0.0798	0.07375	0.0532	0.0254	0.0128
1	0.02984	0.0290	0.02536	0.0201	0.0137	0.0088
2	-0.0026	0.0018	0.00239	0.0043	0.0049	0.0017
3	-0.0072	-0.0082	-0.01406	-0.0146	-0.0098	-0.0063
4	-0.0188	-0.0167	-0.01396	-0.0073	-0.0026	0.0055
5	5.36274e-04	0.0024	0.00429	0.0043	0.0037	3.27962e-04
6	-0.0133	-0.0155	-0.01569	-0.0130	-0.0137	-0.0096
7	-0.0090	-0.0044	-0.00110	0.0027	0.0069	0.0046
8	-0.0180	-0.0169	-0.01324	-0.0090	-0.0049	-0.0031
9	-0.0017	0.0032	-6.60102e-04	3.32281e-04	0.0011	0.0028
10	-0.0229	-0.0296	-0.02353	-0.0150	-0.0086	-0.0046
11	-0.0042	-0.0045	-0.00276	3.83478e-04	0.0046	0.0069
12	-0.0249	-0.0209	-0.01423	-0.0107	-0.0076	-0.0050

Table 5: Asymmetric responses to monetary shocks

	Shock direction		Shock size		Shock in business cycle	
	Positive	Negative	Large	Small	Expansion	Recession
3-Month	0.0596	0.1190	0.0921	0.0444	0.0710	0.1123
	(0.0182)***	(0.0170)***	(0.0117)***	0.0767	(0.0159)***	(0.0164)***
6-Month	0.0555	0.1130	0.0873	0.0259	0.0550	0.1187
	(0.0174)***	(0.0163)***	(0.0113)***	(0.0739)	(0.0151)***	(0.0156)***
1-Year	0.0508	0.1037	0.0812	-0.0213	0.0533	0.1058
	(0.0172)***	(0.0161)***	(0.0114)***	(0.0742)	(0.0150)***	(0.0155)***
2-Year	0.0353	0.0810	0.0617	-0.0330	0.0352	0.0852
	(0.0159)**	(0.0149)***	(0.0104)***	(0.0678)	(0.0138)**	(0.0143)***
5-Year	0.0130	0.0416	0.0296	-0.0321	0.0087	0.0489
	(0.0129)	(0.0121)***	(0.0082)***	(0.0538)	(0.0112)	(0.0116)***
10-Year	0.0018	0.0270	0.0161	-0.0242	-0.0027	0.0343
	(0.0104)	(0.0097)***	(0.0065)**	0.0426	(0.0090)	(0.0093)***

***,**,* stand for statistical significance at 1%, 5%, and 10% level, respectively. Parentheses contain stand errors. The equations are estimated using seemingly unrelated regressions.

Table 6: Asymmetric responses to monetary shocks

	Positive x Expansion	Positive x Recession	Negative x Expansion	Negative x Recession
3-Month	0.0440(0.0159)***	0.0320(0.0308)	-0.1153(0.0469)**	-0.0373(0.0069)***
6-Month	0.0357(0.0152)**	0.0448(0.0294)	-0.0779(0.0448)*	-0.0381(0.0066)***
1-Year	0.0318(0.0150)**	0.0279(0.0290)	-0.0937(0.0442)**	-0.0344(0.0065)***
2-Year	0.0230(0.0136)*	0.0092(0.0264)	-0.0420(0.0403)	-0.0303(0.0059)***
5-Year	0.0070(0.0110)	-0.0046(0.0213)	0.0006(0.0324)	-0.0173(0.0048)***
10-Year	-0.0002(0.0088)	-0.0015(0.0170)	0.0186(0.0260)	-0.0117(0.0038)***

***,**,* stand for statistical significance at 1%, 5%, and 10% level, respectively.
The equations are estimated using seemingly unrelated regressions.

Table 7: Asymmetric responses to monetary shocks

	Positive x Large	Positive x Small	Negative x Large	Negative x Small
3-Month	0.0405(0.0148)***	0.5239(1.0885)	-0.0393(0.0071)***	-0.3944(1.0160)
6-Month	0.0359(0.0141)***	0.1323(1.0426)	-0.0394(0.0068)***	-0.3385(0.9732)
1-Year	0.0287(0.0142)**	-0.6207(1.0465)	-0.0364(0.0068)***	-0.2946(0.9769)
2-Year	0.0173(0.0127)	-0.9323(0.9378)	-0.0314(0.0061)***	-0.3132(0.8754)
5-Year	0.0023(0.0100)	-0.5893(0.7363)	-0.0176(0.0048)***	-0.0020(0.6873)
10-Year	-0.0021(0.0079)	-0.4081(0.5809)	-0.0114(0.0037)***	0.0074(0.5422)

***,**,* stand for statistical significance at 1%, 5%, and 10% level, respectively.
The equations are estimated using seemingly unrelated regressions.

Table 8: Asymmetric responses to monetary shocks

	Expansion x Large	Expansion x Small	Recession x Large	Recession x Small
3-Month	0.0259(0.0162)	-0.1135(0.8839)	-0.0342(0.0071)***	0.4903(1.7123)
6-Month	0.0214(0.0155)	-0.4350(0.8450)	-0.0345(0.0068)***	1.1009(1.6368)
1-Year	0.0153(0.0155)	-0.8478(0.8427)	-0.0321(0.0068)***	1.1860(1.6324)
2-Year	0.0126(0.0137)	-0.9575(0.7479)	-0.0292(0.0060)***	1.0589(1.4487)
5-Year	0.0037(0.0106)	-0.6408(0.5810)	-0.0173(0.0047)***	1.5104(1.1255)
10-Year	-0.0001(0.0083)	-0.6689(0.4532)	-0.0116(0.0036)***	2.1009(0.8780)**

***,**,* stand for statistical significance at 1%, 5%, and 10% level, respectively.
The equations are estimated using seemingly unrelated regressions.

Table 9: Statistics for VAR shocks and narrative (RR) shocks.

	RR shock	VAR shock
Variance	0.1156	0.0995
Stand error	0.3400	0.3155
Skewness	-1.5237	-0.3935
Kurtosis (excess)	29.3812	2.8015
Minimum Value	-3.2208 (1980:04)	-1.6057 (1979:11)
Maximum Value	1.8714 (1980:11)	1.1217 (1979:10)

Figure 7: Impulse responses of VAR shocks on nominal bond yields.