The Changing Transmission Mechanism of U.S. Monetary Policy[*]

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May 12, 2009

ABSTRACT: In this paper, we examine the relative importance of the money and credit channels for the transmission mechanism of monetary policy in the United States. A key aspect of our analysis is the use of short-run sign restrictions, rather than less plausible zero restrictions, to identify monetary policy shocks. Given the policy shocks, we quantify the relative importance of transmission channels via counterfactual analysis. While the overall findings are consistent with a nontrivial role for the credit channel, we find that its importance has diminished greatly since the early 1980s. Interestingly, however, there does not appear to be any link between changes in the transmission mechanism and the observed volatility reduction in output that occurred around the same time.

Keywords: Transmission Mechanism, Money Channel, Credit Channel, Monetary Policy Shock Identification, Volatility Reduction
JEL Classification: C32; E52

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I. Introduction

This paper examines the relative importance of the money and credit channels for the transmission mechanism of U.S. monetary policy. There is much agreement on the view that monetary policy has a significant influence on the real economy. Among the many empirical studies demonstrating that monetary policy affects output are Bernanke and Blinder (1992), Christiano and Eichenbaum (1995), Christiano, Eichenbaum and Evans (1996), Leeper, Sims and Zha (1996), Kim (1999) and Uhlig (2005). While there has been general acceptance among economists about the role of monetary policy in influencing output, there is no consensus on the transmission channels of the policy, i.e. the process through which monetary policy decisions affect the real economy.

Taylor (1995) classified different theories of the transmission mechanism into two broad categories. The financial market price view, also known as the “money” view, which primarily consists of the interest rate and exchange rate channels, stresses the impact of monetary policy on prices and rates of return of financial assets and thereby on the spending decisions by firms and households. Alternatively, the “credit” view emphasizes the balance sheet and bank-lending channels, which are also hypothesized to affect spending behavior. The existence of these credit channels is contingent on assumptions about the size and nature of capital market imperfections.[1] Thus far, results from studies that compare the importance of these channels have been mixed. For example, Bernanke and Gertler (1995) provide some illustrative evidence of a direct link between the credit channels and monetary policy shocks. However, Romer and Romer (1990) and Ramey (1993), find that the credit channels play an insignificant role in transmitting monetary policy shocks.

In this paper, we employ a novel approach to monetary policy shock identification in order to examine the relative importance of the different channels associated with the money and credit views of the monetary transmission mechanism. This approach applies

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[1] The balance sheet channel operates through the net worth of business firms and arises from the problems of adverse selection and moral hazard (Mishkin, 1995). The bank-lending channel emphasizes the role of banks in determining the supply of loans in an environment where information is not symmetric (this channel is discussed in detail in the next section).

standard vector autoregression (VAR) techniques to estimate a reduced-form forecasting model of the macroeconomy and to obtain orthogonal shocks. However, unlike most other VAR studies, we follow Canova and De Nicolo (2002) by exploiting sign restrictions based on theory to identify the underlying structural shocks. Importantly, identification is achieved without imposing zero constraints on impact responses of variables to structural shocks. Furthermore, since all of the sign restrictions are explicitly stated in the model, there is no circularity between identification and inference. Given the identified monetary policy shocks, we employ counterfactual analysis to quantify the relative importance of different channels. In particular, we consider constrained versions of the VAR model in which the transmission channel variable under examination is held constant. Comparisons of the responses of output with respect to monetary shocks between the benchmark and the constrained models provide a measure of relative importance of a given channel.

Using the bank-lending channel to represent the credit view and the interest rate channel to represent the financial market price view, we find interesting differences between the transmission channels. Results for U.S. data from the 1960s and 1970s indicate that the credit channel played a more important role than the money channel. However, during the 1980s and 1990s, the credit channel appears to have played a greatly diminished role in transmitting monetary shocks. During this latter period, the money channel exerted a greater influence in propagating monetary policy innovations.

We explore possible connections between changes in the transmission mechanism and the recent moderation of the U.S. business cycle that has been documented in numerous studies. For example, Boivin and Giannoni (2006) show that from the 1960s and 1970s to the 1980s and 1990s, the standard deviation of output growth has fallen 30% while that of inflation has decreased more than 40%. Many other studies, including Niemira and Klein (1994), Kim and Nelson (1999) and McConnell and Perez-Quiros (2000), document a similar reduction in macroeconomic volatility for similar time periods. These changes raise several important questions for policymakers, but most important is the question of the source of the moderation. Specifically, is the volatility reduction due to smaller and less frequent shocks in the economy or to changes in the propagation of these shocks that make output and inflation less responsive to disturbances? Clearly, changes in the transmission mechanism of monetary policy could play a role in altering the propagation mechanism in the economy. We proceed by conducting additional counterfactual experiments in the spirit of Stock and Watson (2002), Ahmed, Levin, and Wilson (2004), Boivin and Giannoni (2006), and Kim, Morley, and Piger (2008). Interestingly, from these experiments, we do not find a strong connection between changes in the nature of the transmission mechanism of monetary policy and the observed reduction in volatility of output for the past two decades. However, changes in the dynamics of the shocks do exert some influence in stabilizing inflation.

The rest of the paper is organized as follows. Section II provides a more detailed discussion of the different views of the monetary transmission mechanism. Section III presents the details of our approach to identifying monetary policy shocks and the quantification of the relative importance of different transmission channels. Section IV reports the empirical results. Section V examines the relationship between changes in the monetary transmission mechanism and the moderation of macroeconomic volatility since the 1980s. Section VI concludes.

II. Theoretical Framework of the Monetary Transmission Channels

In this section, we discuss in greater detail the money and credit views of the monetary transmission mechanism that provide the basis for our empirical analysis. We begin with the money view, focusing on the interest rate and exchange rate channels, and then proceed to the credit view, in particular outlining the bank-lending channel. For a comprehensive discussion of the monetary transmission mechanism, see Mishkin (1995).

Money View

Taylor's (1995) broader classification of the financial market price view mentioned in the introduction originates from the argument advocated by what is traditionally known in the literature as the "money view". The money view emphasizes the role of monetary aggregates and operates via the interest rate channel. The theory underpinning the money view relies on a two-asset model with money and bonds as imperfect substitutes in portfolios. The interest rate adjusts to give equilibrium in the asset market as widely illustrated in the literature by applying the IS–LM framework (Bernanke and Blinder, 1988). Given rational expectations and sticky prices, a contractionary monetary policy shock leads to an increase in long-term real interest rates, which increases the cost of capital, thereby causing a reduction in investment, leading to a contraction in aggregate demand and a decline in output. In addition to affecting businesses' decisions about investment, the interest rate channel is also recognized to affect consumers' decisions about spending on housing and consumer durables.

The exchange rate also potentially affects monetary transmission because of its effect on net exports. With a flexible exchange rate regime, an appreciation of the country's exchange rate will lead to the decline in exports and an increase in imports. A contractionary monetary policy shock raises the domestic real interest rate. Based on the traditional Mundell-Fleming framework, the interest rate effect on the exchange rate is determined by the movement in the flows of capital. Following the assumption of perfect capital mobility, a higher interest rate induces an inflow of capital into the country, leading to an appreciation in the value of the domestic currency relative to the other currency. The higher value of the domestic currency makes domestic goods more expensive than foreign goods. Export volume decreases due to the deterioration in the country's competitiveness in the world market while imports increase as a result of expenditure switching by residents in favor of foreign goods, thereby causing a fall in net exports. This generates a reduction in aggregate demand and output.

Credit View

The credit view emphasizes how imperfect information and other "frictions" in the credit market work as an important channel of monetary policy. Bernanke and Gertler (1995) argue that, because of information asymmetry in the credit market and costly enforcement, agency problems arise in the financial market and create an "external finance premium". The external finance premium is defined as the difference in cost between funds raised externally (by issuing equity or debt) and the opportunity cost of funds generated internally (by retaining earnings). They postulate that monetary policy shocks change the external finance premium faced by borrowers. Consequently, this channel magnifies the effect of monetary policy on real spending.

The bank-lending channel is one specific mechanism in the credit view. According to Bernanke and Gertler (1995), the bank-lending channel operates on the premise that bank loans are of special importance, particularly for small firms that rely on bank loans as their main source of financing. The change in monetary policy then affects the external finance premium through shifts in the supply of intermediated credit, particularly the quantity of loans supplied by banking institutions to the credit markets. The critical part of this argument is the presumption that monetary policy significantly affects the supply of bank loans (i.e. the assets side of the banks' balance sheet). The Bernanke and Blinder (1988) model of the bank-lending channel suggests that when monetary policy is tightened, the central bank drains reserves and hence deposits from the banking system.[2] This in turn limits the supply of bank loans by reducing banks' access to loanable funds.[3] This is the key difference in the theoretical foundation between the credit and money views. According to the proponents of the credit view, the use of a two-asset model (i.e., either money or bonds) in the analysis of the money view is too simplistic. Bank loans differ from bonds, and as such are not a perfect substitute of each other. Thus, proponents of the credit view extend the basic IS-LM framework into a three-asset model, namely into money, bonds and loans. See Bernanke and Blinder (1988) for further discussion of the extended IS-LM model.

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[2] Contraction of bank loans reduces spending of firms and households that depend on bank loans. Capital market imperfections imply that some, perhaps most, agents cannot directly issue securities in imperfect capital markets. These agents depend on intermediated credit for external finance. See Fazzari, Hubbard and Petersen (1988).

[3] Bernanke and Gertler (1995) discuss extensively the justification for why banks cannot easily replace the lost deposits with other source of funds. In contrast, Kashyap and Stein (1994) showed that it is sufficient to argue that banks do not face a perfectly elastic demand for their open-market liabilities and hence, central bank operations that shrink their core deposit base will force them to rely more on managed liabilities and also increases their cost of funds. The latter will shift the supply of loans inward, and in turn will negatively affect bank-dependent borrowers and raise the external finance premium.

III. Specification and Estimation of the Model

Studies of monetary policy transmission have relied heavily on the identification of monetary policy shocks. The justification for studying the shocks rather than the actual actions of monetary authorities is because policy actions reflect, in part, responses to non-monetary developments in the economy. That is, a given policy action and the economic events that follow it reflect the effects of all shocks to the economy (Christiano, Eichenbaum and Evans, 1999). However, in understanding the influence of monetary policy, we are interested in the impact of a change in monetary policy given all other shocks to the economy. It is, therefore, important to consider the extent to which a policy action is an unexpected exogenous shock or whether it is part of an explicit or implicit policy rule whereby the monetary authorities systematically respond to evolving economic conditions.

There are numerous techniques used to identify monetary policy shocks, including many that make use of VAR models. The attractiveness of a VAR approach stems primarily from its simplicity in implementation and the need to impose fewer restrictions to achieve parameter identification than often used in the large-scale simultaneous equation macro-econometric models that have been considered in the past. In particular, the VAR approach can be used to isolate policy disturbances affecting the economy without imposing much structure on the economy's dynamics. However, the residuals from a reduced-form forecasting VAR model do not, in general, correspond to shocks with a structural interpretation. To isolate the structural shocks that drive the business cycle, and to ensure that these shocks have the desired structural interpretation, we need to make some additional assumptions. This section briefly outlines the issues surrounding structural identification that have consumed much of the debate in the VAR literature and it presents the particular approach used in this paper.

The Model

A VAR model attempts to explain a set of variables in terms of the lags of all of the variables under consideration. For the specific case of the monetary transmission mechanism, suppose that y_t is an $n \times 1$ vector of economic variables observed at time t. A typical VAR system in the monetary transmission literature consists of variables that represent (i) immediate target or policy instrument; (ii) intermediate targets, i.e. transmission channels; and (iii) final targets such as output and price. It is hypothesized that the behavior of the variables in vector y_t is governed by the following model:

$$B_{(nxn)}\, y_{t\ (nx1)} = \Gamma_{o\ (nx1)} + \Gamma_{1\ (nxn)}\, y_{t-1\ (nx1)} + \ldots .. + \Gamma_{p(nxn)}\, y_{t-p\ (nx1)} + \varepsilon_{t\ (nx1)} \quad \varepsilon_{t} \sim iid(0,D) \qquad (1)$$

where B is an nxn matrix of coefficients with the diagonals normalized to unity and ε_t is a vector of serially uncorrelated disturbances with its variance covariance matrix, $E(\varepsilon_t \varepsilon_t^{'}) = D$, a diagonal matrix with positive elements on the diagonal.

A reduced form version of the model in equation (1) can be written as follows:

$$y_t = c + \Phi_1 y_{t-1} + \ldots .. + \Phi_p y_{t-p} + e_t \quad e_{t} \sim iid(0, \Omega) \qquad (2)$$

where $c = B^{-1}\Gamma_o$; $\Phi_k = B^{-1}\Gamma_k$, k=1,…,p; and $e_t = B^{-1}\varepsilon_t$ is a vector of serially uncorrelated residuals with variance covariance matrix, $\Omega = B^{-1}DB^{-1}$. The vector MA representation of the system will be following form:

$$y_t = \mu + \Psi(L)\, e_t \qquad (3)$$

where $e_t = B^{-1}\varepsilon_t$ and $\Psi(L) = I + \Psi_1 L + \Psi_2 L^2 + \ldots$; thus, $\Psi(L) = (I - \Phi_1 L - \ldots . - \Phi_p L^p)^{-1}$. Rewriting the vector MA yields:

$$y_t = \mu + \Psi(L)\, B^{-1}\varepsilon_t = \mu + \theta\,(L)\,\varepsilon_t$$

where $\theta(L) = \Psi(L)\, B^{-1} = B^{-1} + \Psi_1\, B^{-1}L + \Psi_2\, B^{-1}L^2 + \ldots .$; or $\theta_i = \Psi_i\, B^{-1}$, with $\Psi_0 = I$.

The objective of the VAR model is to study the impact of changes in the elements of the vector of innovations ε_t on all the variables in the system. The impulse-response function summarizes the impact of a shock to the orthogonal component of each variable under consideration on all other variables of the system, including itself, over a specified period of time. Thus, for the analysis of monetary policy, the impulse response function captures the essence of the transmission of monetary policy shocks across the economy.

Identification of Monetary Policy Shocks

Upon estimating the reduced-form model, the challenge is to obtain the orthogonal disturbances. The estimated reduced form model does not allow us to directly compute and examine the contribution of different sources of the shocks to each of the variables. The approach used to obtain these shocks or, more technically, to derive the orthogonal decomposition of the vector e_t is a crucial aspect of the VAR methodology. The most common approach used to achieve the orthogonalization of e_t in VAR analysis is based on the Cholesky decomposition. In essence, this approach assumes that the vector B (recall $e_t=B^{-1}\varepsilon_t$) is a lower triangular matrix, thus imposing a strictly recursive contemporaneous structure on the system. This entails placing the variables under consideration in a particular order where any innovation to the first variable (such as the monetary policy variable) is assumed contemporaneously unaffected by the innovation to any of the other variables. It follows that the innovation to the second ordered variable is assumed to be affected contemporaneously only by the innovation to the first ordered variable, and so on (Hamilton, 1994). The results of approach will, therefore, be dependent on the choice of the ordering of the variables that, in turn, may not have any theoretical foundation.

Other approaches used to obtain orthogonal decomposition of vector e_t are (i) restrictions of the form that some variables cannot contemporaneously affect each other (through restrictions on B), commonly termed as the Bernanke-Blinder restrictions, (ii) imposition of some long-run a priori theoretical restrictions (Blanchard and Quah, 1989), and (iii) some combination of these identification schemes, for example by restricting elements of the covariance matrix to be of certain values using what are called "informal restrictions on the reasonableness of the impulse response functions." Christiano, Eichenbaum and Evans (1999) present a survey of the various studies.

One crucial question remains: how do we select between competing identifying assumptions? The selection scheme suggested by Christiano, Eichenbaum and Evans (1999) is to eliminate a policy shock measure if it implies a set of impulse response functions that is inconsistent with any element in the set of monetary models that we wish to discriminate between. Implicitly, this amounts to imposing a set of sign and shape restriction on impulse response functions. Canova and De Nicolo (1998), Faust (1998) and Uhlig (2005) make formal arguments along these lines. In the spirit of these papers, Canova and De Nicolo (2002) provide a practical alternative to the identification approaches above. This method first involves extracting orthogonal innovations from the reduced-form model. These innovations have, in principle, no economic interpretation but they have the property of being contemporaneously and serially uncorrelated. Second, they employ the signs of the theoretical co-movements of selected variables in response to an orthogonal innovation based on macroeconomic theory to study the information content of and assign a structural interpretation to the VAR disturbances. There are several reasons why this method is more attractive relative to competing ones. First, this procedure clearly separates the statistical problem of orthogonalizing the covariance matrix of reduced-form shocks from issues concerning the identification of structural disturbances. Second, unlike many other structural VAR approaches, it achieves identification without having to impose the zero constraints on impact responses.[4] Third, because all of the constraints are explicitly stated in the model, there is no circularity between identification and inference. Finally, the approach does not restrict our focus to only monetary disturbances, but it also enables us to identify other types of structural shocks in the system. By contrast, the standard practice in the VAR literature is to identify only the dynamic response to a shock of a particular interest, namely the monetary policy shock, leaving the causal structure of the rest of the system without interpretation (Faust and Rogers, 2003).

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[4] Faust (1998) provides anecdotal and quantitative examples of the danger in restricting contemporaneous interactions among variables.

To obtain the structural shocks after estimating our reduced-form VAR model, we follow the approach developed in Canova and De Nicolo (2002). From equation (3), an orthogonal decomposition of a Wold MA representation with contemporaneously uncorrelated shocks featuring unit variance will have the following form:

$$y_t = \mu + C(L)\,u_t \qquad u_t \sim iid(0, I) \tag{4}$$

where $C(L) = \Psi(L)V$, $u_t = V^{-1} e_t$ and $\Omega = VV'$. It follows that for any orthonormal matrix Q, $QQ' = I$. Thus, $\Omega = VV' = VQQ'V'$ is an admissible decomposition of Ω. This will yield an infinite number of candidates for the decomposition of Ω. One example of an orthogonal decomposition is the Cholesky factorization. Another would be the eigenvalue-eigenvector decomposition, i.e. $\Omega = PDP' = VV'$ where P is a matrix of eigenvectors, D is a diagonal matrix with eigenvalues on the main diagonal and $V = PD^{1/2}$. The impulse response of each variable to any orthogonal shock, α, is therefore given by the coefficients of the vector of lag polynomials $C(L)\alpha$ where $\alpha'\alpha = 1$.

The challenge here is twofold. One is to transform the matrix Ω into candidates of orthogonal eigenvalue-eigenvector decompositions, V. Second is to search in the space of V for a particular orthogonal decomposition of Ω that satisfies a set of criteria. Following Canova and De Nicolo (2002), we address the first problem by employing the technique originating from Press (2001), which uses the Jacobi rotation as a means of transformation. In particular, we partition the space for V into 345 equally distant candidate decompositions of Ω. To address the second problem, we impose sign restrictions on the short-run co-movement of variables as a means of selecting a candidate decomposition of Ω. To elaborate further, economic theory provides important information on the signs of the pair-wise dynamic cross-correlations between certain variables in response to structural shocks. The dynamic cross correlation function of y_{it} and y_{jt+r}, at lag $r = 0, \pm 1, \pm 2, \ldots,$ is

$$\rho_{ij}(r) \equiv Corr(y_{it}, y_{j,t+r}) = \frac{E[C^i(L)u_t C^j(L)u_{t+r}]}{\sqrt{E[C^i(L)u_t]^2 E[C^j(L)u_{t+r}]^2}}$$

where E[.] indicates expectations and C^h the h^{th} row of C(L). Hence the pair-wise dynamic cross-correlation conditional on the particular shock defined by α is

$$\rho_{ij/\alpha}(r) \equiv Corr(y_{it}, y_{j,t+r} / \alpha) = \frac{(C^i(L)\alpha)(C^j(L+r)\alpha)}{\sqrt{(C^i(L)\alpha)^2 (C^j(L+r)\alpha)^2}}$$

the sign of which only depends on the sign of the numerator, i.e. the cross product of the impulse response of variables i and j at lag r to the shock. Given an orthogonal candidate, we can check whether the shock produces the sign of the cross correlation function prescribed by economic theory.

Canova and De Nicolo (2002) present a model based on an economy with limited participation to derive the signs of cross correlation functions to use as sign restrictions.[5] From the theoretical model one can derive sign restrictions for co-movements in output, inflation, real balances, bank loans, and the slope of the term structure as a result of technology, government and monetary shocks to the economy. The sign restrictions that this model produces are generic in the sense that there is a broad class of models where shocks affect the aforementioned variables in the way described by this model, including economies with different micro-foundations and frictions. Table 1 summarizes the sign restrictions obtained from the simulation exercise conducted in Canova and De Nicolo (2002) for output, price and real balances.

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[5] For details of the theoretical model, see Christiano, Eichenbaum and Evans (1997) and Canova and De Nicolo (2002). The limited participation class of models generates frictions via the sluggish demand for money by households.

Table 1: Sign Restrictions

Structural Shocks	**Co-movements for r = 0, 1, 2, 3 (r = month)**		
	Output and Price	Price and Real Balance	Real Balance and Output
Monetary	Positive	Positive	Positive
Government	Positive	Negative	Negative
Technology	Negative	Negative	Positive

Succinctly, a positive monetary shock decreases the cost of production for firms, which increases labor demand, raising both wages and working hours and leading to an increase in output and consumption. Because the increase in money supply is larger than the increase in output, there will be inflation. However, because the increase in inflation is smaller than the rise in money, real balances will rise. Because the liquidity effect dominates the expected inflation effect, a positive monetary shock decreases nominal short-term rates (raises the slope of the term structure). On the contrary, a positive government shock leads to the decline in private consumption. Labor supply and output, however, will increase because of the wealth effect. The increase in aggregate demand from a positive government shock will in turn exert upward pressure on prices. Money demand also declines as consumption falls and the short-term rate decreases (the slope of the term structure increases) to induce agents to continue holding the existing money stock and as a result, real balances decline because of the rise in inflation. A positive technology shock increases output and consumption on impact and reduces inflation (government consumption is assumed constant at its steady-state level). An increase in consumption necessitates a rise in real balances to finance spending. In this case, short-term nominal rates must increase (the slope of the term structure decreases) in order for agents to hold exactly the right amount of money. These explanations briefly describe responses to policy shocks on impact. However, simulation exercises conducted by Canova and De Nicolo (2002) suggest that these responses hold well into the first quarter.

It should be noted that even a static model with a downward sloping aggregate demand curve, an upward sloping short-run aggregate supply curve, and a vertical long-run aggregate supply curve in the inflation-output plane (for example, see the textbook by Abel and Bernanke, 1995) has the feature that technology, government, and monetary shocks will generate signs of co-movements in output, inflation, and real balances that are the same as those presented above. Yet, while these signs are generic, they are also sufficient to identify each type of shock in the economy. In other words the signs of the co-movement between output and price, output and real balances, and price and real balances generated from each shock are uniquely different such that we are able to discriminate between the three structural shocks in terms of the implied co-movements.

The search for a single decomposition of the covariance matrix Ω over the space of V is carried out by restricting our attention to those decompositions that maximize the number of shocks exhibiting conditional correlations consistent with theory, at $r = 0$ (lag zero refers to response of variables to the shock on impact). If more than one decomposition produce the same maximum number of identifiable shocks, these decompositions will be sequentially eliminated by making the sign restrictions more stringent i.e. each candidate must then satisfy the sign restrictions at $r = 1, 2, \ldots$ and so forth until a single candidate is obtained ($r = 1$ refers to response of variables to the shock after one month, $r = 2$ after two months). Upon obtaining our choice for the decomposition of Ω, we proceed to analyze the impulse response functions for each variable in response to the monetary policy shock(s). In practice, we find that sign restrictions for $r = 0, 1, 2$, and 3 months are sufficient to identify the shocks for the U.S. data, with only one of the shocks satisfying the restrictions of a monetary policy shock.

Examining the Importance of a Channel

The test of the relative importance of channels is conducted using counterfactual experiments on the VAR system described above. First, a VAR model is estimated and a monetary policy shock is identified as in the preceding section. Then a benchmark impulse response of output with respect to the monetary policy shock is calculated and plotted. Next, a channel is shut down by assuming that the related variable is exogenous. Specifically, dynamic response coefficients for the related variable are set to zero in a constrained version of the VAR. The resulting impulse response of output to a monetary shock, referred as the constrained impulse response, is compared to the benchmark. The difference between the benchmark and constrained impulse responses provides a measure of the relative importance of the excluded variable in the transmission mechanism. A large change in the path of output implies that the channel that was shut down was an important part of the transmission mechanism. Conversely, the closer the constrained impulse response function is to the benchmark case, the weaker the transmission channel under analysis. This approach is similar to the approach employed in Ramey (1993).

In this study, we measure the distance between the benchmark and constrained impulse response functions. This allows us to quantify the marginal importance of the channel that is shut down. Let the impulse response functions of output (y_1) with respect to a monetary policy shock (ε_1) for each model be written as follows:

$$\frac{\delta y_{1t+s}}{\delta \varepsilon_{1t}} = \theta_{11,s}^{j}$$

with j = b or c; where b and c denote the benchmark and constrained impulse responses, respectively. Our distance measure is computed by calculating the difference of the θs between the constrained and benchmark cases at each horizon. The distance measure can be written as the following:

$$\text{Distance measure} = \frac{(\theta_{11,s}^{b} - \theta_{11,s}^{c})}{\theta_{11,0}^{b}} \quad \text{for each s.}$$

The measure is standardized by $\theta_{11,0}^{b}$ to give the interpretation of distance as a percentage of the initial size of the shock.

In our analysis, we consider three channels based interest rates, bank loans, and the exchange rate. In terms of the transmission mechanism, the interest rate and exchange rate channels correspond to the "money" view, while the bank loan channel corresponds to the "credit" view. In order to consider counterfactuals based on shutting down these particular channels, it is necessary that these variables are not part of the identification scheme for monetary policy shocks. Thus, we consider the generic restrictions presented above in Table 2, which only place short-run restrictions on output, the price level, and real balances.

IV. Results

Our VAR model comprises of variables that represent (i) the slope of the term structure, (ii) real balances, (iii) bank loans, (iv) the exchange rate, (v) the price level and (vi) income. The following data represent the above variables respectively; (i) the difference between long-term (5-year government securities) and short-term (3-month treasury bills) interest rates; (ii) money supply (M1) over the price level; (iii) total loans at all banks; (iv) the trade weighted value of the U.S. dollar, St. Louis Federal Reserve Bank index (1980=100); (v) the consumer price index, CPI, (1982-84=100) and (vi) industrial production index (1997=100). The monthly series are seasonally adjusted, where applicable, and were obtained from the Federal Reserve Bank of St. Louis (FRED).[6] In order to interpret responses to disturbances as short-term dynamics around a steady-state, the VAR must be stationary, possibly around a deterministic trend. The inability to reject the null hypothesis of a unit root in most of the series raises concerns about estimation given data in levels.[7] To address this issue, we first difference all of the series except for the interest rate spread, which appears to be stationary. The model is estimated using one lag length based on the AIC criterion.

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[6] Data are converted to natural logarithms except for interest rates.

[7] Many studies in the monetary policy shock literature ignore this issue and proceed to estimate in levels. See, for example, Bernanke and Blinder (1992), Eichenbaum and Evans (1994) and Leeper, Sims and Zha (1996).

The stability of parameters in estimated macroeconomic relationships has been investigated in a number of recent papers. Stock and Watson (1996) find widespread instability in bivariate relationships among 76 macroeconomic variables. In the VAR context, mixed results have been obtained. Boivin (1999) argues that the different conclusions are due mainly to the small sample properties of the stability tests and to the effect of the number of parameters tested on the power of these tests. He concludes that there is compelling evidence of parameter instability in monetary VARs. We test for instability using an F-test for a structural break and, based on this test, we split our sample into two periods, 1959:01 to 1982:09 and 1982:10 to 2002:12. We believe the two sub-samples are adequate to capture structural changes in the U.S. economy, as this approach is consistent and within the range of breakpoints found in the existing time series literature (see for examples, Kim, 1999; Stock and Watson, 2002; and Boivin and Giannoni, 2006).

Evidence of Monetary Propagation

We assess the importance of monetary innovations as sources of cyclical movements in output and inflation using variance decomposition analysis. In the first sample period, for a 24-month horizon, monetary disturbances account for 51.4% of the total variation in output. In the latter period, they account for 37.4% of the total variation at the same horizon. Meanwhile, the monetary shocks explain as much as 58.1% of the variation in the price level in the earlier sample and up to 84% in the second period at the same horizon.

While we find a relatively large role for monetary shocks in the total variation of output, our estimates are consistent with those in some other studies. As a comparison, Canova and De Nicolo (2002), using data for the period of 1973:01-1995:07, find that monetary disturbances affect between 16-60% of the variation in output at a similar horizon. Faust (1998), using data for the period of 1960:01-1996:03, finds that monetary disturbances account for between 52-86% of the variation at a longer 108-month horizon. Meanwhile, our results indicate a relatively large role of monetary shocks when compared to other studies that suffer from identification problems reflected by the common presence of the price puzzle and the liquidity puzzle. For example, in Christiano, Eichenbaum and Evans (1999), using quarterly data for the period of 1965:3-1995:2, find that monetary shocks account for only 8% of the variation in output at a 12-quarter horizon when non-borrowed reserves were used to measure monetary policy, although they find a higher estimate of 38% when the Federal Funds Rate was used. Kim (1999), using data for the period of 1961:3-1994:3, finds that monetary disturbances account for 26.9% of the total output variation at a 24-month horizon.

Identification of the Monetary Policy Shock: 1959:01 – 1982:09

Figures 1a and 1b display the impulse response functions for the variables as they appear in the benchmark model. The innovation to monetary policy is defined as a one standard deviation shock to the orthogonalized error term identified as the monetary policy shock. A glance at these impulse response functions reaffirms that all the variables in the model are responding to the monetary policy disturbance according to the predictions obtained from theory.

Figure 1a: Impulse Response of Output and Price

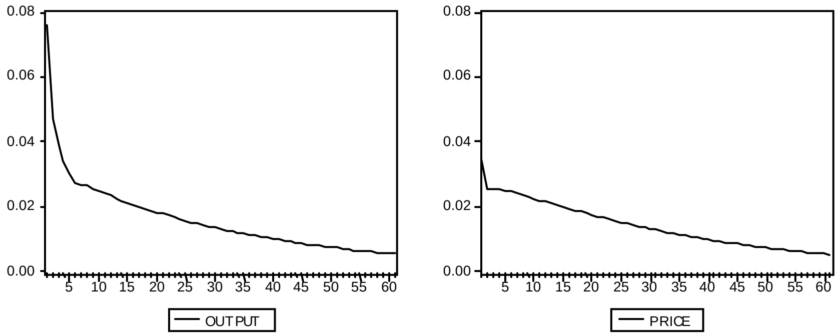
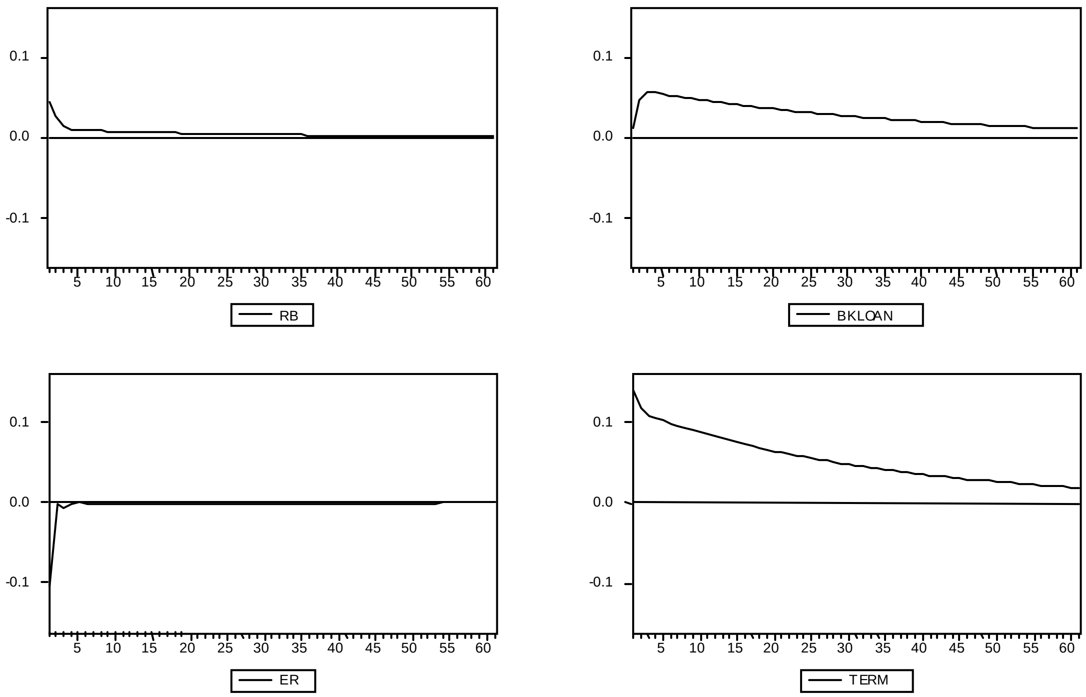


Figure 1a shows that, on impact, monetary policy innovations produce a large response in output as measured by industrial production. The increase in price, as measured by the CPI, is smaller, but the impact dies down more gradually over the period of five years. These impulse response functions are consistent with findings in Canova and De Nicolo (2002).

Figure 1b: Impulse Response of Real Balance, Bank Loan, Exchange Rate and Slope of the Term Structure of Interest Rate



The impulse response functions in Figure 1b depict an expansionary monetary shock that increases demand for real balances, despite the increase in prices, and raises bank loans. At the same time, the decline in domestic short-term interest rates, represented by the positive slope of the term structure, widens interest rate differentials and induces outflows of capital abroad. This, in turn, results in the depreciation of the domestic currency. Persistent depreciation of domestic currency following monetary expansion is consistent with results from Eichenbaum and Evans (1995) and Faust and Rogers (2003).

Analysis of Transmission Channels: 1959:01 – 1982:09

Figure 2 displays results for the test of the marginal importance of the different channels. The lines show the response of output to one standard deviation monetary shock. The line "Benchmark" is derived from the estimated model. The lines "IR Channel Blocked", "BL Channel Blocked" and "ER Channel Blocked" refer to results from excluding the impact of the interest rate, bank-lending, and exchange rate channels, respectively.

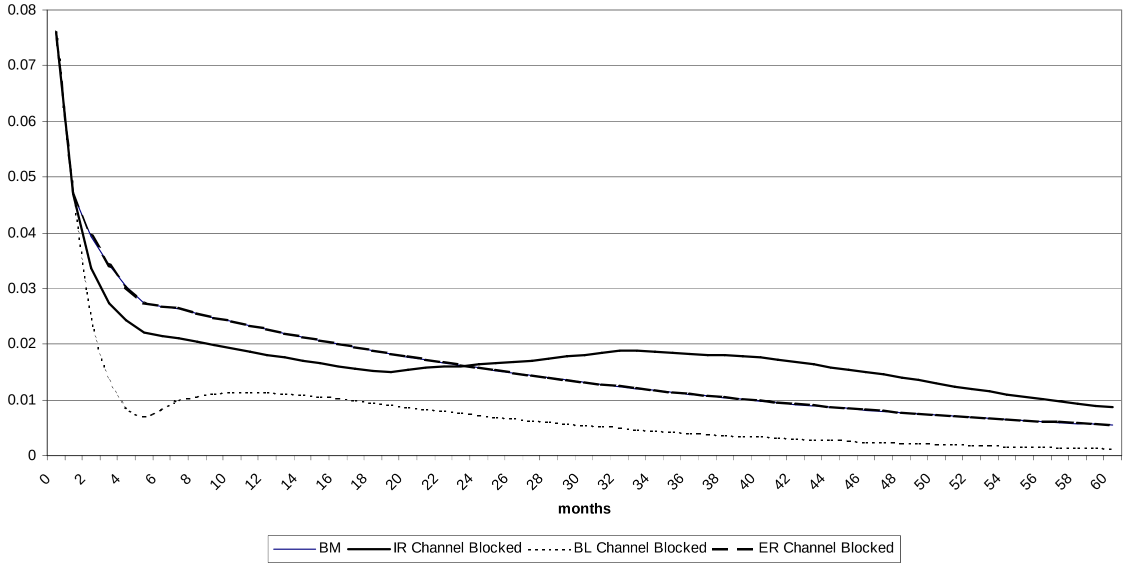


Figure 2: Impulse Response Function of Output (1959:01-1982:09)

An inspection of the figure suggests that the bank-lending channel is relatively more important. The interest rate channel matters, at least over a two-year horizon, although it is not as important as the bank-lending channel. It is clear that the exchange rate channel plays an insignificant role in transmitting monetary policy. In particular, the impulse response function for the case that the exchange rate channel is shut down remains almost identical to the benchmark case and is difficult to distinguish from it in the figure.

We compute the distance measure based on the impulse response functions in order to quantify the importance of the various channels. Based on the notion that transmission channels are intermediate channels, it is reasonable to argue that it is most informative to focus our analysis on the effect of these channels at a specific horizon. Because standard monetary models in current use, for example Rudebusch and Svensson (1999), incorporate monetary transmission lags (Goodhart, 2001), many studies focus on the window between the 2nd and 8th quarter.[8] To make our results comparable and to avoid the shorter horizons for which we have imposed sign restrictions, we focus our analysis

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[8] The exchange rate channel is probably an exception, as it may possibly respond to policy disturbances immediately.

on assessing the horizon r = 7 to 24 months. Figure 3 shows the plot of the distance measure between the constrained and benchmark impulse response functions.

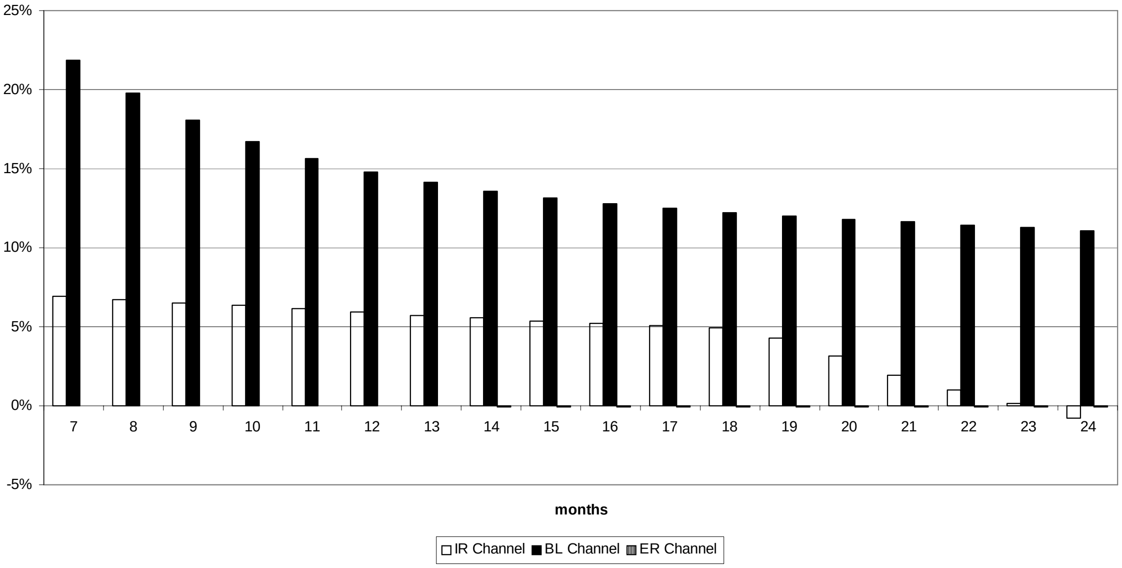


Figure 3: Marginal Importance of Channels (1959:01-1982:09)

Figure 3 indicates that, when the influence of the exchange rate channel is shut off, the distance measure between the constrained and benchmark models is exceedingly small. That is, exchange rate movements as a result of a monetary policy innovation have little effect on the U.S. economy. Again, it is difficult to see the distance measure for the exchange rate on the common scale in the figure. We offer two explanations for the exchange rate result. One, the U.S. economy is largely driven by the domestic sector hence movements in the external sector of the economy have minimal impact on overall economic growth. Two, many studies find that little of the volatility in exchange rates is due to monetary disturbances.

From Figure 3, it is also evident that the credit channel matters in transmitting monetary policy innovations and in fact plays a greater role than money channel during this period. As discussed in Section II, one of the fundamental assumptions for the credit view is that it is difficult for banks to replace the lost deposits following monetary tightening, which in turn shifts the supply of bank loans (Bernanke and Blinder, 1988). Together with the assumption that bank loans and bonds are not perfect substitutes, proponents of the credit view have highlighted the importance of the bank-lending channel. Thus we argue that these assumptions adequately fit in the description of the banking system for the U.S. in the 1960s and 1970s based on the results of our analysis for the early sample period. Indeed, prior to 1980s, the imposition of "Regulation Q" by the Federal Reserve on banks placed a ceiling on the interest rates banks could pay depositors. It follows, therefore, that during monetary contraction, when open-market interest rates went above the ceiling, banks had no way of competing for funds and suffered great declines in deposits. Moreover, there were marginal reserve requirements on large CDs during this period, inhibiting further the ability of banks to raise funds. In addition, the markets for bank liabilities were relatively shallow and illiquid during this period (Bernanke and Gertler, 1995). Another important components of the bank lending channel is the idea that bank loans play a special role, namely for small firms which rely on bank loans as their main source of financing. The inability of small firms to raise funds elsewhere without incurring an exceptionally high cost, termed as financial constraints, is part of the reason for the importance of bank lending channel. Many studies (for example, Fazzari, Hubbard and Petersen, 1988) find evidence that during this period firms were financially constrained. This finding strengthens the role of bank loans in propagating monetary shocks.

Identification of the Monetary Policy Shock: 1982:10 - 2002:12

Figure 4a and 4b display the impulse response functions for the benchmark model for the sample of 1982:10-2002:12. An inspection of these impulse response functions reaffirms that all the variables in the model respond to the monetary policy innovation in a way that is consistent with theory and also with results obtained in Canova and De Nicolo (2002).

Figure 4a: Impulse Response of Output and Price

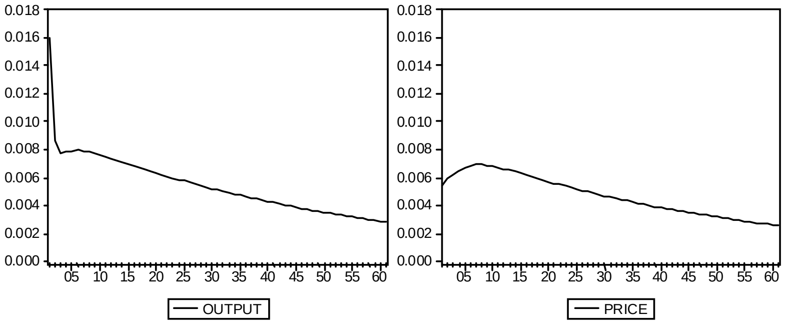
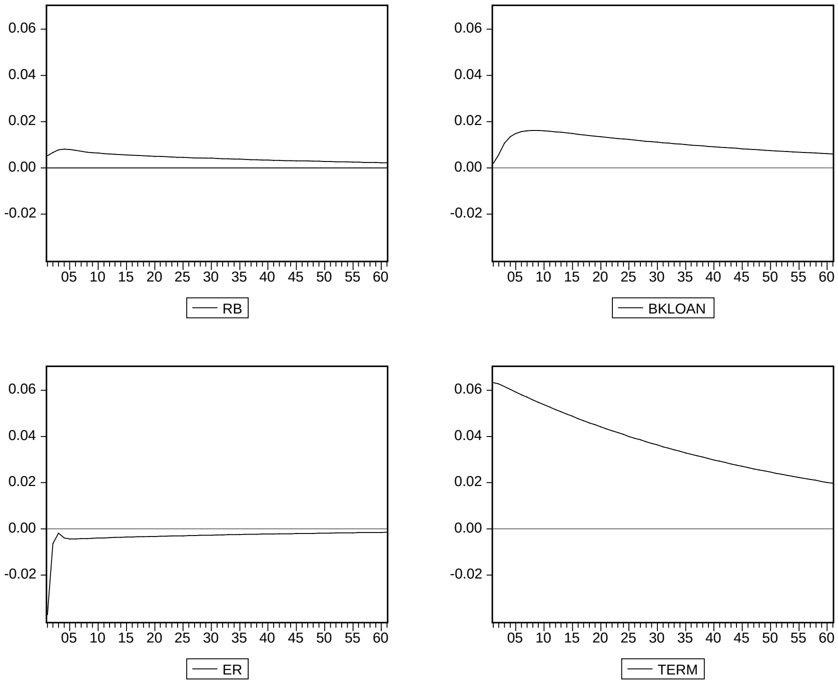


Figure 4b: Impulse Response of Real Balance, Bank Loan, Exchange Rate and Slope of the Term Structure of Interest Rates



Analysis of Transmission Channels: 1982:10 - 2002:12

Figure 5 plots the impulse response functions for the benchmark and various constrained cases and Figure 6 plots the distance measure.

Figure 5: Impulse Response of Output (1982:10-2002:12)

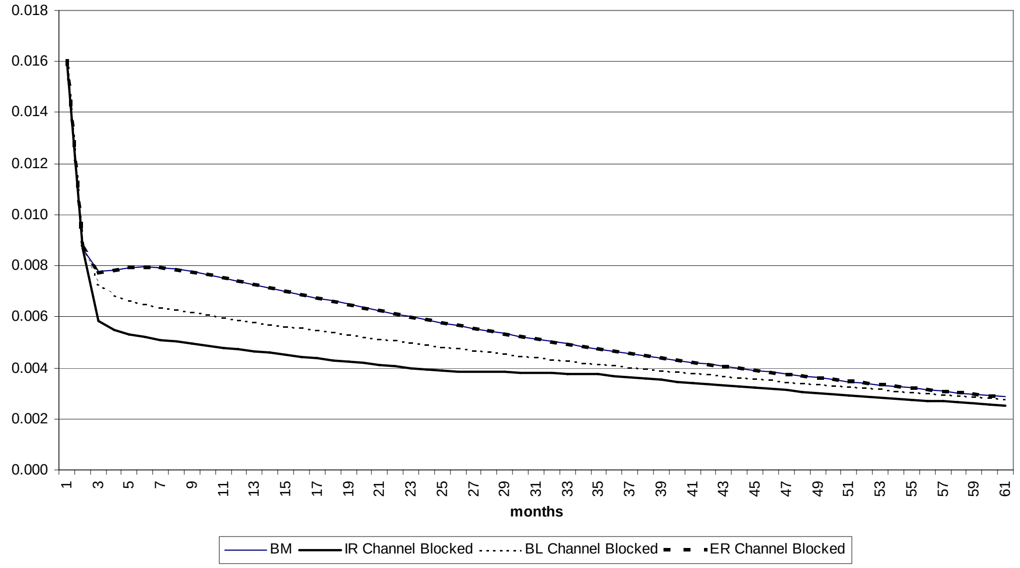
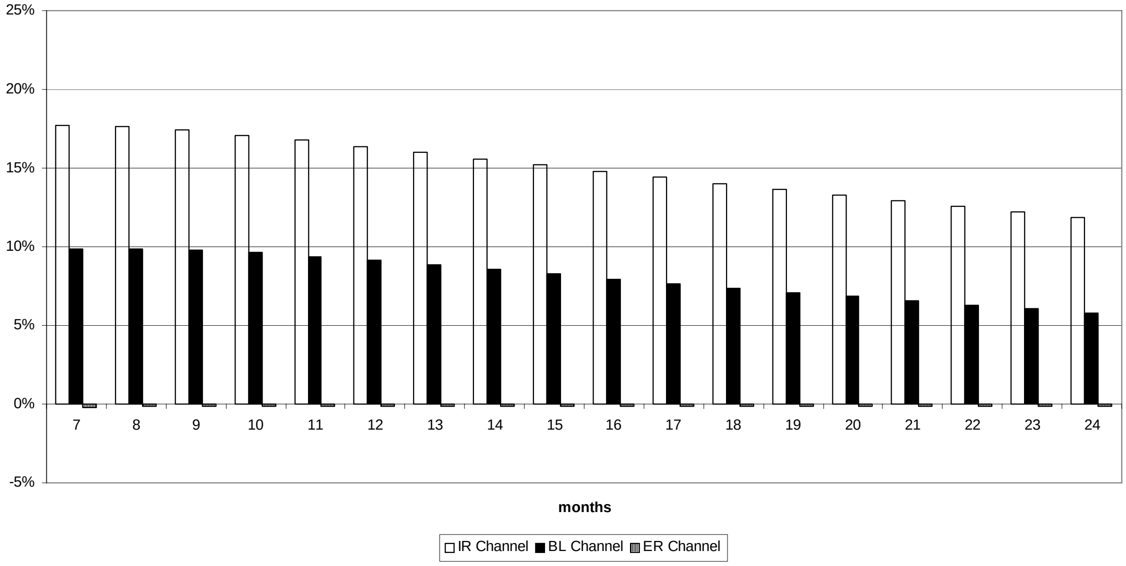


Figure 6: Marginal Importance of Channels (1982:10-2002:12)



As with the previous sample period, we find that the impulse response function for the case that the exchange rate channel is blocked is virtually identical to that of the benchmark. However, in contrast to the previous sample period, the interest rate channel plays a relatively more important role than the bank-lending channel in transmitting monetary policy.

Comparison across Subsamples

The results from this section can be broadly interpreted as follows. Evidence from the earlier sample suggests that bank loans are highly imperfect substitutes for other assets. Prior to the 1980s, the credit channel is significantly more important than the money channel in transmitting policy. However, the role of the credit channel is much weaker in the recent two decades, while the money channel becomes more important. Hence, a contribution of this paper to the debate on the monetary transmission mechanism is to provide evidence for some role of the credit channel, but also to emphasize that the role of this channel has diminished in the recent two decades.

Financial deregulation and massive financial reforms in recent decades may have increased banks' access to alternative source of funds. This in turn, perhaps, caused monetary policy to have less impact on bank lending and hence weakened its role in the transmission mechanism. At the same time, as capital markets have developed and deepened, financial constraints may have become less severe for firms.[9] This, again, weakened the role of bank lending as a transmission channel during the period. To some extent, our results support the view that the changes in the characteristics of the U.S. financial conditions over the recent two decades have successfully widened and deepened capital markets and thus reduced the imperfections inherent in the capital market in the prior period.

Recognizing that the above analysis is only in terms of the relative importance of channels, we proceed to measure the absolute importance of each channel for the variation in output over the two sub-samples. This analysis may provide further support

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[9] Chen (2004) finds that financial constraints among firms have become less severe.

for arguing the case of a weakening role for the bank-lending channel. We calculate the absolute importance of these channels for output by evaluating the average distance measure for each of the channels over the 7 to 12 month horizons, scaled by the standard deviation of a monetary policy shock in terms of its impact on output.[10]

Table 2: Absolute Importance of Channels (Standard Deviations)

	Sample: 1959:01-1982:09	Sample: 1982:10-2002:10
Size of Monetary Policy Shock	0.03	0.008
	Absolute Measure	
BL Channel	0.0042	0.0006
IR Channel	0.0013	0.0012

Table 2 underscores two important facts. First, it further supports our results for the test of relative importance; i.e. the bank-lending channel plays a significantly greater role than the interest rate channel in transmitting monetary policy in the first sub-sample but the latter plays a more important role in the second sub-sample. Second, there is a significant decline in the absolute role of the bank-lending channel over the four decades whereas the absolute role of interest rate channel has not changed by as much. From these findings, it is interesting to speculate whether the reduced potency of monetary propagation on output observed over the last two decades as shown by the variance decomposition results is primarily due to weakening of the bank-lending channel. The results in Table 2 provide some grounds for this conjecture, but we explore the issue in much more detail in the next section.

V. Transmission Changes and Volatility Reduction

Apart from illustrating that the role of transmission channels changes from the 1960s and 1970s to the 1980s and 1990s, the results in the previous section beg the question of

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[10] This six-month window incorporates the bulk of the impact of the monetary policy shock for each sub-sample.

whether changes in monetary policy dynamics correspond to changes in the volatility of output growth and inflation.

Studies by Niemira and Klein (1994), Kim and Nelson (1999), and McConnell and Perez-Quiros (2000), among others, have concluded that there was a sharp decline, or break, in the volatility of U.S. output growth in 1984. These papers have motivated substantial recent literature that characterizes this decline in volatility and investigates the reasons for it. Recent studies include Stock and Watson (2002), Kim, Nelson and Piger (2004), Ahmed, Levin and Wilson (2004), Boivin and Giannoni (2006), and Kim, Morley, and Piger (2008). These studies investigate whether the moderation in volatility of output growth is associated with a reduction in its conditional variances or changes in its conditional mean. In the context of a reduced-form VAR, these studies investigate whether the observed reduction in volatility is associated with a change in the magnitude of the VAR forecast errors, i.e., the impulses or shocks, or a change in the lag dynamics (autoregressive coefficients) modeled by the VAR, i.e., the dynamic propagation of shocks. This section presents counterfactual experiments similar to those in the literature motivated by the conjecture that the changes in transmission channels may alter the dynamic propagation of monetary impulses and hence lead to the reduction in volatility of output growth and inflation.

Variance Counterfactuals

The basic idea of the counterfactual analysis of structural change can be illustrated as follows. Recall equation (2), which gives us the reduced form version of the model. This reduced form equation can be rewritten as in equation (5) as follows:

$$y_t = c^{(i)} + \Phi_1^{(i)} y_{t-1} + \ldots\ldots + \Phi_p^{(i)} y_{t-p} + e_t, \mathrm{Var}(e) = \Omega^{(j)} \qquad (5)$$

where the superscripts i,j = 1, 2 denote the subsample (i.e. 1=before and 2=after the structural break). Let $\Psi_k^{(i)}$ be the matrix of coefficients of the kth lag in the matrix polynomial $\Psi_k^{(i)} = (I - \Phi_1^{(i)} L - ...... - \Phi_p^{(i)} L^p)^{-1}$. With this notation, the variance of the nth series in y_t can be written as:

$$\mathrm{Var}(y_n)^{(i,j)} = \sum_{k=0}^{\infty} \Psi_k^{(i)} \Omega^{(j)} \Psi_k^{(i)\prime} = \sigma_n (\Phi^{(i)}, \Omega^{(j)})^2 \tag{6}$$

The standard deviation of y_{nt} in period 1 is $\sigma_n = (\Phi^{(1)}, \Omega^{(1)})$ and in period 2 is $\sigma_n = (\Phi^{(2)}, \Omega^{(2)})$. By evaluating expression (6) for different Φ (propagation) and Ω (shocks), we can compute counterfactual variance of y_{nt} that would have been obtained had either Φ and Ω had taken on different values. For instance, $\sigma_n = (\Phi^{(1)}, \Omega^{(2)})$ would be the counterfactual standard deviation of y_{nt} had the first period propagation been associated with the shocks of the second period rather than the shocks of the first period. See Kim, Morley and Piger (2008) for a full discussion of the issues surrounding variance counterfactual experiments.

Results from Counterfactuals

The two sub-samples studied in this paper adequately represent the distinct break in volatility since the break date of 1982:09 is similar to findings of break dates in other studies in this area. For example, Stock and Watson (2002) found that the 67% confidence interval for the break date in the conditional variance of GDP is 1982:Q4 to 1985:Q3. Accordingly, we utilize the VAR benchmark models estimated for the two samples 1959:01-1982:09 and 1982:10-2002:12 from the preceding section to investigate how much of the reduction in the variance of output is due to changes in the VAR coefficients and how much is due to changes in the covariance matrix for the forecast errors.

Table 3: Results from Counterfactual Experiments

	Sample Standard Deviation		Standard Deviation From VAR Estimation		Standard Deviation Using Counterfactual Experiments	
	1959:01-1982:09	1982:10-2002:12	1959:01-1982:09	1982:10-2002:12	Shocks: 1982:10-2002:12 Propagation: 1959:01-1982:09	Shocks: 1959:01-1982:09 Propagation: 1982:10-2002:12
Output Growth	0.010088	0.005436	0.020117	0.006057	0.005717	0.022484
Inflation	0.003560	0.001884	0.003422	0.001824	0.004678	0.001670

Table 3 shows the results of our counterfactual experiments. The first two columns provide the sample standard deviation of the series of the two sub-samples. The next two columns show the VAR-based estimates of the standard deviations before and after the structural break. The final two columns give the counterfactual scenarios. First, consider the results for output. The estimated counterfactual standard deviation corresponding to a change in shocks but not propagation is of a similar magnitude to the standard deviation after the structural break. By contrast, the counterfactual standard deviation corresponding to a change in propagation but not shocks is of closer magnitude to the standard deviation before the structural break. Intuitively, these results suggest that if the shocks of the second sample had occurred in the 1960s and 1970s, these periods would have been almost as stable as the recent two decades. Similarly, had the first sample shocks occurred in the second sample, second-period output would have been the same or perhaps even more volatile. Hence, we can deduce that the change in the size of he shocks across the two distinct periods is primarily the reason for the reduction in the observed volatility of output growth. In this case, we are therefore unable to make any connection between the changes in the transmission mechanisms of monetary policy observed in Section IV and the recent moderation of the U.S. business cycle.

The same experiments for inflation suggest a different conclusion. In this case, the magnitude of the counterfactual standard deviation corresponding to a change in shocks but not propagation is similar to, albeit higher than, the standard deviation prior the structural break, while the counterfactual standard deviation corresponding to a change in propagation but not shocks is closer in magnitude to the standard deviation before the structural break. It follows, therefore, that changes in the propagation mechanism of shocks in the economy in the recent sample might have made inflation less sensitive to shocks.

VI. Conclusion

This paper analyzes the transmission mechanism of monetary policy in the U.S. economy, with special attention to the relative importance of the money and credit channels. We use short-run sign restrictions, introduced by Canova and De Nicolo (2002), to identify structural shocks. Their technique has several advantages over competing procedures. It separates the statistical problem of orthogonalizing the covariance matrix of reduced-form shocks from issues concerning the identification of structural disturbances. Contrary to most other structural VAR approaches, it does not arbitrarily impose restrictions on the contemporaneous impact of the shocks. This procedure also avoids recurrent problems of circularity between identification and inference since all of the constraints are explicitly stated in the model. Having identified our monetary policy shocks, we use counterfactual experiments to compare the strength and importance of the money and credit channels.

The results point towards the presence of both channels in the two samples. However, the credit channel is more important in the earlier sample covering data from 1959:01 –

1982:09 while the money channel plays a significantly greater role in transmitting policy impulses in the sample of 1982:10 – 2002:12. Results from analysis of the absolute importance of these channels to the variation in output growth provide further justification for the weakening of the role of the credit channel in the recent years. We note that this weakening is consistent with financial liberalization that occurred over the same time period.

The evidence that the U.S. transmission mechanism has undergone discernible changes motivates the last part of our study. Using different counterfactual experiments, we look for connections between changes in the transmission mechanism and increased economic stability in the past two decades. Perhaps surprisingly, we do not find any link between changes in the nature of the transmission mechanism of monetary policy and the observed reduction in volatility of output. However, we find suggestive evidence that a change in propagation reduced the volatility of inflation.

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