The Liquidity Effect: Identifying Permanent and Transitory Components of Money Growth

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Abstract

One strand of the recent literature on the monetary transmission process has focused upon the weak empirical evidence of a liquidity effect in the U.S. The effect of changes in the money supply growth rate on short-term interest rates has two competing components. The first is the liquidity effect where interest rates, both real and nominal, move in the direction opposite to the change in money growth. The second is the expected inflation effect, which causes nominal interest rates and expected inflation to move in the same direction as the change in money growth. If the money growth process is I(1), then at least one of the innovations impinging on the growth rate of the money is permanent. Permanent innovations in money growth are directly associated with a permanent change in the rate of price inflation according to the superneutrality hypothesis. If economic agents are able to discern between money growth innovations that are permanent versus those that are temporary, then only the temporary innovations in money growth supply should yield a liquidity effect. This study uses some recent advances in the application of structural VARs to separately identify the permanent and transitory money growth innovations. The results confirm that the liquidity effect is associated with transitory money growth supply innovations only.

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I. Introduction

Recently there has been a resurgence in the analysis of the effects of exogenous monetary shocks on short-term interest rates within the broad context of the "monetary transmission mechanism."[1] Perhaps the most commonly held monetary transmission mechanism is the "liquidity effect" and as such it has received the most focus from economists. While an important policy issue in its own right, the impetus for this reappraisal of the liquidity effect has both other theoretical and empirical roots.

Christiano (1996, p. 3) defines the liquidity effect as "[a]n exogenous, persistent, upward shock in the growth rate of the monetary base engineered by the central bank and not associated with any current or prospective adjustment in distortionary taxes, drives the nominal interest rate down for a significant period of time." It is the absence of this negative relationship between monetary base growth (hereafter simply money growth) and nominal interest rates that characterized earlier empirical investigations of the liquidity effect.[2] About this same time, macroeconomic theory was becoming enamored with dynamic general equilibrium models introduced by Kydland and Prescott (1982) and Long and Plosser (1983). The first of these real business cycle (RBC) models were limited to real economies and did not incorporate money. When money was introduced into the RBC models it was superneutral in the short run as well as the long run (see Cooley and Hansen (1989) and King, et al. (1988)). It wasn't until Fuerst (1992) that a computable dynamic general equilibrium model yielded the

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[1] These include Cochrane (1989), Bernanke and Blinder (1992) Christiano (1991, 1996), Christiano and Eichenbaum (1992, 1995), Strongin (1995), Pagan and Robertson (1995), Lastrapes and Selgin (1995), Coleman et al. (1996), and Thornton (1996), inter alia.

[2] These include Melvin (1983), Mishkin (1982) and Reichenstein (1987).

negative short-run relationship between money growth and interest rates implied by the liquidity effect. The question then arose, "If there is little empirical evidence in favor of a liquidity effect, should macroeconomists build models that generate a liquidity effect?"

The results of Leeper and Gordon (1992) cast considerable doubt on the ability to resuscitate the liquidity effect empirically. They found virtually no support for a negative correlation between unanticipated money shocks and nominal interest rates. Leeper and Gordon set the tone for subsequent work when they point out that any conclusions regarding the validity of the liquidity effect depend upon the identification of monetary policy shocks apart from other shocks that my affect money demand.

Two distinct approaches were developed to identify "exogenous" policy shocks from endogenous changes due to money demand and central bank reaction functions. Bernanke and Blinder (1992) used innovations in the federal funds rate as an exogenous policy shock in their study of the monetary transmission mechanism. On the other hand, Christiano and his co-authors (see note 1) and Strongin (1995) used innovations in the nonborrowed reserves component of the monetary base to proxy for exogenous policy shocks. While both identification schemes were successful in generating a negative relationship between innovations in money growth and nominal interest rates consistent with the liquidity effect, they have been criticized in Coleman et al. (1996) and Thornton (1996). These two studies provide a convincing argument that the negative response of the nominal interest rates to innovations in nonborrowed reserves is actually due to the interest sensitivity of the demand for borrowed reserves and the definition linking nonborrowed and borrowed reserves.

Taking a completely different path, Lastrapes and Selgin (1995) use a simple VAR and identify money supply shocks using a long-run neutrality restriction on the innovations to the log level of the monetary base.[3] They find significant liquidity effects. One difficulty with their analysis concerns the way in which nominal money enters the system. As Christiano (1996) defines the liquidity effect, it is changes in the money growth rate and not its level that should be associated with the liquidity effect. Lastrapes and Selgin implicitly recognize this when they say that innovations that lead to "permanent changes in the level of nominal money supply" are the same as "temporary changes in the growth rate" (p. 390). The liquidity effect should be due to temporary changes in the growth rate of money. What if the growth rate of money is subject to both permanent and temporary changes? This would imply that the level of money needs to be differenced twice to render it stationary.[4] Leaving money supply in first differences may lead to a serious misspecification error. Lastrapes and Selgin use a specification that is unable to distinguish if the innovation to the level of money is a permanent shock to money growth or a temporary shock to money growth.

Fundamentally, there are two distinct effects of changes in the money growth supply process on nominal interest rates. The liquidity effect is associated with the short-run response of the money market to an temporary excess supply (demand) of money. As agents buy (sell) bonds to eliminate the temporary disequilibrium, the price of nominal bonds rises (falls) and

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[3] Lastrapes and Selgin (1995) also present results for M1 and M2 with no qualitative difference in the results.

[4] Several studies have concluded that there is evidence that the growth rate of the nominal money supply in the U.S. has been nonstationary over the postwar period. These include Crowder (1996), Norbin and Reffet (1996) and Tatom (1990).

the rate of return on these bonds falls (rises). If the change in the money supply growth rate is permanent, the inflation expectations effect on interest rates, through the Fisher relation, should cause interest rates to move in the same direction as the change in the money supply growth rate. If it is assumed that economic agents have enough information that they can distinguish permanent from temporary money growth shocks, then the econometrician should be able to estimate the liquidity effect by decomposing money growth into permanent and transitory components.[5]

Consider an increase in the short-term nominal interest rate. This increase may be attributed to; 1) a permanent increase in either money growth supply or demand[6], 2) a temporary increase in money growth demand, or 3) a temporary decrease in money growth supply. When attempting to identify the liquidity effect, the source of permanent changes in money growth is immaterial since permanent supply and demand innovations in the money growth process have the same effect on nominal interest rates.[7] The key to identification of the liquidity effect is to distinguish between temporary (or transitory) demand and supply innovations in the money growth process.

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[5] This is precisely what Cochrane (1989) did using a spectral band pass filter technique.

[6] It is unclear how a permanent increase in money growth could be demand induced. Most models of money demand relate the level of money to other variables, not the growth rate. It may be more appropriate to consider all permanent innovations in money growth to be supply shocks.

[7] The distinction becomes critically important if the analysis is to focus on inflation effects. A permanent money growth supply increase will lead to higher inflation while a permanent money growth demand increase will lead to lower inflation. In practice the monetary authority usually accommodates demand increases to prevent disinflation.

Cochrane (1989) used a spectral filter to remove the long-run components of money growth and interest rates. He found that there is a statistically significant negative correlation between these two short-run components. Cochrane did not, however, distinguish between short-run supply and demand components of the money growth process. This paper extends Cochrane's work by using time series methods to decompose money growth innovations into three distinct types; 1) permanent (whether demand or supply is unimportant for the task at hand), 2) transitory demand, and 3) transitory supply.

The method employed to identify the single permanent and two transitory components of money growth is based upon the two equilibrium relationships of the Fisher relation and the superneutrality hypothesis. These two equilibrium conditions imply that money growth, inflation, and nominal interest rates all share the same permanent component. Identification of this component is achieved by statistical analysis first introduced by Stock and Watson (1988) and extended by Warne (1991), Crowder, Hoffman, and Rasche (1996), inter alia. The existence of the single common permanent component implies that no other ad hoc restrictions are necessary to identify it. The identification of the two transitory innovations is achieved by assuming that the transitory innovations are orthogonal and a short-run exclusion restriction.[8]

The rest of the paper is organized as follows. Section II describes the long-run relationships used to motivate the statistical model. Section III outlines the empirical methodology. Section IV presents the empirical results and section V concludes.

[8] It is demonstrated that the results are completely robust to the "arbitrary" exclusion restriction.

II. Long-Run Relationships

The objective in this study is to disentangle transitory innovations in money growth due to demand shocks from transitory changes due to supply shocks. The latter will be associated with the liquidity effect while the former will not. The equilibrium relationships discussed are used to motivate the econometric model and the identification procedures used in the empirical section.

The identification of the structural innovations from the reduced form estimates is accomplished by exploiting two long-run equilibrium relationships. Both have long histories in macroeconomics, including controversial empirical evidence on their validity. Initially we want to distinguish between the liquidity and inflation expectations effects of changes in the money supply growth process, i.e., transitory supply shocks versus permanent supply shocks. The three variables relevant for this analysis are the money supply growth rate, the inflation rate, and the short-term nominal interest rate.

The Fisher hypothesis describes relationship between nominal interest rates and expected inflation and has its root in Fisher (1930). The hypothesis simply states that the nominal return on a default-free bond should equal the required real return plus the amount of decline in the purchasing power of money over the bond holding period. It is most commonly given as in (1).

$$i_t = \Delta p_{t+1}^e + r_t \tag{1}$$

The standard assumption in the Fisher hypothesis literature, e.g. Fama (1975) and Mishkin (1992), is to treat the real interest rate as a constant. This assumption is consistent with the consumption CAPM under certainty (see Rose (1988)).

The empirical evidence suggests that the nominal interest rate is non-stationary over the postwar period. The time series evidence with respect to inflation is, however, quite mixed. There are theoretical precedents for a unit root in the inflation process, e.g., Mankiw (1987) and Calvo and Leiderman (1992). If the nominal interest rate is nonstationary while the real rate is stationary (or constant in the steady state), it must be the case that the inflation rate is nonstationary and cointegrated with the nominal interest rate for the Fisher hypothesis to be valid. Recent evidence supports this empirically (see, Crowder and Hoffman (1996), Mishkin (1992), Evans and Lewis (1995)). The Fisher hypothesis implies then, that inflation and nominal interest rates must share a common permanent component or common trend in the vernacular of Stock and Watson (1988).

The second long-run relationship is the superneutrality hypothesis. This hypothesis states that in the long run, changes in the money supply growth rate must be reflected in proportional changes in the inflation rate. Using a simple extension of the Lucas aggregate supply function, the long-run neutrality of inflation is demonstrated.

$$\Delta y_t - \Delta y_t^f = \gamma(\Delta p_{t+1}^e - \Delta p_{t+1}) \tag{2}$$

In (2) Δy_t is the actual rate of growth of real output and Δy_t^f is the full employment rate of growth of real output. In the steady state $\Delta y_t = \Delta y_t^f$ and expected inflation equals actual inflation. Introducing a simple money demand model of the form,

$$m_t - p_t = f(y_t, \ldots) \tag{3}$$

and noting that money supply must equal money demand in equilibrium, it is easily derived that in the steady state the following equalities must hold.

(4) $$\Delta m_t = \Delta p_t^e = \Delta p_t$$

Thus, superneutrality implies inflation is equal to money growth in the long run.[9] If inflation is nonstationary then the money supply growth rate must also be nonstationary. If the superneutrality hypothesis is true as well, then inflation and money growth are cointegrated or share a common trend. Crowder (1996) presents evidence for the U.S. that supports the superneutrality hypothesis.

Combining these two equilibrium relationships implies that there exists a single common permanent component among the three variables of interest. In the next section it is demonstrated how using these equilibrium relationships in a vector autoregression (VAR) will allow the econometrician to separately identify the permanent and transitory components of each of the variables.

III. Econometric Model

The specific modeling strategy used is similar to specifications exploited by Stock and Watson (1988), Shapiro and Watson (1988), and Blanchard and Quah (1989). Specifically, the use of a structural vector autoregression (SVAR) is employed. The econometric problem is one of identifying the structural innovations from the reduced form errors. In the system of three variables under consideration, it is assumed that there are three primitive innovation sequences

[9] This assumes that money demand is stable. For empirical evidence supporting this, see Hoffman and Rasche (1991).

that determine the time path of each of the variables.[10] The structural dynamic model is given by,

$$A(L)X_t = \nu_t \qquad E\left(\nu_t'\nu_t\right) = I \tag{5}$$

where X_t is a $3{\times}1$ vector of endogenous variables, A(L) is a matrix polynomial in the lag operator and ν_t is an innovation sequence such that its elements are uncorrelated both contemporaneously and across time.[11,12] The unrestricted reduced form VAR is given by

$$B(L)X_t = \varepsilon_t \qquad E\left(\varepsilon_t'\varepsilon_t\right) = \Sigma_\varepsilon \tag{6}$$

where B(L) is related to the structural coefficient matrix lag polynomial by $B(L) = A(0)^{-1}A(L)$ such that B(0) is the $3{\times}3$ identity matrix. The reduced form errors and structural innovations are similarly related, i.e., $\varepsilon_t = A(0)^{-1}\nu_t$. One final relationship is derived by adopting the conventional assumption that the variances of the three structural innovations are equal to unity. Thus $A(0)'\Sigma_\varepsilon A(0) = I$ or equivalently $A(0)^{-1}{}'A(0)^{-1} = \Sigma_\varepsilon$.

The retrieval of the structural innovations (and the structural parameter matrices) from the reduced form errors is an exercise in identifying the matrix A(0). This parameter matrix has nine distinct elements. The relationship between the reduced form errors and structural innovations, along with the assumption of unit variances of the structural innovations, yields six restrictions on the admissible values of the A(0) matrix. Three additional restrictions are

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[10] It is quite likely that there are many more than three shocks impinging upon the variables of interest, but as Blanchard and Quah (1989) point out this assumption is probably not too damaging to the interpretation of the structural model.

[11] The deterministic terms have been suppressed for ease of exposition.

[12] If the variables are difference stationary it may be necessary to apply an appropriate difference to the variables prior to estimation.

needed to exactly identify the A(0) matrix. In the early VAR literature these three restrictions would have come from assuming a recursive structure to A(0), i.e., elements above the main diagonal would be assumed to be zero. This procedure was seen by many to be too arbitrary for reasonable interpretation of the implied structural model. Subsequent refinements of the VAR identification methodology stressed the importance of using restrictions that are economically plausible (see Bernanke, 1986). Since economic theory, especially macroeconomic theory, has more specific implications for long-run relations than short-run movements, the most recent VAR studies have relied on long-run restrictions to yield the necessary additional identifying information (see Blanchard and Quah, 1989).

To see how long-run restrictions can be used in identifying the structural innovations, it is useful to use the moving average representation (MAR) of the reduced form VAR in (6). Inverting (6) yields,

$$\Delta X_t = C(L)\,\varepsilon_t \tag{7}$$

where $C(L) = B(L)^{-1}$ or $C(L) = A(0)A(L)^{-1}$. The long-run or total impact matrix C(1) is equal to $A(0)A(1)^{-1}$ implying that $A(1)^{-1\prime}A(1)^{-1} = C(1)'\Sigma_\varepsilon C(1)$. Thus restrictions on C(1) imply corresponding restrictions on A(0) that aid in the identification of A(0). Often these restrictions take the form of zeros on certain elements of C(1) implying long-run neutrality of certain elements of X_t.

Two problems may arise in the use of long-run neutrality restrictions; 1) the variables of interest may be stationary in levels implying that C(1) = 0, or 2) the variables of interest may be difference stationary individually but cointegrated implying that the system of variables has a reduced number of common trends or that C(1) is not full rank.[13] In the first case, one is left with only contemporaneous restrictions to identify the structural model. The second "problem" is actually a benefit when the proper methodology is employed.

If the variables of interest are cointegrated, Engle and Granger (1987) have proven that the system has a special VAR representation called and error correction model (ECM). The ECM is given in equation (8) where $\Pi = I - B(1)$ and $\Gamma_j = I - B_1 - B_2 - \ldots - B_j$, and the B matrices are from equation (6). The total impact matrix Π can be decomposed into two $p \times r$

$$\Delta X_t = \Pi X_{t-1} + \sum_{j=1}^{\kappa} \Gamma_j \Delta X_{t-j} + \varepsilon_t \tag{8}$$

matrices α and β such that $\Pi = \alpha\beta'$, where p is the number of endogenous variables in the VAR and r is the number of cointegration vectors. The r columns of β represent the r stationary linear combinations and the columns of α represent the error correction coefficients. The economic interpretation of the cointegrating relations is that these represent long-run equilibrium relationships between the variables, such as those given in section II.

Johansen (1991) derives conditions to ensure that the Wold vector MAR exists as in equation (7).[14] The matrix polynomial C(L) may be written as $C(L) = C(1) + (1-L)C^*(L)$. Using this decomposition, (7) may be rewritten as,

[13] Faust and Leeper (1994) point out a third problem that arises when the long-run neutrality restriction is invalid.

[14] Non-Wold representations as in Lippi and Reichlin (1993) are not analyzed.

(9) $$X_t = X_0 + C(1)\,\xi_t + C^*(L)\,\varepsilon_t$$

where $\xi_t = \xi_{t-1} + \boldsymbol{\varepsilon}_t$ or $\xi_t = \Sigma^t_{j=1}\boldsymbol{\varepsilon}_j$. Equation (9) is the reduced form common trends representation with the total impact matrix C(1) having reduced rank of k, where r+k = p, the number of endogenous variables in X_t.

As in the case where no cointegration prevails among a system of difference stationary variables, the structural innovations can be identified from the reduced form estimates by suitably restricting the C(1) matrix. But since cointegration implies a reduced number of permanent components, complete identification may not be achieved if one relies solely upon long-run neutrality restrictions without careful consideration of the implications for cointegration.[15] Furthermore the existence of cointegration itself implies restrictions upon the parameter matrices so that any long-run restrictions imposed must also be consistent with the cointegrating relations (see Crowder, 1995). Cointegration implies that $\beta' C(1) = 0$ and that $C(1)\alpha = 0$. These two relationships impose kr restrictions on the reduced form model. It is these kr additional restrictions that make the "problem" of cointegration a benefit by reducing the number of ad hoc restrictions needed to identify the structural model from the reduced form.

King, et al (1991) and Crowder, et al (1996) demonstrate that the assumption of structural error independence implies that identification of the permanent and transitory innovations may be handled separately. When there are k permanent innovations the

[15] Another implication of the reduced rank of C(1) is the practical problem of obtaining an estimate in practice. Unlike the non-cointegrated system, one cannot simply invert the reduced form VAR since the reduced rank of Π in (8) implies singularity. Johansen (1991) and Engle and Yoo (1991) derive the proper procedure for the inversion of a cointegrated VAR.

econometrician needs only k(k-1)/2 restrictions to just identify the permanent innovations, in addition to the restrictions implied by structural error independence, normalization and cointegration. These additional restrictions may take the form of long-run neutrality restrictions as in the case of a full rank C(1). Similarly, when there are r transitory innovations, the econometrician need only impose r(r-1)/2 additional restrictions to just identify the structural model. These restrictions may take the form of contemporaneous exclusion restrictions and need not imply a recursive structure to the economic model.

The long-run relationships presented in section II suggest that theoretically r = 2, i.e., there are two cointegrating relations, and k = 1 or one common trend. This has the further implication that no long-run restrictions are necessary to identify the permanent innovation sequence and only one restriction is necessary to identify the transitory innovations. Thus the existence of cointegration has reduced the number of arbitrary restrictions needed to identify the structural model from three to one. It is still important to justify the particular restriction imposed using some economic reasoning.

The estimation and testing of β can be accomplished by numerous procedures including a simple OLS two-step procedure (Engle and Granger (1987)), a canonical cointegrating regression procedure (CCR) (Park (1992)), fully modified OLS (FMOLS) (Phillips and Hansen (1990)) or by FIML (Johansen (1988)), and others. When applicable the underlying economic theory may provide the value of β. Once β is known, an estimate of α can easily be obtained by estimating the ECM in (8) by OLS.[16] The residuals from (8) can be used to obtain a

[16] Due to the superconsistency of the estimate of β, this parameter can be treated as if known in subsequent statistical analysis.

consistent estimate of Σ_ε and Γ_j and $C(1) = \beta_\perp[\alpha_\perp' \Gamma^*(1) \beta_\perp]^{-1}\alpha_\perp'$, where $\alpha'\alpha_\perp = 0$ and $\beta'\beta_\perp = 0$ and $\Gamma^*(1) = I - \Gamma_1 - \Gamma_2 - \ldots - \Gamma_{\kappa-1}$.

In the following section, the Johansen procedure is used to estimate and test the implied cointegration vectors among $X_t = \{\Delta b_t\ i_t\ \Delta p_t\}$, where Δb_t is the monetary base growth rate, i_t is the short-term nominal interest rate and Δp_t is the inflation rate. The reduced form MAR is obtained and the structural transitory innovations are identified by imposing the restriction that inflation responds to money demand shocks with a one period lag. The robustness of the results to this restriction are analyzed by imposing the relatively implausible restrictions that the nominal interest rate only responds to money demand shocks with a lag.

IV. Empirical Results

A. Data

The data used in this study are monthly observations on the U.S. monetary base growth rate adjusted for reserve requirements, CPI inflation, and three-month T-bill interest rates. All data are taken from the St. Louis Federal Reserve Bank and are sampled from January 1951 to December 1996 (see Figure 1). The money growth and CPI inflation series have been seasonally adjusted at the source.[17] The choice of base money as the monetary aggregate is due to two considerations; 1) this is the money measure that Christiano (1996) specifically cites as associated with the liquidity, and 2) that FED policy is best captured by the aggregate which

[17] The sensitivity of the empirical results to seasonal adjustment procedures was examined using the non-seasonally adjusted version of money growth and inflation, again from the St Louis FED. The results, available from the author upon request, are almost identical with those presented in the text.

it most directly controls. The ability of the Federal Reserve to control broader aggregates is controversial since it depends upon their ability to control the multiplier. One component of the multiplier that is completely out of the control of policy makers is the currency-to-deposits ratio. Therefore, it seems prudent to use the monetary base as the money supply variable.[18]

B. Cointegration Analysis

The theoretical relationships that exist between the three variables, presented in section II, imply cointegration vectors of the form $\Delta b_t - \Delta p_t$, long-run superneutrality, and $i_t - \Delta p_t$, long-run Fisher relation, where $b_t \equiv$ natural log of the monetary base and $p_t \equiv$ natural log of the cpi and $i_t \equiv$ three month T-bill nominal interest rate. These long-run relationships suggest that β, the cointegrating vectors, will have the form given in equation (10) when $X_t = [\Delta b_t \; i_t \; \Delta p_t]'$.

$$\beta = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ -1 & -1 \end{bmatrix} \tag{10}$$

To test the hypothesis that the empirical equilibrium relationships are consistent with the theoretical relationships, Johansen's (1988) FIML estimator is employed. This estimator is based upon the ECM in (8). The lag length used in the analysis is set at $\kappa = 13$ in order to eliminate statistically significant autocorrelation in the residuals as determined by the Ljung-Box Q-test. The trace test statistic of the null that $r = 0$, where r is the number of cointegration vectors, is 43.08 which can be compared to the 95% critical value given in table 1 of Osterwald-Lenum

[18] It should be noted that other monetary aggregates were used, i.e, Federal Reserve Board monetary base, M1 and M2, with no qualitative difference in the results. These results can be obtained from author upon request.

(1992) of 29.68. We can reject the null of zero cointegration vectors in favor of at least one cointegrating vector. The null that $r \leq 1$ yields a trace test statistic of 16.88 which is greater than the 95% critical value of 15.41. We can reject the hypothesis of one cointegration vector in favor of at least two cointegrating vectors. The null that $r \leq 2$ yields a trace statistic of 2.89 which is less than the 95% critical value of 3.76. Thus, the Johansen trace tests suggest that two cointegration vectors prevail among the three variables. This is consistent with the equilibrium models, the superneutrality and Fisher equations, presented in section 2.

The estimated (normalized) cointegration vectors are given in (11). The numbers in parentheses are asymptotic standard errors.[19]

$$(11) \qquad \hat{\beta} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ -1.07\,(0.16) & -1.09\,(0.19) \end{bmatrix}$$

Using a likelihood ratio test to test whether (11) is statistically different from (10), the theoretically implied vectors, yields a statistic of 0.17 which is distributed as a $\chi^2(2)$. The marginal significance level is 0.9176 implying that this restriction is not rejected at any conventional level of significance.[20] Figure 2 presents plots of the estimated cointegration vectors.

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[19] The estimates demonstrate that neither of the vectors is a trivial vector, i.e., [1 0 0]′. This result implies that the data are in fact consistent with unit roots in each series.

[20] It should be noted that the identification problem does not depend upon the estimates of the cointegration vectors. These estimates are simply presented in order to demonstrate that the empirical results are generally consistent with the theoretical relationships used to motivate the exercise.

The temporal stability of the equilibrium relationships is necessary to conduct valid impulse response analysis. Hansen and Johansen (1994) have suggested a methodology to test for the stability of the cointegrating relations within the framework of Johansen's (1991) FIML estimator. The basic idea is to concentrate the short-run dynamics out of the likelihood function using the full sample of data, as is done normally in the first stage of Johansen's reduced rank procedure. Then apply a recursive estimation to the long-run components testing the restrictions on the cointegration space at each iteration. Hansen and Johansen demonstrate that the test statistics at each iteration are asymptotically distributed as a χ^2 variate. Figure 3 presents the recursive calculated stability test statistics normalized by the appropriate 5% critical value, i.e., $\chi^2(2) = 3.84$, such that a value greater than one implies significance at the 5% level. This test yields no evidence of instability in the long-run equilibrium relationships.

The estimated error correction coefficient matrix, α in equation (8), is given in (12). Again, standard errors are in parentheses.

$$(12) \qquad \hat{\alpha} = \begin{bmatrix} -0.17\,(0.06) & 0.04\,(0.08) \\ 0.02\,(0.01) & -0.03\,(0.01) \\ 0.14\,(0.04) & 0.07\,(0.06) \end{bmatrix}$$

From the estimated error correction coefficients it can be determined that none of the variables in the system are weakly exogenous, in the sense of Engle, et al (1983). This implies that all three variables must be modelled jointly to efficiently estimate the long-run parameter matrices α and β.

Using the estimates of α, β and the short-run dynamics parameter matrices, Γ_j's, from (8), the common permanent component can be estimated and extracted from each series.

Figure 4 displays the transitory components of each series, i.e., detrended by the common stochastic trend. These detrended series can be thought of as deviations from the long-run steady state value. Note that the low interest rates in the 1970s followed by the high rates of the 1980s then followed by very recent low interest rates all reflect movement in the transitory component of nominal interest rates. From this simple interpretation one may conclude that the interest rate observed at this writing is above its "trend value" and must fall in order to restore the long-run equilibrium. Inflation and base money growth both appear to be close to their "trend value".

C. Impulse Responses

The one extra restriction employed to identify the structural model is to restrict the inflation rate from responding contemporaneously to innovations in money demand. This seems a sound constraint on theoretical grounds since it is consistent with slowly adjusting goods prices.[21] The impulse response functions are calculated from the MAR. Figures 5, 6 and 7 present plots of the impulse response functions (IRFs) and 90% simulated confidence intervals.

Figure 5 displays the IRFs associated with an impulse in the permanent component. This has the natural interpretation as a permanent increase in the base growth rate. The IRFs display significant short run variation as the economy adjusts to the innovation. But a permanent supply innovation in base growth results in higher steady state inflation and nominal interest rates. The response of the real rate reveals that the real rate actually falls

[21] This restriction is also consistent with the results in Crowder and Hoffman (1996) in the analysis of the bivariate relationship between nominal interest rates and inflation within the Fisher paradigm.

during the adjustment to the new steady state as inflation "overshoots" its long run steady state level. Thus while economic agents may be capable of determining the permanence of the innovation to money supply growth they are unable to determine its long-run magnitude until sufficient time has passed. The response of nominal interest rates suggests a considerable amount of time is necessary for the market to adjust their inflation expectations to its long-run steady state level. This is not inconsistent with the argument presented in section II, to identify the liquidity effect, that agents can perceive permanent and transitory innovations. It does suggest that even when the innovation is perceived (correctly) to be permanent, there is considerable short-term uncertainty with respect to its long-run impact or magnitude.

Figure 6 displays the IRFs associated with the first transitory innovation which can be interpreted as a money growth supply innovation. This graph displays the liquidity effect for both nominal and real interest rates. Note that there is relatively little statistically significant response of inflation to the transitory money growth supply shock, and what little there is in the opposite direction of the change in money growth, perhaps capturing what has been called the "price puzzle" (see Balke and Emery, 1994).

Figure 7 displays the IRFs due to an innovation in money demand. The responses due to this money demand innovation are also consistent with an interpretation of the shock as an aggregate supply shock. Indeed the two types of shocks would be observationally equivalent in the present system. It may be that what is called a money demand shock here is just the result of a more primitive innovation in say productivity, in this case a negative productivity shock. It is observed that while money growth and the real interest rate decline (temporarily) inflation rises (again temporarily) and the nominal interest rate falls but insignificantly so. This pattern fits quite nicely with a simple IS-LM/AD-AS model. A negative productivity shock will shift the AS curve to the left resulting in a higher price level. The subsequent decline in output reduces the demand for the level of money which in turn has a very temporary impact on money growth. The decline in the demand for money leads to a decline in both real and nominal interest rates.

These responses were generated under the restriction that inflation responds to transitory money growth supply shocks with a one period lag, which was argued is consistent with sticky price models of the economy. An alternative identification restriction is to restrict the nominal interest rate from responding to the transitory money growth demand shock with a lag. While this restriction is less plausible economically, it has no qualitative effects on the impulse responses. Figure 8 presents the IRFs due to an innovation in the transitory money growth supply process. This figure can be compared with figure 6 since they both capture the liquidity effect. In this case a negative money growth supply shock increases both nominal and real interest rates and displays evidence of the "price puzzle". This is qualitatively identical to the IRFs displayed in figure 6 obtained under an alternative identification restriction.[22] Figure 9 displays the IRFs due to the transitory money growth demand shock. These IRFs can be compared to those in figure 7. Again the qualitative results are left unchanged by new identification restriction.

D. Reconciling Early and Later Studies

[22] The IRFs due to the permanent shock are identical in both cases.

This robustness to the particular restriction used to identify the short-run or transitory innovations suggests that the important issue in identifying the liquidity effect is the permanent versus transitory innovations dichotomy. Further evidence that this permanent-transitory decomposition is the relevant one can be gleaned from the variance decompositions. Melvin (1983) and Reichenstein (1987) have found that evidence of the liquidity effect vanished around 1973-1975. Prior to this period the evidence was in favor of a liquidity effect as in Cagan and Gandolfi (1969) and Gibson (1970). What could account for the apparent disappearance of the liquidity effect?

Table 1 presents the decompositions of the forecast error variance for monetary base growth for two sub-periods, 1951-1973 and 1974-1996. It is quite clear from these numbers that prior to 1974, transitory money growth supply shocks were a more important source of money growth fluctuations than such shocks have been since. In the 1951 - 1973 period transitory money growth supply shocks explained 40% of the money growth forecast error variance while in the 1974 - 1996 period these same shocks often explain less than 20% of the money growth variance.[2] The implication of this for tests of the liquidity effect should be obvious. In the early sub-sample transitory money growth supply shocks were "stronger" or more important making their detection by reduced form models much easier. As the permanent shocks became more dominant over the later sub-sample the transitory money growth supply shocks became

[23] The date of demarcation is not critical. Based upon results in Melvin (1983) and Reichenstein (1987), each year from 1972 to 1979 was analyzed as the break point in the sample with no qualitative difference in the results. The results presented are, however, the strongest quantitatively.

more difficult to detect in a reduced form model. Thus it is not that the liquidity effect vanished after a particular time period, it has simply become more difficult to detect.

Table 1.

Variance Decompositions of Money Growth

Forecast Step	Permanent Supply Shock		Transitory Supply Shock	
	1951 - 1973	1974 - 1996	1951 - 1973	1974 - 1996
1	59.23	77.45	40.75	1.57
2	59.48	72.91	40.47	7.04
3	59.53	72.17	40.38	7.99
4	57.90	66.84	40.90	14.57
12	56.81	58.89	40.02	23.04
24	58.38	57.81	38.23	24.29
36	60.16	59.68	36.57	22.99
48	61.82	61.82	35.04	21.77
60	63.36	64.10	33.64	20.55
120	69.49	73.77	28.01	15.07

V. Conclusion

This study has used the restrictions implied by two common macroeconomic equilibrium relationships to reduce the number of ad hoc restrictions necessary to structurally identify a dynamic time series model of the monetary base growth, the three-month T-bill interest rate and the CPI inflation rate. The two equilibria are supported by the empirical results such that two cointegration vectors exist between the three variables and the space spanned by the cointegration vectors is statistically identical to that which is theoretically implied.

The main result is that a structural VAR based upon the cointegration results yields impulse responses that demonstrate both the liquidity effect and the Fisher effect. The former is associated with transitory innovations in money growth supply while the latter is associated with permanent innovations in money growth. Further analysis was also able to reconcile the divergent results of early studies and more recent ones. Specifically, since the early 1970s the importance of the transitory money growth supply shock has diminished in its ability to explain money growth changes while at the same time the importance of the permanent innovation has risen. This implies that reduced form models are less capable of capturing the important source of the liquidity than they once were.

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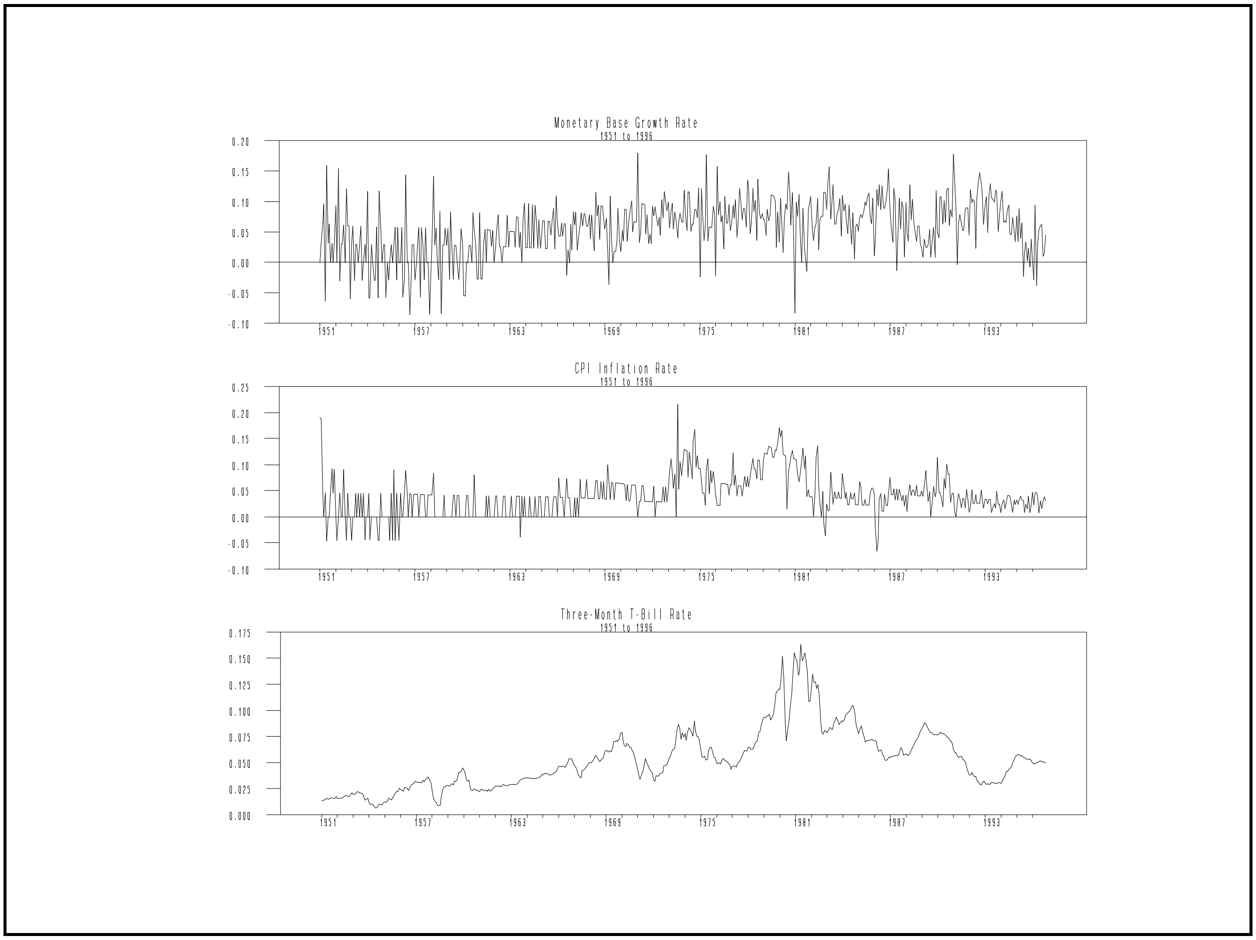

Monetary Base Growth Rate
1951 to 1996
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
1951
1957
1963
1969
1975
1981
1987
1993
CPI Inflation Rate
1951 to 1996
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
Three-Month T-Bill Rate
1951 to 1996
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000

Figure 1

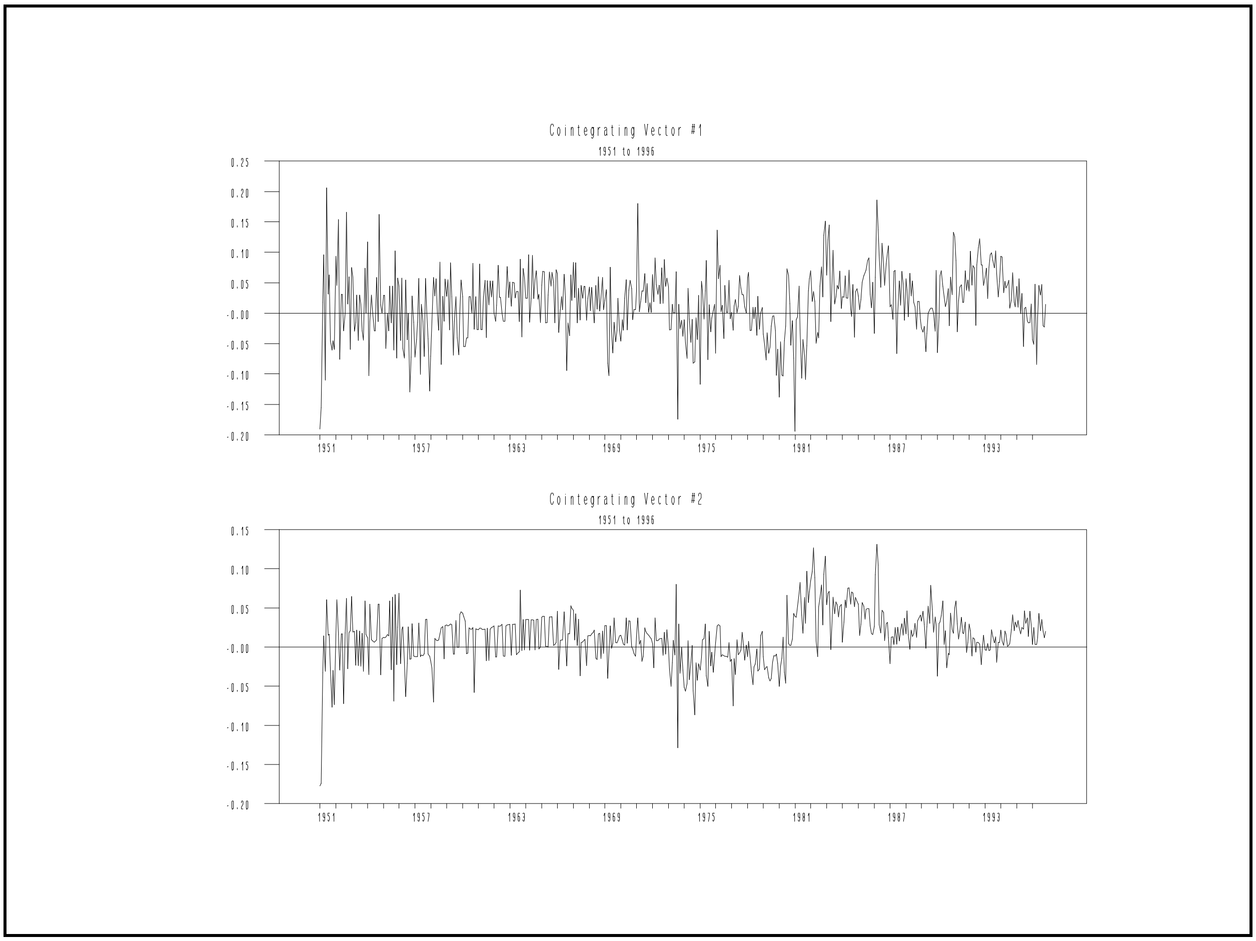

Cointegrating Vector #1
1951 to 1996
0.25
0.20
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
-0.20
1951
1957
1963
1969
1975
1981
1987
1993
Cointegrating Vector #2
1951 to 1996
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
-0.20
1951
1957
1963
1969
1975
1981
1987
1993

Figure 2

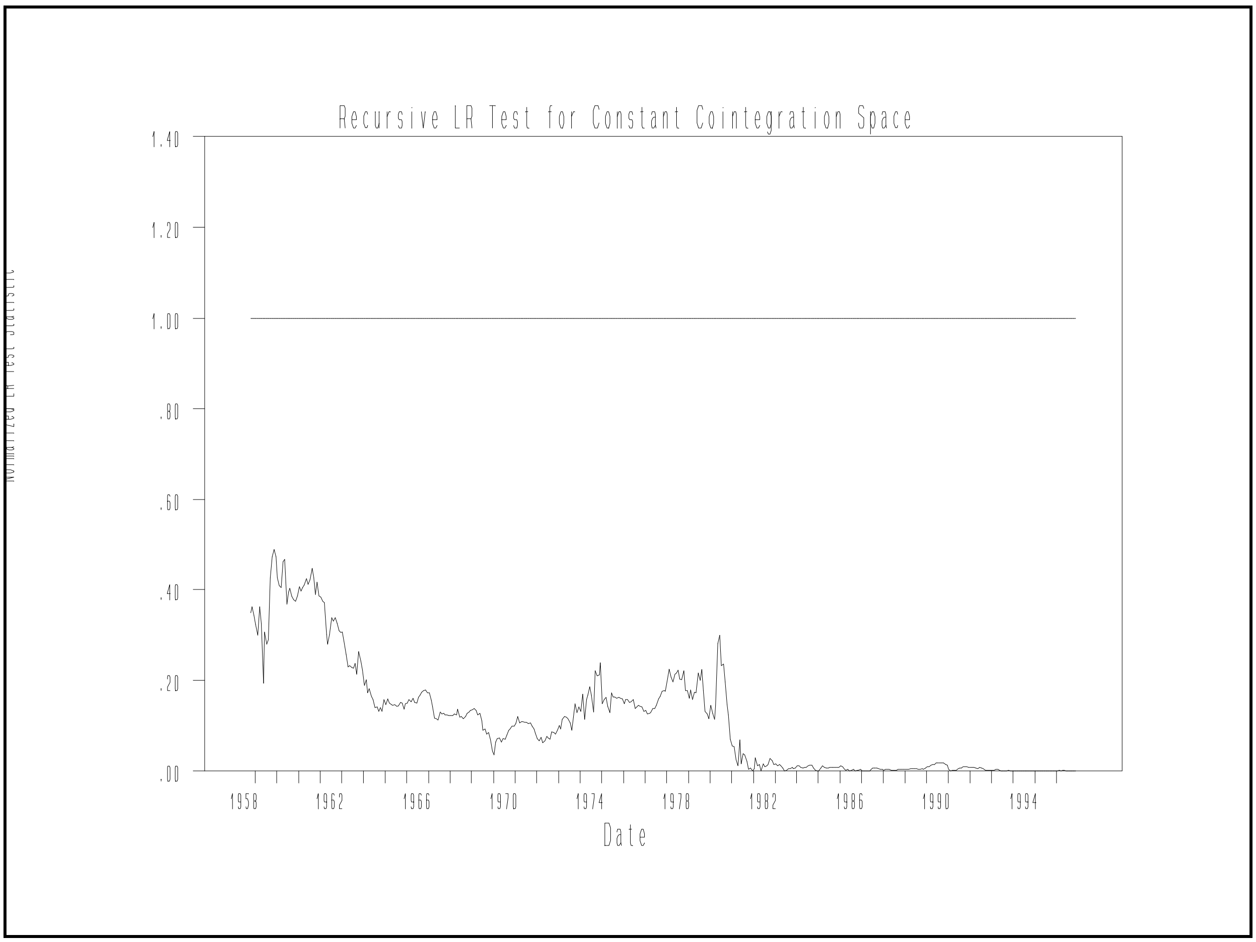

Recursive LR Test for Constant Cointegration Space
1.40
1.20
1.00
.80
.60
.40
.20
.00
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
Date

Figure 3

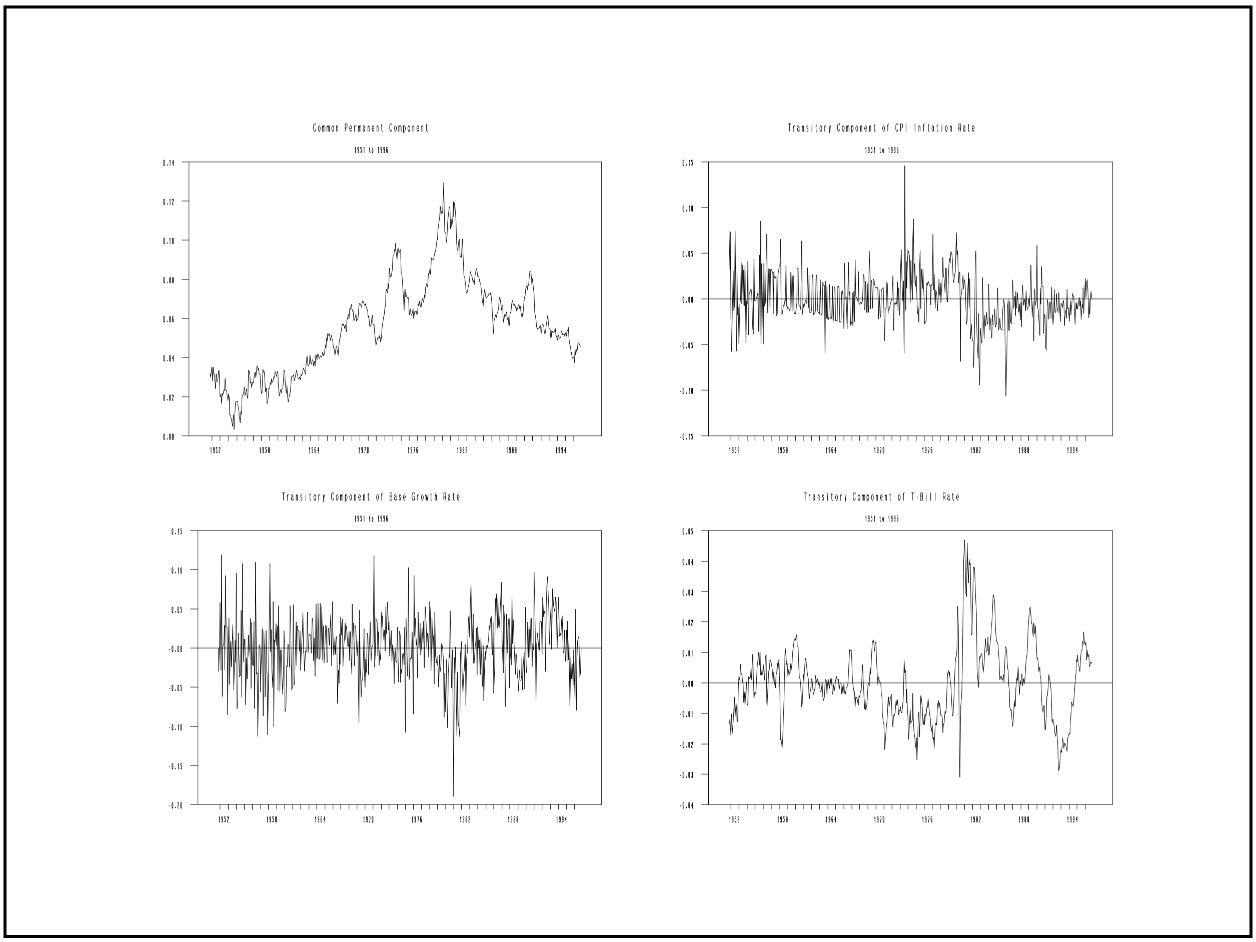
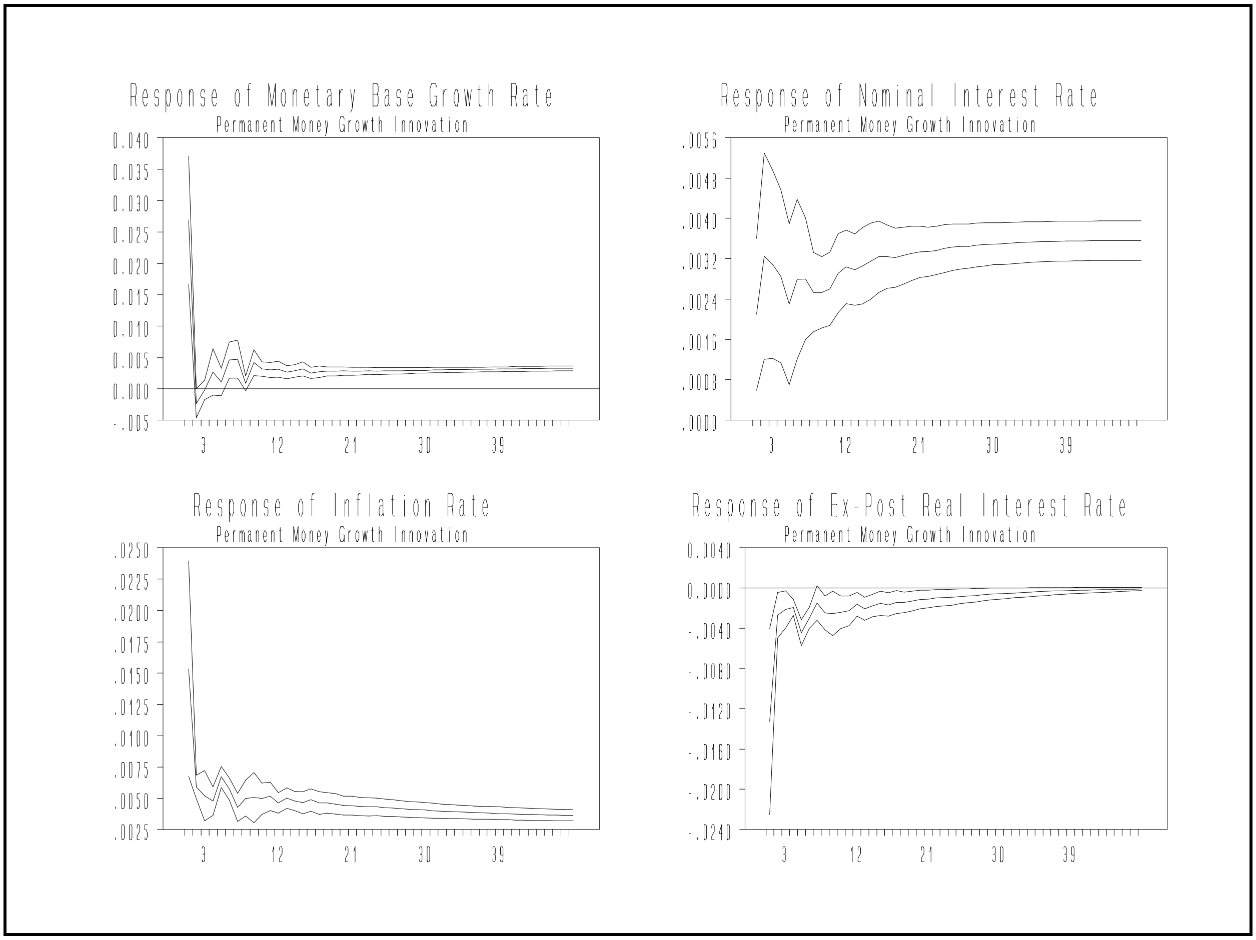
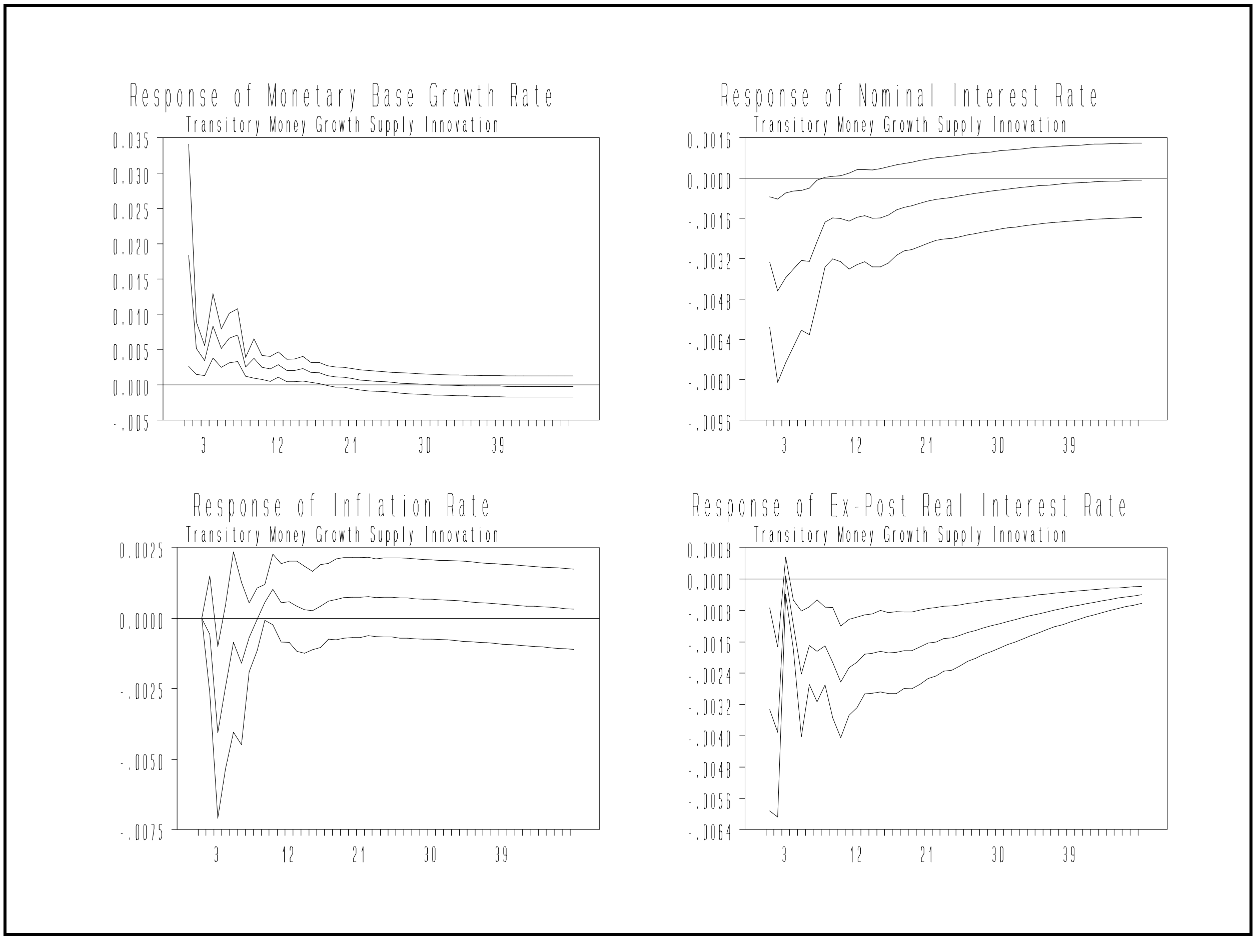

Common Permanent Component
1951 to 1996
Transitory Component of CPI Inflation Rate
1951 to 1996
Transitory Component of Base Growth Rate
1951 to 1996
Transitory Component of T-Bill Rate
1951 to 1996

Figure 4



Response of Monetary Base Growth Rate
Permanent Money Growth Innovation
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-.005
3
12
21
30
39
Response of Nominal Interest Rate
Permanent Money Growth Innovation
.0056
.0048
.0040
.0032
.0024
.0016
.0008
.0000
3
12
21
30
39
Response of Inflation Rate
Permanent Money Growth Innovation
.0250
.0225
.0200
.0175
.0150
.0125
.0100
.0075
.0050
.0025
3
12
21
30
39
Response of Ex-Post Real Interest Rate
Permanent Money Growth Innovation
0.0040
0.0000
-.0040
-.0080
-.0120
-.0160
-.0200
-.0240
3
12
21
30
39

Figure 5



Response of Monetary Base Growth Rate
Transitory Money Growth Supply Innovation
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-.005
3
12
21
30
39
Response of Nominal Interest Rate
Transitory Money Growth Supply Innovation
0.0016
0.0000
-.0016
-.0032
-.0048
-.0064
-.0080
-.0096
3
12
21
30
39
Response of Inflation Rate
Transitory Money Growth Supply Innovation
0.0025
0.0000
-.0025
-.0050
-.0075
3
12
21
30
39
Response of Ex-Post Real Interest Rate
Transitory Money Growth Supply Innovation
0.0008
0.0000
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-.0016
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-.0040
-.0048
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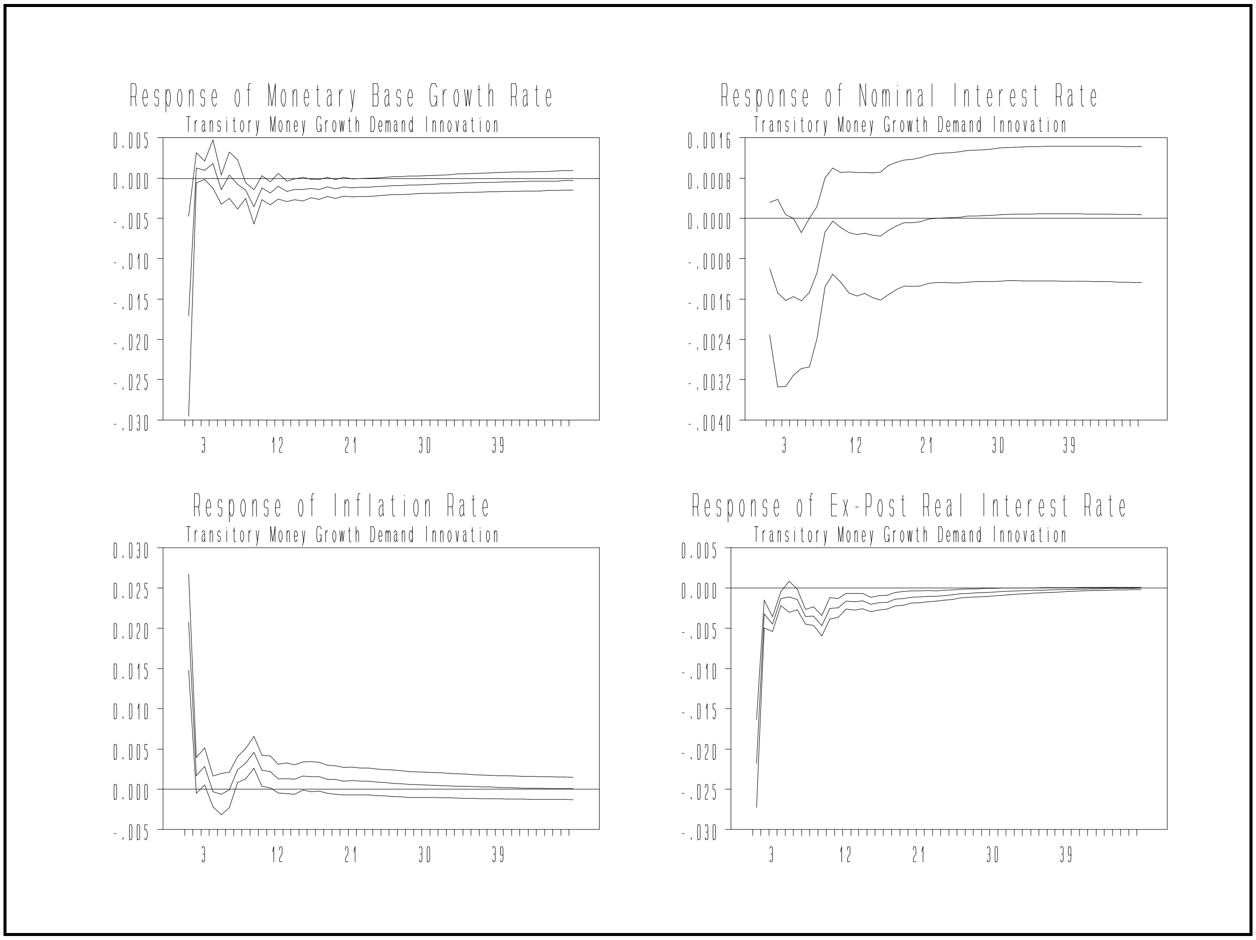
3
12
21
30
39

Figure 6


Response of Monetary Base Growth Rate
Transitory Money Growth Demand Innovation
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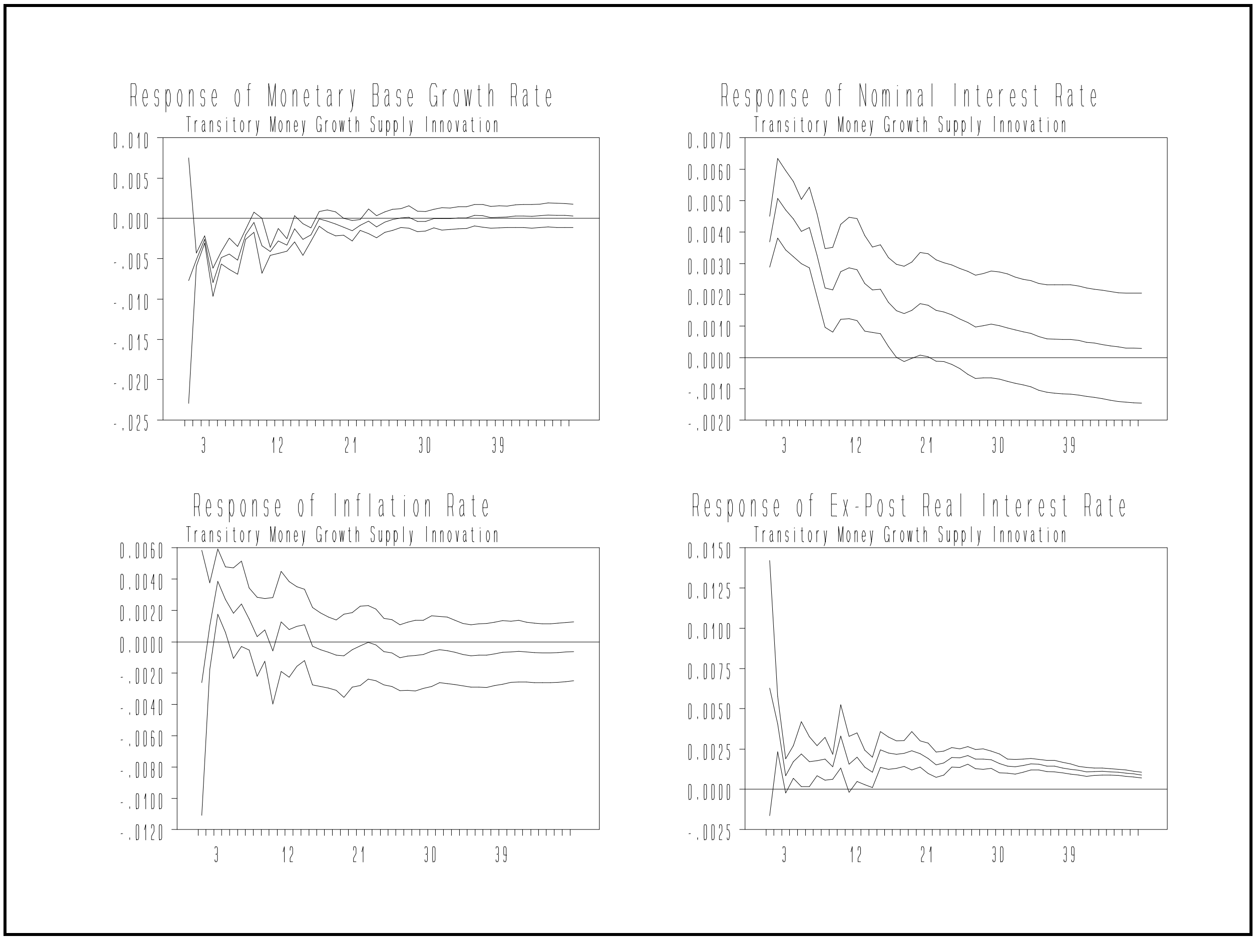
0.000
-.005
-.010
-.015
-.020
-.025
-.030
3
12
21
30
39
Response of Nominal Interest Rate
Transitory Money Growth Demand Innovation
0.0016
0.0008
0.0000
-.0008
-.0016
-.0024
-.0032
-.0040
Response of Inflation Rate
Transitory Money Growth Demand Innovation
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-.005
Response of Ex-Post Real Interest Rate
Transitory Money Growth Demand Innovation

Figure 7



Response of Monetary Base Growth Rate
Transitory Money Growth Supply Innovation
0.010
0.005
0.000
-.005
-.010
-.015
-.020
-.025
3
12
21
30
39
Response of Nominal Interest Rate
Transitory Money Growth Supply Innovation
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
-.0010
-.0020
3
12
21
30
39
Response of Inflation Rate
Transitory Money Growth Supply Innovation
0.0060
0.0040
0.0020
0.0000
-.0020
-.0040
-.0060
-.0080
-.0100
-.0120
3
12
21
30
39
Response of Ex-Post Real Interest Rate
Transitory Money Growth Supply Innovation
0.0150
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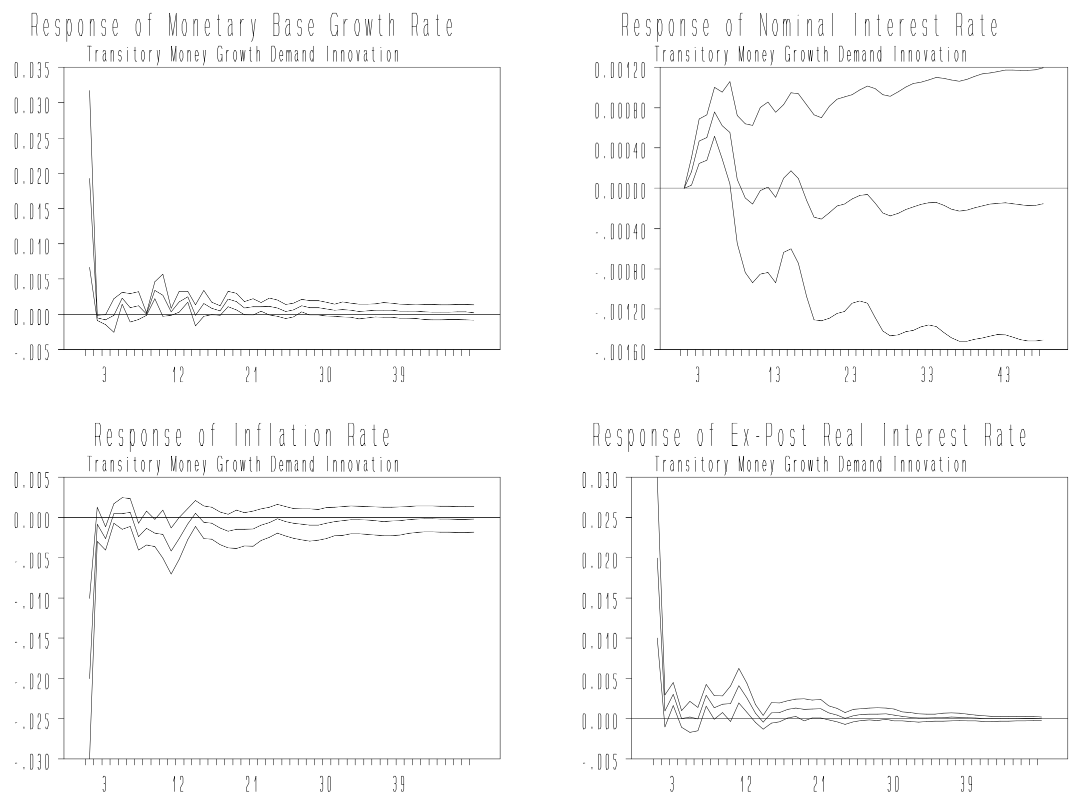
0.0100
0.0075
0.0050
0.0025
0.0000
-.0025
3
12
21
30
39

Figure 8



Response of Monetary Base Growth Rate
Transitory Money Growth Demand Innovation
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-.005
3
12
21
30
39
Response of Nominal Interest Rate
Transitory Money Growth Demand Innovation
0.00120
0.00080
0.00040
0.00000
-.00040
-.00080
-.00120
-.00160
3
13
23
33
43
Response of Inflation Rate
Transitory Money Growth Demand Innovation
0.005
0.000
-.005
-.010
-.015
-.020
-.025
-.030
3
12
21
30
39
Response of Ex-Post Real Interest Rate
Transitory Money Growth Demand Innovation
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-.005
3
12
21
30
39

Figure 9