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Does It Matter How Monetary Policy is Implemented?

by

Joseph H. Haslag, Research Department
Federal Reserve Bank of Dallas

and

Scott E. Hein, Finance Department
Texas Tech University

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Joseph H. Haslag*

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Abstract: In the U.S., existing monetary base measures add an adjustment factor for changes in reserve requirement ratios to high-powered money, de facto treating the policy actions as having the same effect. Yet, theory predicts that the effects of changes in reserve requirements on prices and output are different from the effects of changes in high-powered money. We estimate structural VARs, looking at the degree to which the Fed offsets changes in reserve requirements and whether the policy actions have differential effects on output growth and inflation.[1]

* Research Department, Federal Reserve Bank of Dallas and Department of Economics, Southern Methodist University

** First National Bank at Lubbock Distinguished Professor, Finance Department, Texas Tech University

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1. Introduction

Monetary policy in the U. S. is implemented through open market operations, discount window borrowings, and changes in reserve requirement ratios. In open market operations and discount window borrowings, the monetary authority changes nominal balance-sheet quantities. In contrast, changes in reserve requirement ratios represent a tax on intermediated deposits. Since the tools differ in this regard, there is a natural question as to whether the economic response depends on how monetary policy implemented. Yet, Federal Reserve system monetary base measures do not differentiate between the three tools. Implicitly, the monetary base measure treats changes in reserve requirement ratios as having the same effects as changes in nominal quantities due to open market operations or discount window borrowing. By using the monetary base measure as the chief policy indicator, one presumes that the economic effects of the alternative policy tools are quantitatively similar. Plosser (1989) explicitly questions the validity of this restriction: "...monetary base numbers are peculiar mixtures of real and nominal elements of monetary policy. The practice of adjusting the base figures for reserve requirement changes confuses real and nominal disturbances" (p. 261).[2]

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[2] Plosser (1989) and Haslag and Hein (1992) have separately provided evidence suggesting that differences emerge in Granger causality tests. For example, changes in reserve requirements help to predict changes in both output growth and inflation, whereas changes in high-powered money growth only help to predict changes in inflation.

The importance of the monetary base in policy discussions has increased over recent years. Brunner (1981), Meltzer (1984), Poole (1982), Friedman (1984), and McCallum (1988) have argued that the monetary base should be the centerpiece of monetary policy. But, are the quite diverse monetary policy tools adequately summarized in one measure?[3] If the answer to this question is yes, the implication is that policymaker need not care how monetary policy is implemented because the effects of are similar. Consequently, the amalgam monetary base measure adequately captures the thrust of alternative policy actions. In contrast, using the monetary base in empirical analysis is not as problematic if the evidence suggests that changes in reserve requirement ratios have the same effect as changes in high-powered money.

In addition to the policy implications, the monetary base is frequently used in empirical studies. By not separating out the effects of changes in reserve requirement ratios and high-powered money, empirical work using adjusted monetary base measures

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[3] Some people might suggest looking solely at the Federal Reserve's balance sheet, considering high-powered money. The potential problem is that high-powered money could omit important information in the conduct of monetary policy. Haslag and Hein (1989) provide evidence consistent with the notion that changes in high-powered money are coordinated with changes in reserve requirements. Focusing on high-powered money would give a distorted view of monetary policy for those cases: a decrease in high-powered money signals a contractionary monetary policy action. Now suppose that the open market sale offsets a lower reserve requirements. More will said of this type of coordinated monetary policy when we directly test the hypothesis that the Fed uses open market operations to offset changes in reserve requirements.

implicitly impose the condition that the effects of changes in reserve requirement ratios and changes in high-powered money base are equal.

The purpose of this paper is to empirically investigate whether the macroeconomic effects of changes in the Federal Reserve's balance sheet--high-powered money--are significantly different from the effects of changes in reserve requirement ratios. Plosser (1989) and Haslag and Hein (1992) find that different policy actions have different predictive qualities in atheoretical macroeconomic settings. In contrast to those earlier works, our focus is on interpreting structural differences.[4] Here, the competing hypothesis--whether differential output growth or inflation effects are indicated in the data--is tested, using a structural VAR. More specifically, we test the validity of the equality restriction imposed in the monetary base measures, focusing on the monetary policy effects on real GDP growth and inflation, both contemporaneously and over time.

Two main findings are presented in this paper. First, we find evidence that the Fed systematically offsets changes in reserve requirements with changes in high-powered money. Thus, the Fed smooths the effects of changes in its blunt instrument--reserve requirements--with open market operations. For example,

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[4] Here, we use the term structural in the sense that the model is motivated by explicit economic theory [see Bernanke (1986)].

the Fed partially offsets the amount of reserves freed by lowering reserve requirements with open market sales. Hence, the net effect of lowering reserve requirements is a higher growth rate for the monetary base, but not as much as would be suggested by isolated analysis of reserve requirement changes.

Second, the data are consistent with the hypothesis that there are significant differential effects on both inflation and output growth. These differences are not indicated in the contemporaneous relationships, but emerge over time. Thus, the empirical results suggest that the way in which monetary policy is implemented does matter in the sense that the paths of output growth and inflation differ (significantly) when one changes the contribution to monetary base growth from reserve requirements and high-powered money by equal magnitudes.

The paper is organized as follows. In section 2, the literature is reviewed and the testable hypothesis are identified. We empirically test the restriction that changes in reserve requirement ratios are equal to changes in high-powered money in section 3. In addition, we specify alternative models to check the robustness of the findings. The dynamic responses are plotted and discussed in section 4. Section 5 provides a brief summary of the results.

2. Competing Hypotheses

Do changes in reserve requirements and high-powered money have equal-sized effects on prices? The theoretical literature appears split on this issue. Romer (1985) examines this question in a general equilibrium model. He finds that an increase in the reserve requirement does not affect steady state inflation (p. 183). In contrast, Romer's model predicts that changes in high-powered money do affect the inflation rate.

Freeman (1987) specifies an overlapping-generations model in which reserve requirements are necessary for agents to hold fiat money. Both capital and government bonds offer strictly higher rates of return. Using Freeman's model, however, one can show that the elasticity of the inflation rate to a change in reserve requirements is equal to the elasticity to a change in high-powered money.

These studies establish the null and alternative hypotheses for the effects of changes in reserve requirements on inflation. In short, Freeman's model predicts that changes in reserve requirements and changes in high-powered money will have equal-sized effects on the inflation rate. This model provides a theoretical justification for adding the reserve adjustment measures to high-powered money, as is currently done. This is the null hypothesis in our subsequent empirical work. Conversely, the Romer model predicts differential effects for the different policy actions, establishing the basis for the alternative hypothesis.

Another empirical issue is the relationship between high-powered money and changes in reserve requirements. Dwyer and Saving (1986) describe the government as having a patent on money creation. In this framework, reserve requirements serve as a licensing fee. Dwyer and Saving argue that the government's revenue from money creation is independent of whether base money is issued directly or created through the banking system. In their setup, the licensing fee establishes the allocation of revenues between government and public sources, but does not affect the size of the revenues. In other words, the government can generate the same amount of seignorage revenue with a lower growth rate of high-powered money growth when reserve requirements are lowered. Therefore, Dwyer and Saving provide a theoretical justification for a relationship between reserve requirements and high-powered money in which both are tools capable of generating seignorage revenue.

In practice, Dwyer and Saving's model predicts that, for a given level of seignorage revenue, the Fed systematically offsets changes in reserve requirements with open market operations.[5] Hence, there is some coordination between the different monetary policy actions. However, the standard textbook of monetary policy examines the effects of each policy action as if reserve requirements and open market operations are conducted independently. Here, the null hypothesis is that monetary policy actions are not coordinated. If a relationship is evident in the

[5] Muelendyke (1992) states that the Fed does offset changes in reserve requirements with open market operations. Haslag and Hein (1989) provide evidence that a negative correlation between high-powered money and the St. Louis reserve adjustment magnitude (RAM) is present.

structural model, the question then is whether the offset is full or partial.

Table 1 presents the null hypothesis that we explicitly test in the paper. As Table 1 shows, we concentrate on three main hypothesis in our empirical work. These hypothesis bear on the issue of whether the adjusted monetary base measures are justified to add the reserve adjustment measure and high-powered money. In addition to the two hypothesis regarding the effects on inflation and the simultaneous policy actions (H1 and H2), we consider the hypothesis of equal-sized effects on output growth denoted H3.[6][7] The next section implements the strategy to test these hypothesis.

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[6] Champ and Freeman (1990) find that high-powered money and reserve requirements will have differential effects on investment and output, deriving a closed-form solution for the capital stock. Champ and Freeman assume that agents have a required reserves constraint, not a percentage-of-intermediated deposit constraint. For our purposes, finding differential effects is sufficient to motivate the empirical investigation.

[7] A literature has developed that examines whether reserve requirements affect the stability of output. The models generally focus on the 0 and 100 percent reserve requirement cases. The basic idea is that reserve requirements stabilize the demand for money, and mitigate the transmission of monetary shocks to the real sector. Baltensperger (1982), for example, finds that reserve requirements do stabilize the money stock, but not necessarily increase the stability of output growth and inflation. Horrigan (1988) argues that, in general, reserve requirements do affect output variability. However, when the government targets interest rates, he finds that reserve requirements are irrelevant for economic stabilization. These hypothesis are explicitly about the relationship between the variance of output and reserve requirements. Here, we are more interested in the differential effects on the level of output growth, if any, resulting from changes in reserve requirements and changes in high-powered money growth.

3. Model Estimation

In this section, we estimate structural VARs to test whether the changes in reserve requirements and changes in high-powered money have the same effects on economic activity. We consider several different sets of identifying assumptions, thereby checking the robustness of the results. In addition to looking at the contemporaneous coefficients estimated in the particular orthogonalization, we use impulse response functions to consider if dynamic differences are suggested by the data.

Three main hypothesis are tested in the empirical section: (i) to what extent, if any, does the Fed systematically offset changes in reserve requirements with open market operations; (ii) is the effect of a change in reserve requirements significantly different from the effect of a change in high-powered money; and (iii) is the effect of a change in reserve requirements significantly different from the effect of a change in high-powered money. The last two questions bear directly on whether one should use a simple sum approach when constructing the monetary base. Since the monetary base is used extensively in empirical work, the answer could support this practice or could raise serious questions regarding the appropriate interpretation of results obtained with the simple sum measure.

3.1 Data and Related Issues

The conventional measure of changes in reserve requirement ratios is the reserve adjustment magnitude (RAM) constructed by the Federal Reserve Bank of St. Louis. Formally, $RAM_t = (r_b -$

$r_t)'D_t$, where r is a Kx1 vector of reserve requirement ratios and D is a Kx1 vector of deposit types against which reserves must legally be held. The subscript b refers to the period identified as the base period and t denotes the current time period. RAM not only changes when changes in reserve requirement ratios occur, but RAM also changes when deposit levels change, reflecting changes in the vector of deposit types, as long as $r_b \neq r_t$. Haslag and Hein (1993) have constructed an alternative measure that separates out changes in RAM due to changes in deposits from changes in reserve requirement ratios. Like RAM, the Haslag-Hein measure--denoted RSI--adds high-powered money to the reserve adjustment factor, imposing the condition that a \$1 increase in high-powered money is equivalent to \$1 freed by lower reserve requirement ratios.

Formally, $\Delta RSI_t = r_t'D_t - r_{t-1}'D_{t-1}$ (where Δ is the difference operator) for the week in which changes in reserve requirement ratios occur. It is easy to show that $\Delta RAM_t = r_b'\Delta D_t - \Delta RSI_t$ for periods in which changes in reserve requirement occur and $\Delta RAM_t = r_b'\Delta D_t - r_t'\Delta D_t$ for periods in which no changes in reserve requirement ratios occur. We use RSI as our measure throughout the empirical analysis because changes in this measure are straightforwardly interpreted as changes in reserve requirement ratios. The data used in this investigation are quarterly and are, except for RSI, seasonally adjusted.[8]

Following the definition of the monetary base, high-powered money growth and RSI growth are defined in (centered) percentage-change form relative to the monetary base; that is, $\hat{H}_t = \Delta H/[(MB_t + MB_{t-1})/2]$ and $\hat{RSI}_t = \Delta RSI/[(MB_t + MB_{t-1})/2]$, respectively, where H denotes the level of high-powered money and MB is the monetary base. These two variables are used separately in explaining macroeconomic behavior. The measure of output is real GDP, while inflation is measured as the fixed-weight GDP deflator (1982=100).

One property of our definition of the monetary base components is that permanent changes in reserve requirements show up as one-time changes in RSI, and hence, $\hat{RSI}$. Note that RSI will follow a pattern identical to a series with infrequent, permanent shocks. Balke and Fomby (1992) show that one will fail to reject the hypothesis of a unit root in time series subject to infrequent, permanent shocks. Constructing our series in percentage-change form relative to the monetary base serves two purposes. First, and most important, the approach permits us to directly test whether a change in monetary base due to a change in reserve requirements has a different effect on macroeconomic

[8] See Haslag and Hein for a detailed description of the RSI measure. We also used the St. Louis RAM to capture the effects of changes in reserve requirements. RSI is not seasonally adjusted since there is no apparent seasonality regarding when the Fed elects to change reserve requirements. The main findings reported in this paper are not affected by substituting RAM for RSI. Tables and charts using RAM instead of RSI are available from the authors upon request.

variables under the assumption that the monetary base should be constructed as a simple-sum measure. Second, both $\hat{RSI}$ and $\hat{H}$ are stationary series.[9]

3.2 Estimation methodology

The estimation procedure is the structural VAR methodology presented in Blanchard and Watson (1986), Bernanke (1986), and Sims (1986). The procedure is employed in two estimation steps. The first step involves estimating a vector autoregression which is represented as:

$$X_t = \sum_{j=1}^{4} \alpha_j X_{t-j} + u_t, \tag{9}$$

where $X_t = [\hat{RSI}_t \ \hat{H}_t \ \hat{mm2}_t \ INF_t \ \hat{GDP}_t]$, where $\hat{mm2}$ is the growth rate of the M2 money multiplier, INF is inflation measured by the fixed-weight deflator, $\hat{GDP}$ is real GDP growth, 4 is the number of lagged values included, α is the estimated vector of reduced-form coefficients, and u_t is the vector of reduced-form residuals.

In the second step, recall that one can represent the product of structural parameters and the reduced-form errors, u_t, as the structural disturbances (see Bordo, Schwartz, and

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[9] Sims, Stock, and Watson (1990) state the conditions in which statistical inference is valid with non-stationary series. While we may suffer from over-differencing from the standpoint of the effects on output and prices, the contributions to monetary base growth due to RSI and high-powered money are appropriate for looking at output growth and inflation.

Rappaport (1991), for example); that is, the errors from the structural equations. Formally, let v_t denote the "structural" disturbances. The reduced-form errors are characterized as $v_t = u_t\Gamma$. With $E(v_t'v_t) = \Omega$, then $E(u_t'u_t) = \Phi = \Gamma^{-1\prime}\Omega\Gamma^{-1}$. One can then use the observed, reduced-form error terms and the identifying assumptions to estimate the structural coefficients. The reduced-form error terms are conceptually constructed as unanticipated innovations to the series. Thus, the identifying restrictions are applied to testing the effects of unanticipated innovations on variables and represent a rational expectations model.[10]

Table 2 reports the findings from the exclusion restrictions obtained from estimating the first step, namely estimating the unrestricted VAR using four lagged values of the variables. For each variable in the system, the null hypothesis is that coefficients on the lagged values of the excluded variable (the column heading) are jointly equal to zero. The row heading identifies the equation in which we are testing the exclusion hypothesis. Table 2 presents the results obtained when one uses

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[10] Blanchard and Quah (1989) looked at a structural VAR in which they identified permanent and temporary shocks to output. King, Plosser, Stock and Watson (1991) extended Blanchard and Quah to consider the presence of cointegrating relationships between the series in the structural VAR. In this way, the data identified long-run relationships. Here, we use contemporaneous identifying restrictions in our analysis. We tested for cointegrating relationships between the policy variables (which are non-stationary in levels) and output and prices. The evidence does not support the existence of a long-run relationship of this sort between the policy variables and economic activity.

the VAR system described above.

For the null hypothesis that changes in reserve requirement ratios help predict changes in output growth, the F-statistic is 4.01. The five-percent critical value is 2.45. Thus, the evidence from Table 2 suggests that changes in reserve requirement ratios do temporally precede movements in output growth. This finding is similar to that of Haslag and Hein (1992), although a different VAR system is specified and the measure of reserve requirements (RAM vs. RSI) is different.

In addition, the reduced-form parameters suggest that changes in source base growth provide predictive content for future output growth as the F-statistic is 2.98. However, the F-statistic is 1.37 under the null hypothesis that changes in high-powered money help to predict changes in the inflation rate, (the 10-percent critical value is 1.99) rejecting the notion that movements in high-powered money temporally precede changes in inflation. There is also evidence suggesting that changes in the M2 money multiplier temporally precedes changes in output growth (the F-statistics is 4.62), but none of the money variables help to predict changes in the inflation rate.

We estimate the following structural VAR (note that the letter u with subscripted variable names represent the reduced-form, or one-step-ahead forecast, errors from the first step estimation). We hereafter refer to this specification as the Control model:

(1a) $u_{RSI} = z1_t$

(1b) $u_H = \beta_1 u_{RSI} + \beta_2 u_{mm2} + \beta_3 u_{INF} + z2_t$

(1c) $u_{mm2} = \beta_4 u_{INF} + \beta_5 u_{GDP} + z3_t$

(1d) $u_{INF} = \beta_6 u_{RSI} + \beta_7 u_H + z4_t$

(1e) $u_{GDP} = \beta_8 u_{RSI} + \beta_9 u_H + \beta_{10} u_{mm2} + z5_t$,

where u with a subscript denotes the innovation from the reduced-form equation.

Equation (1a) postulates that innovations in RSI are a structural disturbance. Equation (1b) specifies that movements in high-powered money respond contemporaneously to innovations in RSI, indicating that changes in reserve requirement ratios are contemporaneously offset ($\beta_1 < 0$) by changes in high-powered money. This specification examines the Fed's willingness to coordinate different types of monetary policy actions; specifically testing whether there is any contemporaneous coordination of reserve requirement changes and money growth. If so, the evidence gives further credence to the notion that the monetary authority uses fiat money to offset the effects of changes in reserve requirements. In addition, equation (1b) specifies that high-powered money responds to movements in the money multiplier. This specification can be motivated as the Fed trying to achieve its M2 target path. Hence, reductions in M2 money multiplier would be met be increases in base growth.

Equation (1c) is a money demand function. We postulate that innovations in inflation and income affect the demand for M2 assets. We assume that innovations in the money multiplier do not affect the inflation rate, but can affect the output.[11]

Equations (1d) and (1e) represent the contemporaneous models of inflation and output growth, respectively. In these specifications, we can test directly whether innovations in reserve requirements and high-powered money have differential contemporaneous effects.

The top portion of Table 3 reports the estimated contemporaneous coefficients for the structural VAR described in equations (1a-e). Three key conclusions are illustrated in these results. First, note the strong, negative coefficient on the reserve requirement variable in the high-powered money equation. The evidence, therefore, suggests that decreases in reserve requirements, for example, are contemporaneously (within quarter) offset by open market sales. Note also that the coefficient on RSI is significantly less than one (in absolute values), so that the Fed, on average, only partially accommodates changes in reserve requirement ratios with open market operations. In other words, changes in reserve requirements have an activist component to them, but much less than suggested by this tool in isolation.

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[11] King and Plosser (1984) argue that base money is responsible for changes in prices. Movements in the money multiplier reflect "real" factors affecting output determination. Thus, a broader money measure (M2, for example, separated into its base and money multiplier components) is the appropriate measure to gauge monetary policy in their real business cycle model. We consider the contemporaneous role of each component in affecting output growth and inflation in other structural VARs that are used to monitor the robustness of our findings.

Second, the coefficient on high-powered money in the inflation equation is significant at the 10-percent level. The coefficient on RSI is not significant even at marginal levels. Under the null hypothesis that the coefficient on high-powered money is equal to the coefficient on RSI, the t-statistic is 0.52. Hence, one cannot reject the null hypothesis that the effects of changes in high-powered money have the same <u>contemporaneous</u> effect on inflation as changes in reserve requirement ratios.

Third, none of the variables are significant in the output equation. Testing whether the coefficient on RSI is equal to the coefficient on high-powered money, the t-statistic is 0.94. The findings, therefore, indicate that neither RSI nor H are contemporaneously correlated with output growth. Moreover, the effects of changes in reserve requirements and high-powered money on output growth are not statistically differently from one another.

The middle portion of Table 3 reports the estimated contemporaneous coefficients for a modified version of the model used in Sims (1986) paper. Here, the main modification to Sims structure is that the M1 money supply is separated into its money multiplier, high-powered money and RSI components. Other differences include using the implicit price deflator as the price measure and GNP as the output measure. In addition, the sample period is 1948-90.

Generally, the results from the modified-Sims model support the findings reported in the Control model. In particular, there is a negative contemporaneous relationship between changes in reserve requirements and changes in high-powered money. The results from the modified-Sims model also indicate that the Fed systematically and partially offsets the increase in monetary base growth due lower reserve requirements by reducing the contribution due to high-powered money growth. The modified-Sims model excludes reserve requirements and high-powered money from the output growth equation. In the inflation equation, neither high-powered money nor RSI has a significant contemporaneous relationship with inflation. More importantly for our purposes, the coefficients are on RSI and H are not significantly different from one another (t-value = -1.14).

Finally, we specify a third structural VAR, one in which supply shocks play a prominent role. In particular, the relative price of energy is included to account for the chief shocks hitting the economy during the 1970s. The bottom portion of Table 3 reports the contemporaneous effects from this supply-shock model. As in the models above, changes in reserve requirements are contemporaneously correlated with changes in high-powered money and this is a partial offset. The evidence indicates that general price level changes are not contemporaneously related to changes in the relative price of energy, suggesting that energy prices move one-for-one with the price level (equation 2). In addition, inflation is posited as a function of shocks to the relative price of energy and output growth. Neither energy price shocks nor output growth contemporaneously affect the inflation rate. Note that the contemporaneous coefficients on high-powered money and the M2 money multiplier are significant and positively related to changes in output growth.

We test for equal-sized coefficients on the monetary variables in both the inflation and output growth equations. The t-values calculated under the null that the contemporaneous coefficient on RSI is equal to the contemporaneous coefficient on H are -0.80 and -0.67 for the inflation and output growth equations, respectively.[12]

In short, we find evidence suggesting that the Fed partially offsets changes in reserve requirement ratios with open market operations. Second, the evidence suggests that the contemporaneous effects of changes in high-powered money growth and RSI on either inflation or output growth are not significantly different from one another.

4. Dynamic Responses

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[12] We tried other structural VARs differing primarily in terms of the contemporaneous reaction functions for both RSI and H. These structural VARs are not reported because they typically did not converge. The Bernanke procedure uses a nonlinear methodology to solve the simultaneous equations. When the models do not converge, standard errors are not obtained and the hypotheses in which we are interested cannot be tested.

Note further that the data do not include the interwar period (1929-45) which may be very different from the results obtained using postwar data. There is some conjecture that the Fed used reserve requirement changes without offsetting open market operations during the 1930s.

We use impulse response functions to compare different monetary policy actions over time. Milton Friedman (1969) gave considerable support to these experiments when he concluded that there is a lagged effect between monetary policy and changes in economic activity. Thus, it is more likely that differential effects present in the estimated relationships will show up in effects over time rather than in the contemporaneous effects.

Two sets of experiments are investigated here. The first set looks at the impulse responses for one-percentage-point innovations to reserve requirements and high-powered money, separately. The second set examines the responses to a simultaneous changes in RSI and H such that monetary base is constant. This second experiment takes into account the partial accommodation observed in the structural model.

Here, the result that the Fed typically offsets changes in reserve requirements with high-powered money has important implications. The impulse response function uses the contemporaneous specifications (the identifying restrictions) and the reduced-form models. One implication is that the impulse response function is conceptually similar to a total derivative, incorporating contemporaneous ("direct") channels and reduced-form ("indirect") channels. For our purposes, the contemporaneous relationship between high-powered money growth and RSI indicates an immediate response by to innovations in RSI. As such, the experiment with an innovation in RSI is not one in which other monetary policy actions are held constant. In the first set of experiments, we proceed with an innovation in RSI, recognizing the partial offset in H is present.

4.1 Independent monetary policy innovations

In the first experiment, innovations to RSI and to high-powered money are considered. As we found in the contemporaneous equations, a partial offset of changes in reserve requirements is present. With this caveat, we interpret these results as the effects of each policy action, holding the other policy action constant. Such evidence bears indirectly on the issue of whether the effects of the two policy actions are equal-sized. The impulse responses, therefore, are illustrate the effects of each action over time.

Chart 1 plots the dynamic response to a one-percentage-point increase in RSI, which contributes a one-time change in monetary base growth, using the Control model. Ninety-percent confidence intervals are included. The top panel in chart 1 is the inflation-rate response. As the chart shows, the inflation-rate responses are not significantly different from zero during the first few quarters after the reserve requirement shock. However, in the fifth quarter after the change in reserve requirements, the inflation rate is significantly above zero, and the impulse response function remains above zero for about ten quarters. The interpretation is that a (one-time) one-percentage-point increase in RSI (a decrease in reserve requirements) results in temporarily higher inflation.

The bottom panel in Chart 1 plots the impulse response function for output growth, again assuming a 1-percentage-point increase in RSI and again using the Basic model. According to the chart, during the first two quarters after the reserve requirement shock, output growth is significantly higher. Thus, the evidence supports the notion that a one-time change in the reserve requirement ratio results a temporarily higher growth rate in output.[13] This experiment takes into account the partial offsetting of reserve requirement changes using open market operations. Recall the theoretical model predicted that using open market operations to partially offset changes in reserve requirements would result in changes in both output growth and inflation.

Chart 2 plots the dynamic responses given a one-percentage-point increase in high-powered money. The top panel of Chart 2 shows the effects of the increase in high-powered money growth on the inflation rate. As Chart 2 shows, the effect of higher base money growth rises through the first few quarter, and decays slowly as the impulse response function is still significantly above zero 20 quarters after the innovation occurs.

Chart 2 also shows that the effect that an innovation to high-powered money has on output growth. The bottom panel shows

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[13] Lougani and Rush (1991) find evidence that changes in reserve requirements do help to explain movements in output growth and investment. Note that the path for investment spending growth is qualitatively the same as output growth in all of our experiments. As such, our evidence lends further support to Lougani and Rush. Note also that they use the ratio of adjusted monetary base to high-powered money as their measure of changes in reserve requirements.

that increases in high-powered money have a negative effect on output growth about 3 years after the innovation occurs. This effect is significant at the 10 percent level (p-value is 0.097). The economic interpretation is that a one-time change in high-powered money growth has significant, temporary effects on output growth, which first rises and then falls. Statistically, the pattern of the response probably reflects the fact that the innovation to high-powered money growth is stationary so that the series tends towards it (sample) mean after an innovation occurs.

Charts 3 and 4 plot the same set of impulse response functions presented in Charts 1 and 2, except now using the modified-Sims structure and Supply-shock models, respectively. The results from both models are qualitatively similar to those reported in the Control model. There is some difference in the timing of the significant effects, but the direction of the significant effects match the main findings presented in the Control model quite closely. The results from the supply-shock differ somewhat. For example, there is no significant decline in output growth to a one-percentage-point increase in RSI.

Just looking at the charts, it is striking how similar the inflation rate and output growth responses are. Specifically, the effects of a change in RSI and in high-powered money are quite similar in shape and magnitude. Generally, the inflation rate response peaks somewhere between the first and second year after the innovation and then slowly decays. In addition, the peak response is between 0.15 and 0.30 percentage points. This pattern is observed regardless of whether the innovation is in RSI or H.

The output growth responses are also quite similar to each type of policy shock. Generally, the output growth response is more like a cycle with the maximum effect observed two quarters after the innovation and output growth falling below zero some time after the first year post-innovation. The peak response is typically between one-quarter and one-half a percentage point. The similarity in magnitude and shape is, like the inflation rate response, invariant to the source of the innovation.

The evidence thus far suggests that the two policy actions have equal-sized effects. Clearly, what one would want is a test in which equal-sized policy innovations are considered (either independently or simultaneously). The experiments considered thus far violate the standard of same-sized innovation, because of the contemporaneous relationship between shocks to RSI and high-powered money. In short, the innovation to RSI is partially offset whereas the innovation to high-powered money is not. The next section sets up an experiment in which the contemporaneous relationship is exploited.

4.2 Coordinated monetary policy innovations

In the final set of experiments, we consider the effects of a one-percentage-point positive innovation in RSI that is matched by a one-percentage-point reduction in high-powered money. The significant, negative relationship between RSI and high-powered money implies that a partial offset is already built into the model. Let -b denote the contemporaneous percentage change in H to a one-percentage-point change in RSI. We then specify a (b-1) innovation to high-powered money such that the change in RSI and high-powered money exactly offset each other in the period in which the shock occurs. Because the reduced-form system indicates different dynamic responses to these two coordinated monetary policy actions, the impulse responses are not necessarily zero. Note also that the size of b-1 differs across the different structures we estimated; the innovation to high-powered money is -0.28, -0.32, and -0.46 for the Control, modified-Sims, and Supply shock models, respectively.

Charts 5 and 6 plot impulse response functions for inflation and output growth where the innovation is the coordinated monetary policy action described above. Panels (a), (b), and (c) correspond to the Control, the modified-Sims, and the Supply-shock models, respectively. The results are fairly similar across the different structures. The general characterization is that significant, temporary increases to both output growth and inflation are present shortly after the coordinated policy innovation. So that the effects of using open market operations to fully offset changes in reserve requirements resemble the effects of the (endogenous) partial offset. Lowering reserve requirement results (temporarily) in higher output growth and higher inflation.

As Chart 5 shows, the effect of the monetary policy actions on the inflation rate is significant for only one quarter in the supply-shock model, by far the shortest significant duration in any of the three models. Chart 6 reveals another difference; specifically, the modified-Sims model indicates that output growth first increases and then declines in response to the coordinated monetary policy actions. The patten for output growth is similar to the other two models, but the responses are not significantly different from zero.

The presence of significant effects in the coordinated policy experiment is interpreted as evidence against the simple-sum approach. Suppose no significant effects were present. In this contradictory case, one could argue that coordinating monetary policy actions does not significantly affect economic activity. When considered against the findings from the non-coordinated experiments, the absence of monetary policy effects would suggest that holding the monetary base constant and changing both reserve requirements and open market operations does not affect economic activity. In this sense, the simple sum measure of the monetary base is justified. Conversely, our findings indicate that holding monetary base constant (at least contemporaneously) does not insure that economic activity is unaffected. Indeed, the effects of changes in reserve requirements and high-powered money are sufficiently different that employing same-size changes in each type of policy tool will still yield statistically significant effects on output growth and inflation. Thus, even in the weak sense of neutrality employed here, the simple sum is not justified in terms of the dynamic effects of the different monetary policy actions.

5. Summary and Conclusion

Movements in the monetary base reflect changes in high-powered money, changes in reserve requirements ratios, or both. The use of the monetary base measure in empirical work implicitly restricts the effects of these different policy actions to be equal. Yet, some theoretical models predict that changes in high-powered money and changes in reserve requirements have differential inflation and output growth effects. We investigate the empirical relevancy of this constraint. We do so in a framework which explicitly recognizes the Fed may attempt to coordinate policy by using tools together. The specific empirical question is whether the Fed systematically offsets changes in reserve requirements with open market operations. If so, is the offset full or partial? The answers to these questions are of general macroeconomic interest insofar as they investigate whether it matters how monetary policy is implemented. There is also a practical issue, the monetary base currently adds high-powered money to a dollar index measure of changes in reserve requirements, treating the effect that each variable has on economic activity as equal.

In examining this issue, we estimate three different structural VARs to test whether the two effects are significantly different for two macroeconomic variables: output growth and inflation. First, the evidence suggests that the Fed does partially offset changes in reserve requirements with open market operations. The first experiment examines how a one-percentage-point decrease in reserve requirements, which is partially offset, affects inflation and output growth. In all the cases, the evidence suggests that the contemporaneous effects of changes in the monetary base due to high-powered money developments and changes in the monetary base due to reserve requirement ratio developments are not significantly different from one another. With partial accommodation, the impulse response functions indicate that decrease in reserve requirements result temporarily in both significantly higher inflation rate and output growth. Another experiment "rigs" a full-accommodation case. The results suggest that output growth and inflation are significantly different in this case as well.

In short, the evidence indicates that using the existing monetary base measures in empirical work is problematic. The measures impose the restriction that changes in reserve requirements have equal-sized effects in whatever relationship the monetary base is used as an explanatory variable. Yet, the evidence suggests that differential effects are present as indicated in the impulse response functions.

One issue for future research is to examine the welfare implications of the Fed's partial accommodation strategy. Is there an alternative coordination scheme that raises agent's welfare? Freeman examines the welfare implications of reserve requirements in a setting in which money is held because reserve requirement exist. Mourmouras and Russell (1992) suggest that models with different rationales for valuing fiat money may yield different welfare implications. In short, the two questions for future research is to compare welfare under this coordination scheme and other tax policies, and whether these welfare implication are sensitive to different money demand specifications also deserve further investigation.

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Table 1

Null Hypotheses

H1: Reserve requirements and high-powered money have equal-sized effects on inflation.

H2: Changes in reserve requirements are not offset by open market operations.

If H2 is rejected then:

> H2a: Changes in reserve requirements are fully offset by open market operations.

H3: Reserve requirements and high-powered money have equal-sized effects on output growth.

Table 2

Tests of Exclusion Restrictions

Model $[\hat{RSI}_t \ \hat{H}_t \ \hat{mm2}_t \ INF_t \ \hat{GDP}_t]$

Equation	$\hat{RSI}$	$\hat{H}$	$\hat{mm2}$	INF	$\hat{GDP}$
$\hat{RSI}$	2.55**	0.68	0.75	2.61**	3.33**
$\hat{H}$	4.77**	14.16**	2.55**	0.58	0.91
$\hat{mm2}$	0.39	1.17	8.01**	2.23*	0.42
INF	0.68	1.37	1.06	50.70**	2.45**
$\hat{GDP}$	4.01**	2.98**	4.62**	4.27**	0.56

* Indicates that the null hypothesis is rejected at the 10% level.
** Indicates that the null hypothesis is rejected at the 5% level.

Table 3

Control Model, 1959-90

(1) $RSI_t = z1_t$

(2) $H_t = \underset{(0.071)}{-0.72^{**}} RSI_t - \underset{(0.081)}{0.509^{**}} mm2_t - \underset{(0.21)}{0.259} INF_t + z2_t$

(3) $mm2_t = \underset{(0.459)}{0.006} INF_t + \underset{(0.753)}{0.878} GDP_t + z3_t$

(4) $INF_t = \underset{(0.082)}{0.088} RSI_t + \underset{(0.106)}{0.158^{*}} H_t + z4_t$

(5) $GDP_t = \underset{(0.323)}{-0.121} RSI_t + \underset{(0.505)}{0.441} H_t - \underset{(0.731)}{0.758} mm2_t + z5_t$

Modified Sims Model 1948-91

(1) $RSI_t = e1_t$

(2) $INV_t = \underset{(0.242)}{-0.003} RSI_t + \underset{(0.002)}{0.011^{*}} r_t + e2_t$

(3) $r_t = \underset{(6.089)}{-0.429} RSI_t + \underset{(3.424)}{0.247} H_t + \underset{(0.186)}{0.014} mm1_t + e3_t$

(4) $H_t = \underset{(0.065)}{-0.685^{*}} RSI_t - \underset{(0.001)}{0.001} r_t + \underset{(0.051)}{0.083} y_t + \underset{(0.095)}{0.271^{*}} p_t + e4_t$

(5) $y_t = \underset{(0.028)}{0.199^{*}} INV_t + \underset{(0.001)}{0.003^{*}} r_t - \underset{(0.170)}{0.083} mm1_t + e5_t$

(6) $p_t = \underset{(0.041)}{-0.034} RSI_t + \underset{(0.001)}{0.001} r_t + \underset{(0.018)}{0.017} H_t - \underset{(0.043)}{0.012} y_t + e6_t$

(7) $U_t = \underset{(0.935)}{-1.147} INV_t - \underset{(0.025)}{0.098^{*}} r_t - \underset{(2.332)}{16.161^{*}} y_t - \underset{(3.606)}{4.752} p_t + e7_t$

(8) $mm1_t = \underset{(0.001)}{0.001} r_t + \underset{(0.130)}{0.140} y_t - \underset{(0.114)}{0.108} p_t + e8_t$

Table 3 (cont.)

Supply-Shock Structural Model, 1959-90

(1) $$RSI_t = w1_t$$

(2) $$RPE_t = \underset{(27.397)}{-9.987}\ p_t + w2_t$$

(3) $$H_t = \underset{(0.089)}{-0.54^{**}}\ RSI_t - \underset{(0.074)}{0.336^{**}}\ mm2_t + \underset{(0.25)}{0.162}\ p_t + w3_t$$

(4) $$mm2_t = \underset{(0.028)}{-0.022}\ RPE_t - \underset{(0.215)}{0.168}\ p_t + w4_t$$

(5) $$p_t = \underset{(0.09)}{-0.024}\ RSI_t + \underset{(0.235)}{0.157}\ RPE_t + \underset{(0.091)}{0.079}\ H_t - \underset{(0.072)}{0.027}\ y_t + w5_t$$

(6) $$y_t = \underset{(0.179)}{0.171}\ RSI_t - \underset{(0.06)}{0.003}\ RPE_t + \underset{(0.167)}{0.336^{**}}\ H_t + \underset{(0.146)}{0.295}\ mm2_t + w6_t$$

Note: standard errors are in parentheses

Chart 1

Dynamic Response to a 1% Innovation in RSI
Control Model

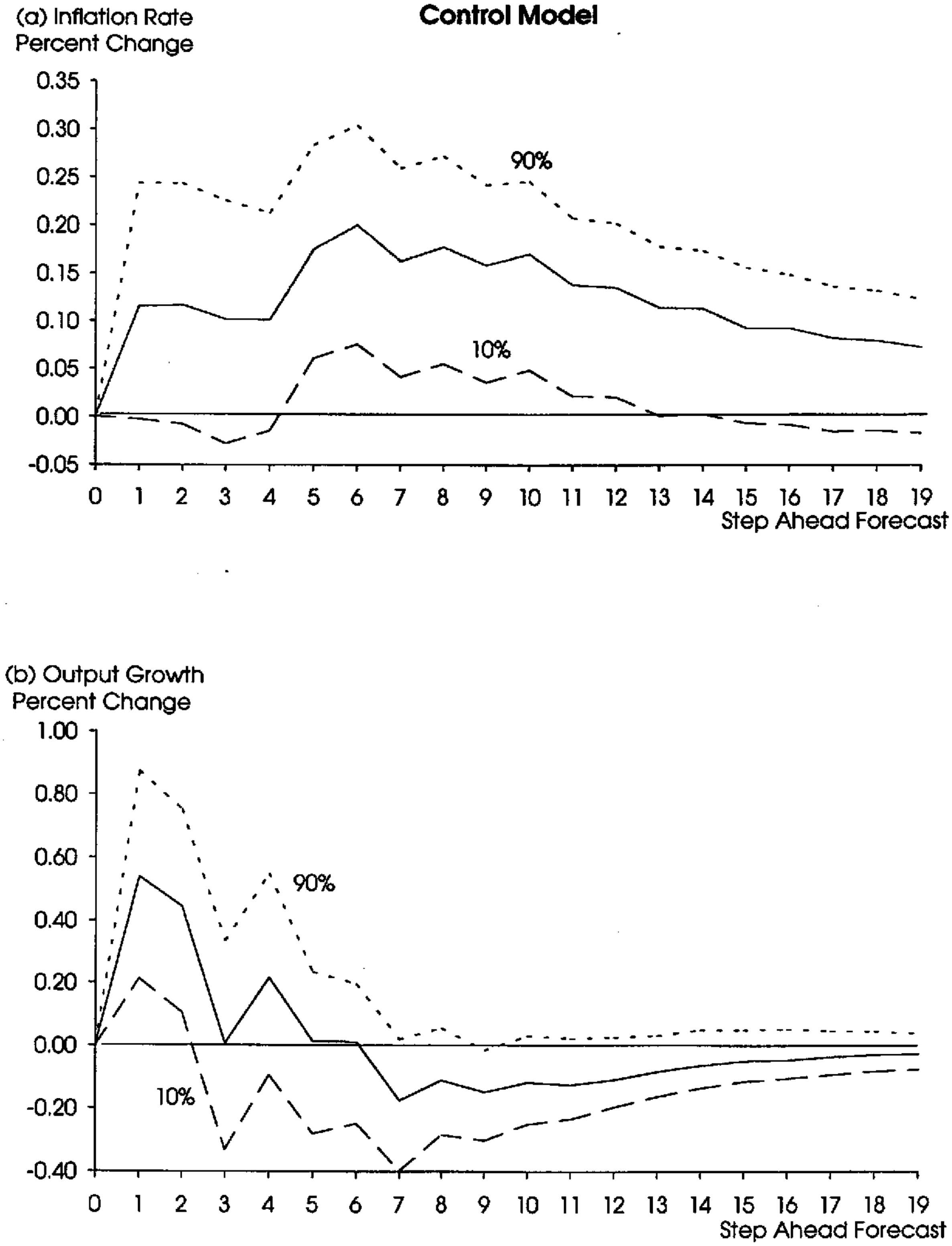
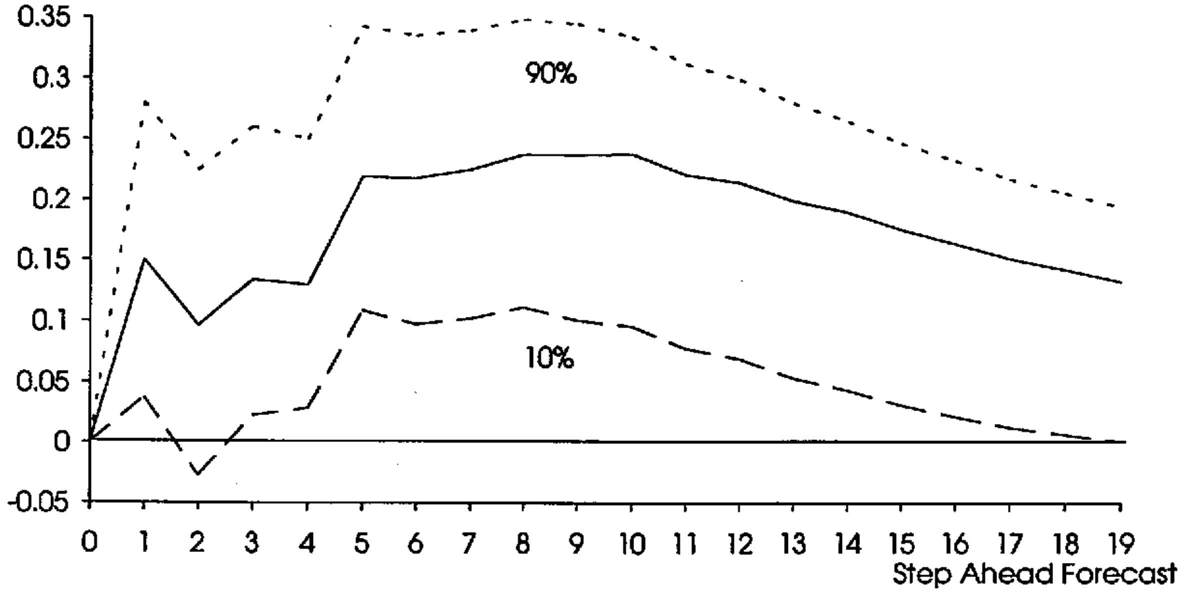


Chart 2

Dynamic Response to a 1% Innovation in H
Control Model

(a) Inflation Rate
Percent Change



(b) Output Growth
Percent Growth

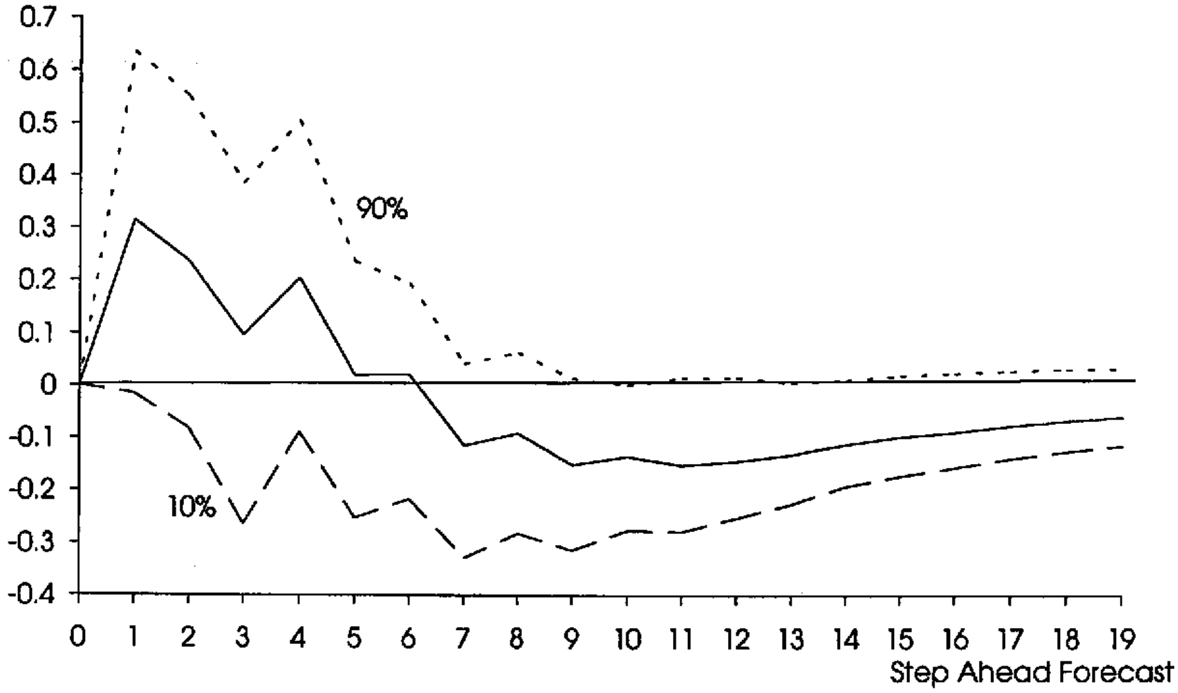


Chart 3

Dynamic Responses - Modified Sims Model

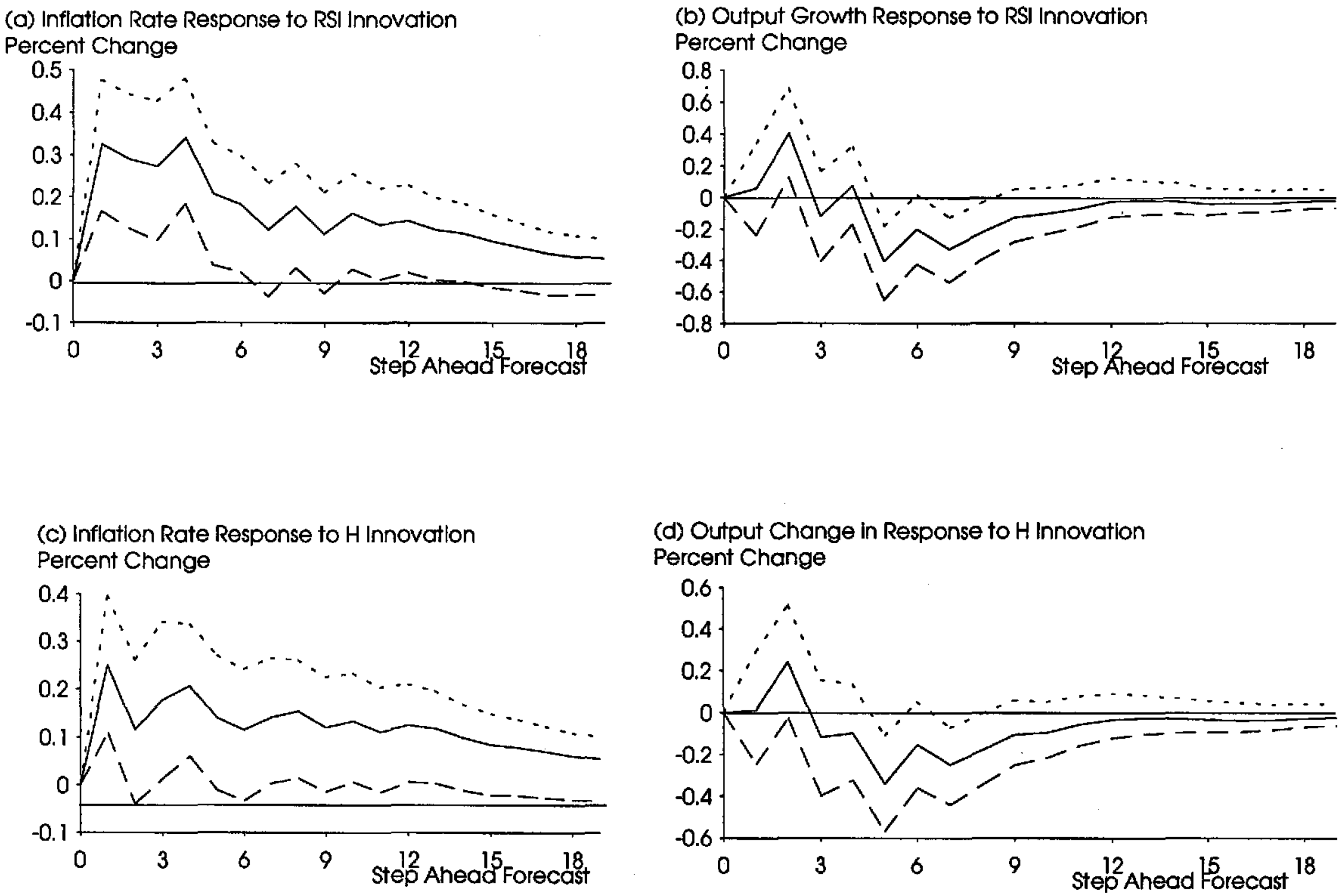


Chart 4

Dynamic Responses - Supply Shock Model

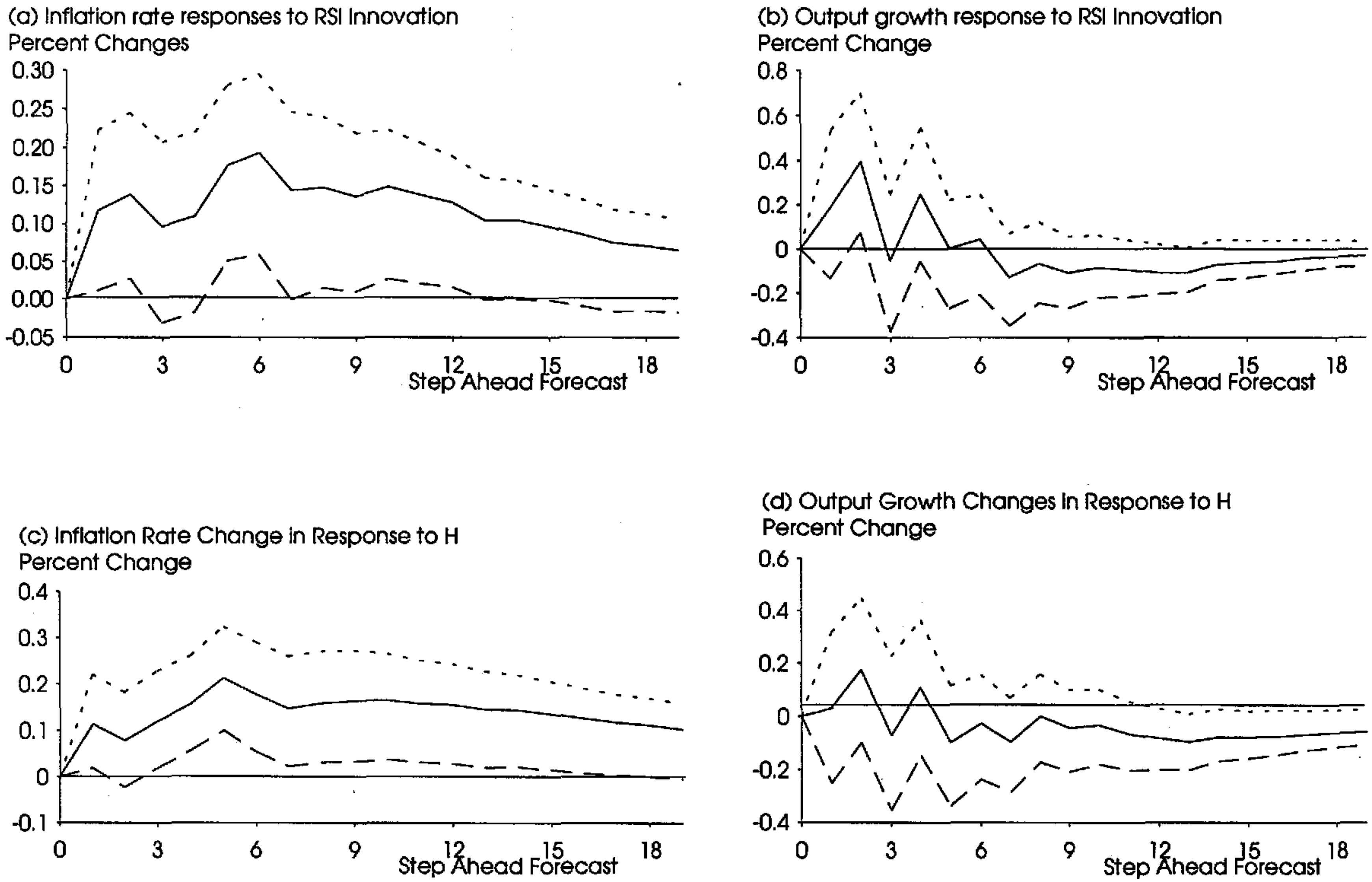
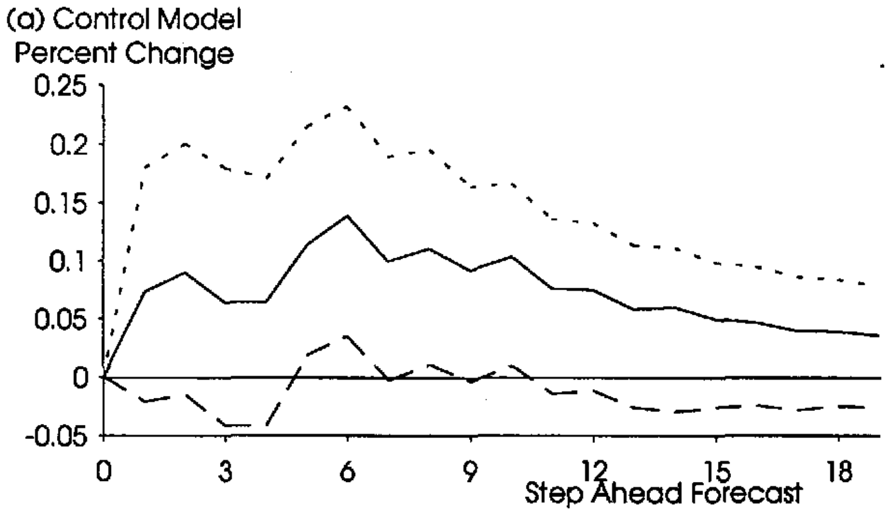


Chart 5

Dynamic Responses in Inflation Rates
Full Accomodation Experiment



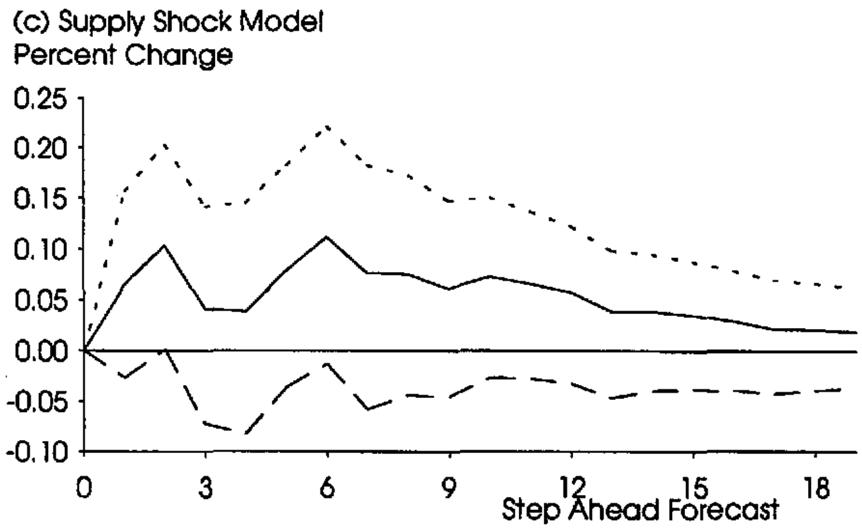
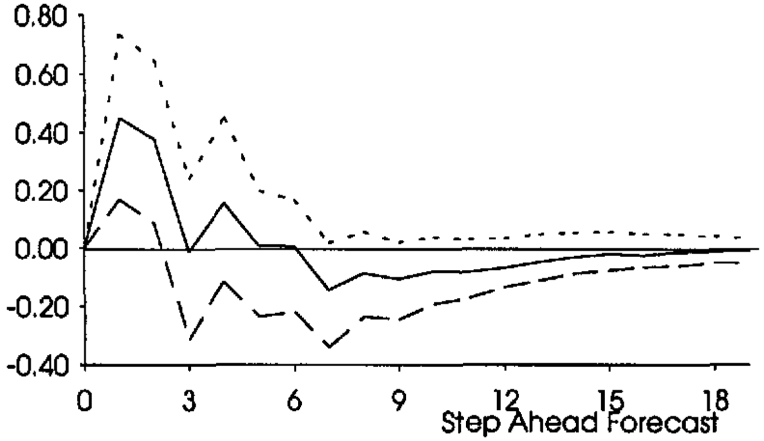


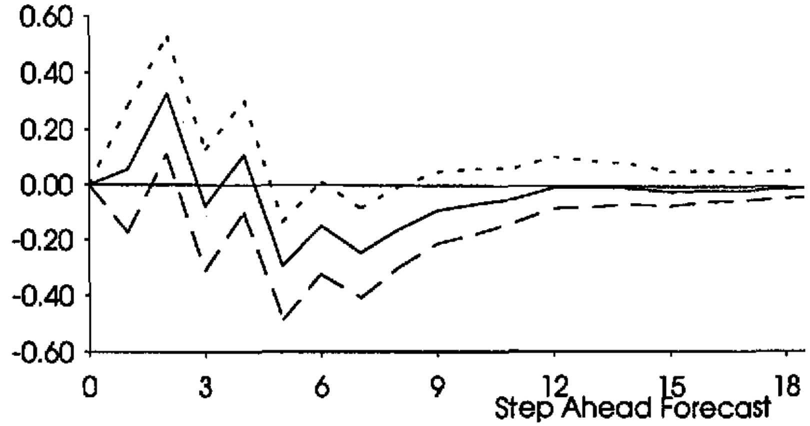
Chart 6

Output Growth Response - Full Accomodation Model

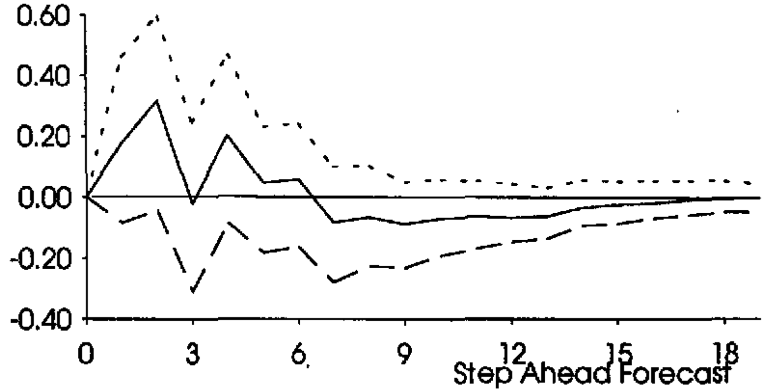
(a) Control Model
Percent Change



(b) Modified Sims Model
Percent Change



(c) Supply Shock Model
Percent Changes



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