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Output Variability and the Money-Output Relationship

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Abstract

The present paper incorporates a rolling regression approach to examine the sensitivity of output responses to monetary shocks. In doing so, the paper finds that the impact of monetary shocks is highly variable. Specifically, the output responses are estimated to be significant during the 1970s and 1990s but not during the 1980s. Several recent authors have suggested that the effectiveness of monetary policy is impacted by the stability of the economic environment, i.e., that the noise associated with estimating the true output level makes it difficult for the monetary authority to "hit its target" or even to estimate the correct target. In this case, supposed optimal policy may produce any number of possible output responses and none of these consistently. The present results provide additional evidence, as the magnitude of output response appears to be negatively related with the degree of output variability.

Key words: monetary shocks; money-income relationship; rolling vector auto regression (VAR)

JEL classification: E52; C32

1. Introduction

The hypothesized relationship between monetary changes and aggregate output has been among the most scrutinized within macroeconomics over the last quarter century. Not surprisingly, given the non-uniqueness of the theoretical literature surrounding the relationship or lack thereof, the empirical literature is quite large. Furthermore, while some empirical models have failed to estimate an impact, others suggest that the monetary authority may have a systematic impact on output. However, even these studies have generally highlighted the sensitivity of the impact to various factors. For example, Cover (1991) suggests that output responses differ

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depending on the direction of the monetary change. Cover's results suggest that while a negative monetary shock produces an output response, a positive monetary shock does not. Along similar lines, Romer and Romer (1989) suggest that the responses differ depending on the state of the business cycle. Specifically, their results suggest that output responses in expansions are significantly stronger than recessionary responses.

The present study highlights an alternative, but not exclusive, factor: the effectiveness of monetary policy is impacted by the stability of the economic environment within which it is enacted. More specifically, a relatively stable economic environment, i.e., a relatively stable level of output, elicits a relatively strong output response, while a relatively unstable economic environment produces a weak output response. Such asymmetric responses have been argued by a recently emerging subset of the monetary literature which has highlighted the difficulty of implementing monetary policy within a noisy environment, e.g., Peersman and Smets (1999), Orphanides (2003), Wieland (1998), and Rudebusch (2001). Erenburg (1993), for example, examines the impact that Kalman filter estimates of long- and short-run movements in inflation have on real output growth rates. Erenburg's results suggest that while unanticipated short-run inflation produces higher growth rates, anticipated long-run inflation produces lower growth rates. The short-run result is consistent with Lucas' (1972) seminal paper as surprise price changes elicit firm production responses. The long-run result is consistent with economic agents internalizing higher long-run inflationary expectations and following Blejer and Leiderman (1980) reduces production efficiency as firms disregard local market signals.

Furthermore, Orphanides (2003), for example, argues that, "... failing to account for the actual level of information noise in the historical data provides a seriously distorted picture of the feasible macroeconomic outcomes and produces inefficient policy rules" (p. 1). Specifically, Orphanides maintains that increased noise within the data acts as a "counterweight" and reduces the effectiveness of interventionist monetary policy. In this case, monetary policy shocks may lose effectiveness or may even be counter-productive. In other words, activist policy may produce any number of possible output responses and none of these consistently.

In general, the results of this paper suggest that while monetary shocks may have an impact on output, their impact is significantly diminished during periods of high output volatility, i.e., periods of increased noise. Specifically, we estimate a six-variable rolling vector autoregression (VAR) and examine associated impulse response functions and variance decompositions. The approach allows us to create a time series of the impact of monetary shocks on output. We then compute a GARCH(1,1) representation of the conditional variance of output.

Overall, the two time series, the impulse responses and variance decompositions, report a marked reduction in the impact of a monetary shock during the highly volatile 1980s. For example, more than 50% of the variance decomposition of output can be attributed to monetary shocks for the late 1990s, a period characterized by the least output volatility. In contrast, monetary shocks explain less than 5% of output variance during the early 1980s, a period characterized by the greatest output volatility. The 1970s provide a middle ground with a value close to 15%.

The plan of the paper is as follows, Section 2 describes the incorporated data and the basic rolling VAR econometric methodology. The following section reports the empirical results from estimating the rolling VAR and the associated impulse response functions and variance decompositions. Finally, Section 4 concludes the paper.

2. Empirical Methodology and Data

In order to measure the impact of monetary shocks on output, we follow much of the recent literature by employing an unrestricted vector autoregression (VAR), e.g., Christiano et al. (1996) and Gordon and Leeper (1992). The approach may be highlighted by the following VAR representation:

$$X_t = \Gamma_0 + \sum \Gamma_i X_{t-i} + \varepsilon_t \,, \tag{1}$$

where X_t represents a p-element vector of n observations on all variables in the system at period t, Γ_0 captures the $p \times 1$ vector of intercepts, and Γ_i contains the ($p \times p$) estimated coefficients for each of the i lags, i = 1, 2, ..., k.

Equation (1) requires the researcher to choose both p, the number of variables to include, and k, the lag structure. As is described in Christiano et al. (1996), the choice of p involves a tradeoff between competing goals: parsimony for identification purposes and removing possible biases associated with omitting relevant variables. Specifically, increasing p increases the number of parameters which must be estimated, i.e., $(kp+1)p$, while decreasing p increases the likelihood of omitted variable bias.

Given these competing goals, we adopt a strategy similar to other authors by choosing a middle ground. Specifically, we incorporate a six-variable system where the variables largely fall into four groups: output, prices, money, and interest rates. More specifically, our analysis requires a minimum of two variables: a monetary measure (FF_t) and an output measure (Y_t). While there are a number of options for the monetary measure, we follow McCallum (1983), Bernanke and Blinder (1992), Leeper (1992), Sims (1986, 1992), and Morgan (1994) and incorporate the federal funds rate. The choice revolves around Laurent (1988) and Bernanke's (1990) recognition that much, if not most, of recent monetary policy changes have been implemented through changes in the funds rate. However, the following results are robust to the use of the alternative monetary measures. In order to maintain the monthly information contained within the monetary measure, we introduce industrial output as our output measure.

In addition to output and monetary measures, we incorporate two price measures, the consumer price index (P) and the spot market index for all commodities (CP). At this point it is customary to note that the integrated level of aggregate price measures is far from a settled issue. However, we believe that the momentum is moving toward an I(1) representation. Recently, for example, Miller (1991), Konishi et al. (1993), Lastrapes and Selgin (1994), and Cutler et al. (1997) all have found that aggregate prices are I(1).

In any event, while the price index is included to capture an alternative non-output response to monetary shocks, the commodities price index is introduced to account for the so-called "price puzzle." As has been well documented in the literature, the puzzle describes the empirical finding of a negative correlation between inflation and money shocks, e.g., Eichenbaum (1992) and Sims (1992). Sims (1992) suggests that the puzzle is an outgrowth of excluding endogenous policy responses to inflationary pressure and further suggests that it may be solved by introducing a proxy for world commodity prices within the VAR framework. Specifically, Sims (1992) suggests that the commodity price measure may account for the fact that the Federal Reserve utilizes this information when setting its reaction function.

Finally, we also included $M2_t$ and total reserves TR_t within the VAR framework. The two variables are introduced to capture demand side adjustments. Following a large and rudimentary literature, Kim (1999) introduces M2 to capture the usual money demand movements. Total reserves are further introduced to capture Strongin's (1995) argument that innovations in total reserves conducted by the Fed mainly reflect the changes in the mixture of borrowed and non-borrowed components to accommodate for innovations in the demand for total reserves. Thus, including the two variables into the VAR may account for the demand shocks in M2 and total reserves and may help identify the policy innovations. In summary, then, the incorporated X_t contains the following six variables: FF_t, Y_t, P_t, CP_t, $M2_t$, and TR_t.

As is documented in much of the related literature, our data are non-stationary and have at least one cointegrating relationship. As pointed out by Phillips and Durlauf (1986), Stock (1987), West (1988), and Sims (1990), econometric models can be estimated with raw data in levels if the non-sationarity data are also cointegrated. In this case, OLS, and thus VAR, provides consistent parameter estimates for non-stationary variables that are cointegrated. Thus, all the variables used in this study are in levels. In addition, the data have been logged, excluding (*N*), seasonally adjusted, excluding (*N*) and (*CP*), and were obtained from the Citibase data set and extend from 1959:01 to 1999:11.

While introducing the six variables within Equation (1) yields estimates for Γ_0, Γ_i, and ε_t, we require the underlying structural (economic) shocks. In order to extract these shocks, we follow Eichenbaum (1992), Sims (1992), Strongin (1995), and Christiano et al. (1996) by placing Y_t, P_t, and CP_t first to reflect the assumption that policy responds to current conditions. In this case, we assume the following Wold-ordering for X_t: (Y_t, P_t, CP_t, $M2_t$, FF_t, TR_t). Furthermore, we stipulate the following relationship between the reduced form errors, ε_i, and the underlying structural shocks, μ_i:

$$\mu_i = C * \varepsilon_i , \qquad (2)$$

where C is lower triangular and ε_i has a covariance matrix equal to the identity matrix. We may therefore use the Choleski decomposition to obtain the underlying structural relationships and to perform the innovation accounting. Finally, it should be noted that the following results were robust to alternative orderings of the latter (3) variables.

The second choice is to choose a lag structure k. The VARs are estimated using monthly data over the period 1960:01-1999:11 with 13 lags of the variables in the system. As pointed out by Friedman (1968), Tanner (1979), and Dewan and Rangazas (1988), the selection of a long lag length in our VAR is consistent with the notion that monetary effects on real activity work with long lags. In addition, the following results were robust to alternative lag lengths.

Finally, we examine the volatility of industrial production, Y_t, by searching for the most parsimonious autoregressive specification. However, the ACF and PACF of industrial production suggest different lags depending on the sample periods. In addition, the high volatility of industrial production suggests some changes in the variance that can be hypothesized by the ARCH, ARCH-M, or GARCH model. We investigated a number of alternative specifications and settled on a GARCH(1,1) with an AR(6) representation. While this specification represents the most parsimonious description of output, the following empirical results were robust to the numerous alternatives.

3. Empirical Results

Our focus is to examine the impact of monetary innovations on aggregate output over time. To that end, we investigate the movements in industrial production associated with innovations in the federal funds rate. In addition, our approach is to estimate rolling versions of Equation (1) and to further incorporate these estimates to produce rolling series estimates of the associated impulse response functions (IRFs) and variance decompositions (VDs). Our choice of a rolling regression approach reflects a compromise between two competing interests. On one side we have a desire to incorporate enough information to capture the underlying relationships. However as our goal is to highlight a possible asymmetry in the responses of output to changes in monetary policy, we desire to attempt to as closely as possible mark possible changes in these responses. In this case, we are trying to capture a structural change in the responses. Our concern is then that the traditional approach would mute the actual changing points. We therefore chose windows (sample sizes) which were moderately long (150 periods) and extended these out to 200 periods. The effect of this experiment was negligible.

We chose an initial window of 180. As our data sample extends from 1960:01 to 1999:11, the initial estimation period for Equation (1) was therefore 1960:01 to 1974:11. We then estimated the associated IRFs and VDs over a 60-month horizon. In addition, 90% confidence intervals for the responses were bootstrapped with a draw of 100. The starting and ending dates were then adjusted forward by one period, and Equation (1) was re-estimated and the associated IRF, VD, and 90%

confidence intervals were re-computed. The process was continued throughout the entire sample to produce two time series of estimates ranging from 1974:11 to 1999:11.

As a point of reference, Figure 1 reports the entire sample's (i.e., 1960:01 to 1999:11) IRF and VD. In addition, we report the individual rolling estimates for three additional periods: 1960:01 to 1974:11, 1970:01 to 1984:12, and 1985:01 to 1999:11. These periods reflect the 180-period windows discussed above and allow us to examine whether the response of output may be time specific. These responses also foreshadow the results in Figures 2 and 3. Specifically, while two of the periods reflect the initial and final rolling regression estimates, the middle observation represents the sample point representing the highest degree of output volatility.

The individual estimates suggest a sensitivity of output responses to a monetary shock. Specifically, the overall sample results imply that a negative monetary shock reduces aggregate output. In addition, the overall results reflect a response much larger than any of the three sub-sample estimates. The sub-sample results, however, offer three very different pictures of the impact of a monetary shock on output. For example, while both the initial and final sub-period estimates report a significant decline in output, the 1970:01 to 1984:12 estimates do not. Moreover, even the initial and final period point estimates differ to the extent of the overall impact of the shock. Specifically, both the initial and final period estimates report significant responses corresponding to roughly 15 periods, but the final period point estimates are smaller.

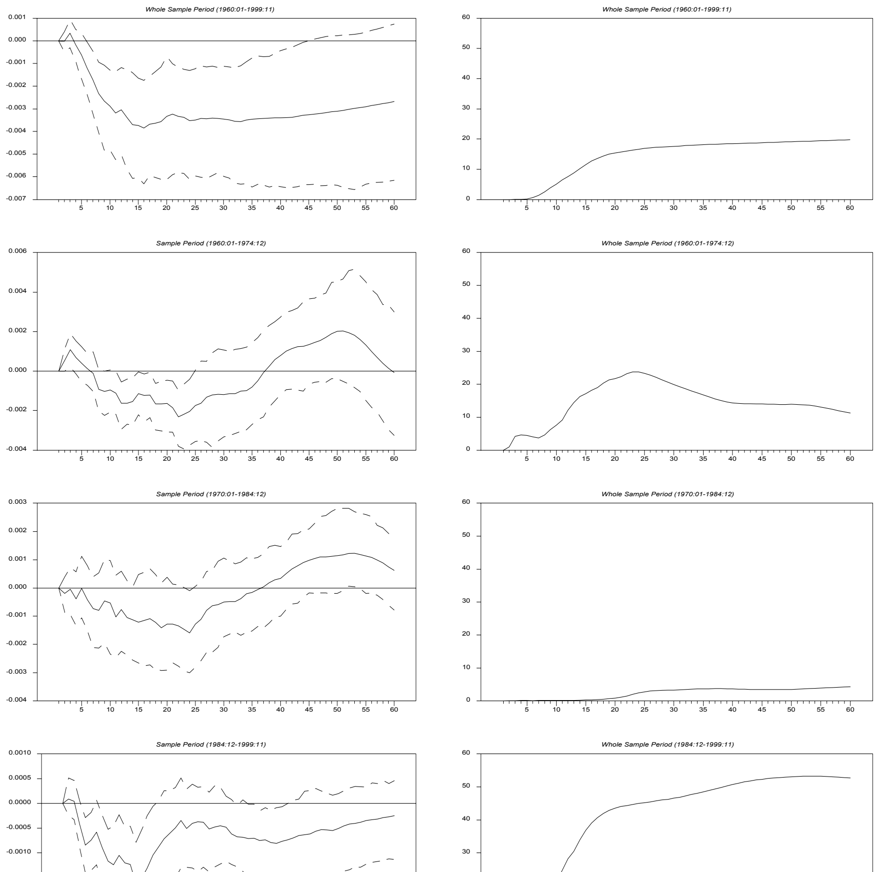
The decomposition results further highlight the variability in output responses. For example, the overall sample VD result also indicates that a monetary shock may influence output. Specifically, the results suggest that nearly 20% of the variation in output may be explained by money supply innovations. Moreover, the overall responses represent an average of the individual sub-sample findings. The three additional periods continue to produce dissimilar responses. For example, while the VD results suggest that only 10% of output variance may be attributed to a monetary shock for the initial period, the final period's value is nearly 50%. The 1970:01 to 1984:12 response suggests a value closer to 3%. Interestingly, the initial and final period results suggest that, while the impulse responses are larger in the initial period, the variance decompositions indicate a greater impact in the final period. In either event, these results suggest that the output responses vary across time.

In order to more closely examine the sensitivity of output responses to sample variation, Figures 2 and 3 report snapshots of the rolling regression for 6-, 9-, 12-, and 24-month estimates for both IRF and VD, respectively. The two series are indexed by their ending date of the sub-samples used to estimate the rolling responses. In addition, the IRFs are reported with their bootstrapped 90% confidence intervals.

Figure 1.

Impulse Resposes of Industrial Production to Money Supply Innovations

Variance Decompositions of Industrial Production to Money Supply Innovations

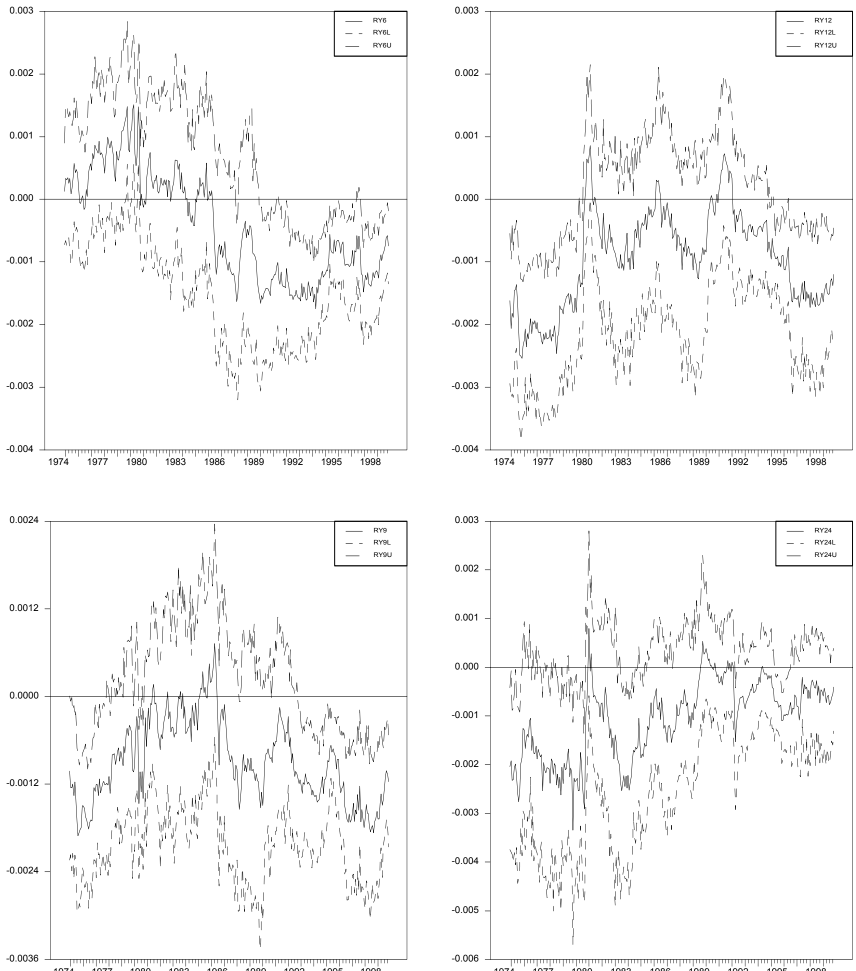


Overall, the created time series continue to highlight significant variation in the response of aggregate output to a monetary shock. Specifically, the IRFs reported in Figure 2 suggest that a monetary shock impacted aggregate output during the 1970s and 1990s, but failed to impact it during the 1980s. Moreover, the responses were more apparent in the 1990s as 6-, 12-, and 24-month responses are significant. However, both the 12- and 24-month responses were also significant during the 1970s. In contrast, none of the responses were significant during the majority of the 1980s.

Similar to the results presented in Figure 2, the variance decomposition results of Figure 3 suggest a lack of aggregate output responses during most of the 1980s. As is highlighted within the 24-month findings, the average output response during the 1980s was roughly 5%. In contrast, the 1970s was closer to 15% and the 1990s was around 30%. Furthermore, the 1990s also produced a perceptible upward trend in the responses.

Figure 2.

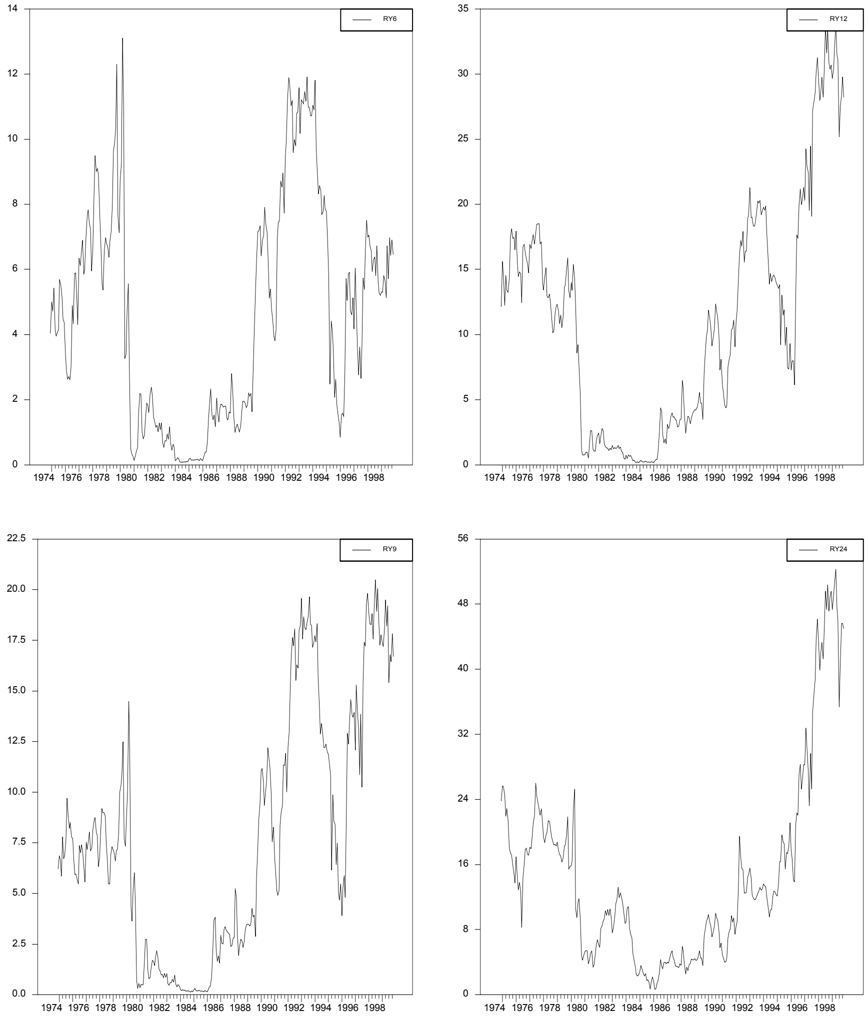
Rolling IRFs of Industrial Production to Monetary shocks at 6, 9, 12 and 24 Steps



As was discussed in the introduction, the patterns highlighted by Figures 1, 2, and 3 suggest an outside influence to the impact of a monetary shock on aggregate output. The partition of the 1970s, 1980s, and 1990s suggests that a possible influence is the behavior of output. As has been highlighted by numerous authors, the latter part of the 1980s and 1990s were periods of significant decline in output variability.

Figure 3

The Rolling VDs of Industrial Production to Monetary shocks at 6, 9, 12 and 24 Steps



As mentioned earlier, we desire to examine the correspondence of our results with the behavior of output. We therefore estimated rolling estimates of the conditional variance of industrial production. The approach was similar to our earlier analysis, as we estimated the variance measure with starting and the ending dates corresponding to the rolling impulse response and the variance decomposition dates. We then calculated the mean of the GARCH(1,1) conditional variance for each sample. The time series estimates are presented in Figure 4.

Figure 4

The Rolling Mean Variance of Industrial Production

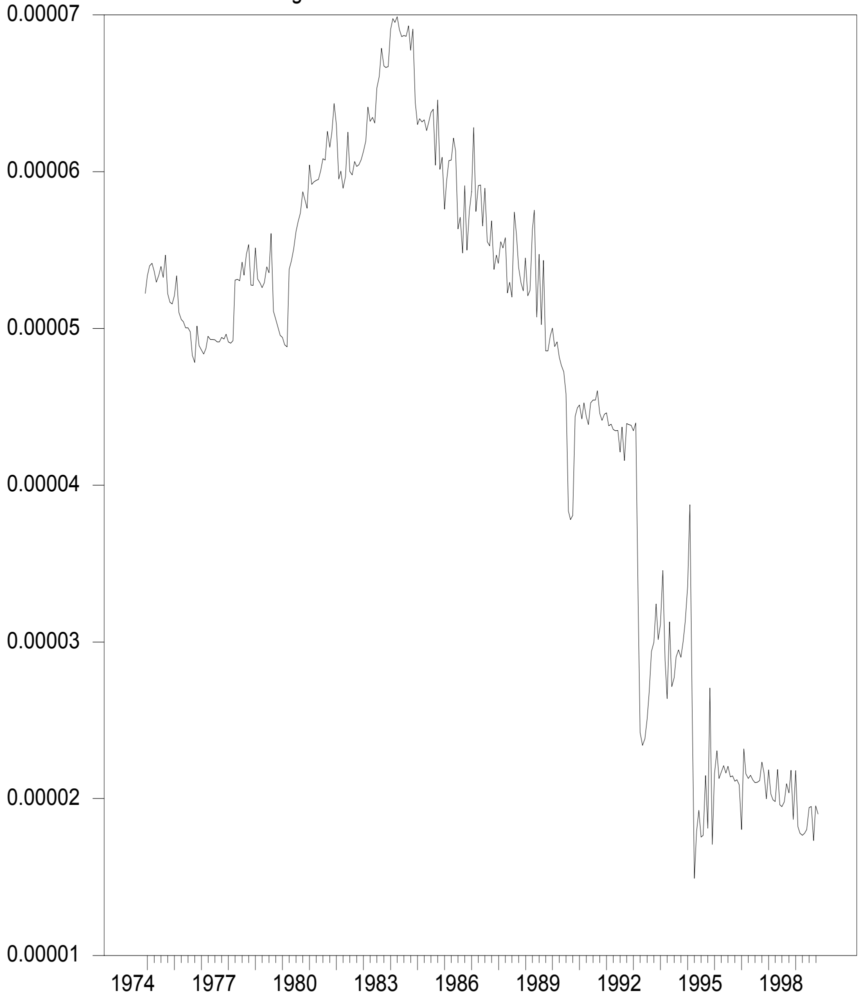
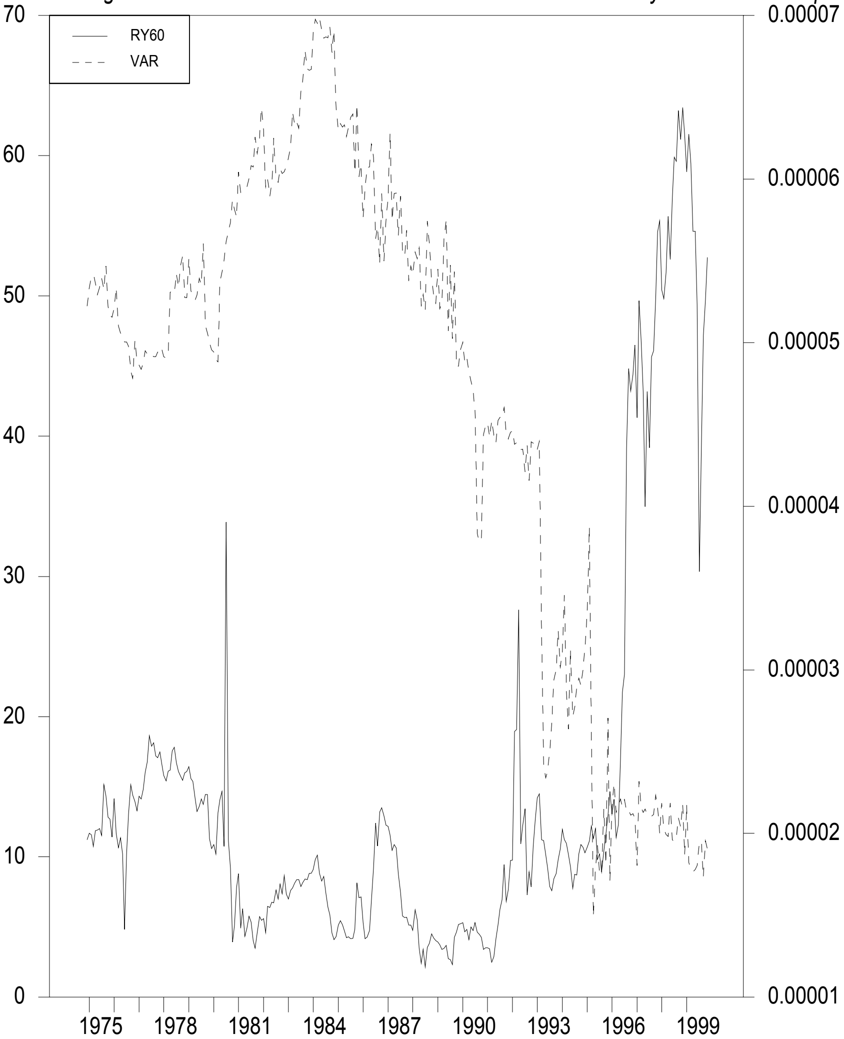


Figure 4 suggests a segmenting of time similar to those presented in the earlier Figures. Specifically, while the variance measure was larger than in latter periods, the measure was stable during the latter 1970s. During the initial period of the 1980s, there was an appreciable rise in the variance measure reaching its peak near the close of 1983. The following period produced a large decline in output variance. In order to more fully highlight the correlation between output responses to monetary innovations and output variability, Figure 5 combines both the output variance measure of Figure 4 with the 60 month VD result. Overall, then, the results suggest a strong inverse relationship between the output responses and output volatility.

Figure 5

The Rolling Mean Variance and VDs of Industrial Production to Monetary shocks at 60 Step



4. Conclusion

The paper has examined the impact of monetary innovations, in terms of the federal funds rate, on aggregate output. In order to more closely investigate the sensitivity of the response to specific time periods, we estimated rolling versions of a six-variable vector autoregressive (VAR) model. We further incorporate the rolling VAR estimates to produce rolling time series estimates of the associated impulse response functions (IRF) and variance decompositions (VD). Finally, we estimated a parsimonious GARCH representation of output variance.

Overall, the IRF and VD results suggest dissimilar responses. Specifically, while the two series suggest a significant response of output to monetary innovations during much of the 1970s and 1990s, the 1980s failed to produce a response. Furthermore, while the decline of output responses corresponds directly with periods of rising output volatility, the rise of output responses corresponds with periods of falling volatility.

The suggestion that the response of output may be influenced, or hampered, by output volatility follows several recent authors who maintain that rising volatility creates additional noise within the output data. The added noise, therefore, adds to the uncertainty surrounding the optimal values for relevant economic measures and reduces the effectiveness of interventionist monetary policy. In this case, following Rudebusch (2001), the Federal Reserve should opt for a more judicious use of monetary policy.

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