NBER WORKING PAPER SERIES

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Working Paper 9552
http://www.nber.org/papers/w9552

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
March 2003

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NBER Working Paper No. 9552
March 2003
JEL No. E410, E430, E520

ABSTRACT

Money demand and the stock of money have all but disappeared from monetary policy analyses. This paper is an empirical contribution to the debate over the role of money in monetary policy analysis. The paper models supply and demand interactions in the money market and finds evidence of an essential role for money in the transmission of policy. Across sub-samples, it finds evidence consistent with the following inferences: (1) the money stock and the interest rate jointly transmit monetary policy; (2) for a given exogenous change in the nominal interest rate, the estimated impact of policy on economic activity increases monotonically with the response of the money supply; (3) the path of the real rate is not sufficient for determining policy impacts.

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PUTTING 'M' BACK IN MONETARY POLICY

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1. Introduction

Money demand and the stock of money have all but disappeared from monetary policy analyses. Reasons for the disappearance vary from the declining correlations between conventional money measures and economic activity to the frustrating instability of empirical money demand specifications. But the main reason money has disappeared is that in the most widely used models of monetary policy, the money stock is redundant for determining output and inflation once the short-term nominal interest rate is present. The near-universal adoption of interest rate instruments by central banks, coupled with the belief that actual central bank behavior is well modeled by a policy rule that sets the interest rate as a function of only output and inflation, has led to an emphasis on theoretical models in which money supply is infinitely elastic [Rotemberg and Woodford (1997)]. Monetary policy without money is so widely accepted that it now appears in pedagogical writings at the undergraduate and graduate levels [Romer (2000), Stiglitz and Walsh (2002), or Woodford (2003)].

Even if one buys the theoretical argument that the stock of money is redundant, a persuasive empirical case has yet to be made. This paper shows that money plays an important role in the transmission of policy in small empirical models. In contrast to many studies, we model the Federal Reserve's rule for setting the Federal funds rate as also including a broad measure of money. As long as money demand is not interest inelastic, this implies that the money supply and the interest rate are determined simultaneously. We show that when this simultaneity is modeled and the interest elasticities of supply and demand for money are freely estimated, policy shocks have significantly larger impacts on real variables and inflation than when either money or the interest rate is treated recursively. Simultaneity also implies far less inertial responses of inflation to policy disturbances. These findings hold across time, even in the face of significant financial innovation and instability in empirical specifications of short-run money demand.

Date: February 25, 2003. Prepared for Cleveland Fed/*JMCB* Conference, November 6-8, 2002. We thank Dale Henderson, Ed Nelson, Anders Vredin, Mike Woodford, and the two discussants, Marty Eichenbaum and Frank Smets, for helpful comments. The views in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System.

To model the money market, we pay a price in having to take a stronger stand on money demand behavior than is typical in the identified VAR literature. But a little economic structure goes a long way. Comparing the simultaneous model’s predictions with those that restrict money’s role in various ways, we find that, for a given initial change in the nominal interest rate, the strength of the output and price effects of policy increase monotonically with the response of the money stock. Moreover, when money and the nominal interest rate jointly transmit policy, monetary policy has impacts that are unrelated to the path of the real interest rate. This evidence is at odds with New Keynesian theoretical structures now in wide use for policy analysis. In those structures, money and the short-term nominal interest rate are interchangeable, and the real interest rate is the sole channel by which policy affects real quantities and inflation.

The paper also sheds light on two persistent puzzles in empirical work in monetary policy. Those puzzles—the liquidity puzzle and the price puzzle—plague empirical work on monetary policy. The liquidity puzzle arises when monetary policy disturbances fail to generate a negative short-run correlation between the nominal interest rate and the money stock; the price puzzle arises when higher nominal rates, which are interpreted as tighter monetary policy, are followed by higher prices for some time. These puzzles are ubiquitous, appearing across empirical approaches. Absence of liquidity effects appears in simple correlations [Christiano (1991)], distributed-lag regressions [Melvin (1983)], recursive VARs [Leeper and Gordon (1992)], and identified VARs [Bernanke, Boivin, and Eliasz (2002)]. Price puzzles appear in simple correlations, distributed-lag regressions [Sargent (1973)], recursive VARs [Sims (1992), Eichenbaum (1992)], identified VARs [Leeper, Sims, and Zha (1996), Christiano, Eichenbaum, and Evans (1999)], and in the narrative approach of Romer and Romer (1989) [Leeper (1997)].

Resolutions of the two puzzles are usually treated independently. The liquidity puzzle has been solved by focusing on narrow monetary aggregates such as non-borrowed reserves [Strongin (1995), Christiano, Eichenbaum, and Evans (1996)]. Following Sims (1992), the price puzzle is widely regarded as arising from the inclusion of too little information in empirical models, which confounds exogenous policy disturbances with forecastable changes in inflation. Sims adds commodity prices to the monetary authority’s information set, ameliorating the perverse price level responses. (But see Hanson (2002) for a critical review of the commodity-price fix.)

Our results indicate that the puzzles have a common source: extreme assumptions about the interest-rate elasticity of either supply or demand in the money market. By restricting the roles of money and interest rates in the transmission of monetary policy, these assumptions confound monetary policy and money demand shocks. When we estimate the elasticities freely, the puzzles disappear from U.S. data from 1959-2001 and various sub-samples.

The solution to the puzzles does not lie in merely "adding money" or other information to the model. Adding money in ways that do not isolate interactions between money demand and monetary policy, and do not help to identify money market supply and demand elasticities, is not sufficient to eliminate the anomalies. A similar argument applies to other non-economic additions of information. This may explain why the factor augmentation of Bernanke, Boivin, and Eliasz (2002) or the commodity-price fix of Sims (1992) diminish but do not eliminate the puzzles.

Some recent papers argue prices should rise following a monetary contraction because monetary policy has supply-side effects operating through the costs of financing [Barth and Ramey (2001) and Christiano, Eichenbaum, and Evans (2001)]. As Barth and Ramey (2001) put it: "...if monetary policy does transmit its effects on real variables through a cost channel, then *rising prices in the short run following a contractionary policy shock are not a puzzle"* [p. 229, emphasis in original]. Our results underscore that inferences about the importance of supply-side effects are not robust, as they depend on assumptions about money market behavior.

Lastly, our findings underscore that although identified VARs may deliver very similar *qualitative* predictions of the dynamic impacts of exogenous disturbances of exogenous monetary policy disturbances, they can differ substantially in their *quantitative* predictions.[1] If quantitative predictions are not robust across equally reasonable identification schemes, questions arise about the efficacy of an increasingly popular methodology proposed by Christiano, Eichenbaum, and Evans (1999) to implement Lucas's (1980) research program. That methodology takes the impulse response functions following a monetary policy shock from a particular identification as offering a set of facts that theoretical models are specified to deliver.[2] But if alternative identifying assumptions imply quantitatively very different response functions, questions arise about which set of "facts" theory should aim to reproduce. As the paper shows, the degree of inertia in inflation is a particularly non-robust feature of identified VARs.

All the estimated models use a common data set: monthly data from 1959:1-2001:6 on real GDP, consumption, unemployment, the personal consumption expenditures price deflator, commodity prices, and the effective Federal funds rate. Models that include money also use the M2 stock and the own rate of return on M2. Reduced-form analyses use some of these variables as well as others to make results comparable to earlier work.[3]

The rest of the paper is structured as follows. Section 2 explores reduced-form evidence for the role of money in the determination of output and inflation, finding

[1]This point is also made by the more agnostic identification procedures of Faust (1998), Canova and Pina (2000), and Uhlig (1997).

[2]Examples of papers following this methodology include Rotemberg and Woodford (1997), Christiano, Eichenbaum, and Evans (2001), Boivin and Giannoni (2002), and Trigari (2002).

[3]Appendix A describes the data.

that there is no consistent evidence of an independent role for money. Reduced-form results alone, however, cannot help sort out the transmission mechanism of policy. To do that, sections 4-6 compare different treatments of interactions between money and interest rates in the money market. This analysis illustrates the importance of modeling the money market and quantifies the errors that accompany a failure to do so. As a robustness check, section 7 considers some nested models of the money market. Section 8 checks the maintained assumption that the behavioral models' disturbances are mutually uncorrelated. Section 9 is a more detailed look at the past 20 years. Our qualitative results obtain in recent data, although there is reason to question how well the transmission mechanism of policy is identified in that period. Finally, in section 10 we show that interpretations of movements in inflation and unemployment over the post-World War II period vary depending on whether one uses the lens of a model without money or the lens of a model that specifies money market behavior.

2. Reduced-Form Evidence

Before moving to identified models, it is useful to review some reduced-form evidence. We start with dynamic correlations among policy and macro variables, and then reproduce some in-sample and out-of-sample tests of the role of money.

Figure 1 shows correlations among the Federal funds rate, M2 money growth, PCE inflation, and real GDP growth estimated over several sample periods. To get a sense of how stable the relationships are, correlations are based on a 15-year moving window of data. Although some instability emerges, unconditional correlations are remarkably stable overall.

The funds rate is robustly negatively correlated with output growth 6 months and 1 year ahead, and it is robustly positively correlated with inflation 1 year in the future. Money growth is consistently positively correlated with inflation 2 years hence, and with output growth 6 months and 1 year in the future. After being negatively correlated contemporaneously for many years, money growth and the funds rate have been strongly positively correlated for the past decade.

It is tempting to line these correlations up with patterns of results in identified models. Those results include strong output effects of interest rate innovations, the price puzzle, and the liquidity puzzle. But the correlations are also broadly consistent with the monetarist prediction that higher money growth first raises output and, with a lag of about 2 years, then raises inflation. With the presence of liquidity and price puzzles in the figure it may appear that monetary policy impacts are not transmitted only by a short-term interest rate or a money aggregate, but rather by some combination of the two. We explore this possibility in the identified sections of the paper.

One rationale for dropping money comes from reduced-form studies. Both in-sample and out-of-sample studies often find that money growth does not help to predict output and inflation. Estrella and Mishkin (1997) and Stock and Watson (1999) are representative of those studies. Svensson (2000) cites both of those papers when he argues the European Central Bank should eliminate its money-growth pillar.

Table 1 extends results in Estrella and Mishkin (1997). Column 4 presents p-values associated with Granger causality tests that all coefficients on M2 growth are zero in the first and second equations of a VAR(9) model of $\{\Delta \ln y_t, \Delta \ln p_t, \Delta \ln M2_t\}$ for a number of data sub-samples.[4] Like Estrella and Mishkin, we find that M2 growth helps predict output growth in the full sample, but that this predictive power disappears if we exclude the period up to 1979:10. Extending the analysis to other sample periods yields inconsistent evidence of a role for M2: it helps predict inflation in the post 1990:1 period, and output growth when 1979:10–1982:12 are excluded; but it provides no useful information in predicting either inflation or output growth when the period through 1982:12 is excluded.

Based on the unconditional correlations in Figure 1, we might expect money and interest rates to play a joint role in determining output and inflation. Indeed, including the current and lagged funds rate in the VAR often improves the predictive power of money growth for output growth or inflation, but it does not do so in a consistent manner.

Stock and Watson (1999) show that money growth also does not improve out-of-sample forecasts of inflation using a Phillips curve relationship. As in Stock and Watson, we compute out-of-sample forecasts of the change in 12-month-ahead inflation, π_{t+12}, based on the estimated Phillips curve specification:

$$\pi_{t+12} - \pi_t = \alpha + B(L)U_t + G(L)\pi_t + \varepsilon_{t+12}, \tag{1}$$

where U_t is the current rate of unemployment (or log difference of hours worked), and $B(L)$ and $G(L)$ are lag polynomials. The initial forecast for 1970:1 is based on parameters estimated from data through 1968:12, and successive forecasts are based on in-sample estimates that are continually updated. Table 2 compares the forecast performance of equation (1) against an alternative specification that replaces U_t with the growth rate of money. The ratios of the mean squared forecast errors from the specification with M2 growth and that with unemployment are reported in columns 2, 4, and 6. The other columns report the estimated parameter in a regression of the actual change in inflation on the two forecasts:

$$\pi_{t+h} - \pi_t = \lambda f_t^M + (1-\lambda) f_t^U + \epsilon_{t+h}, \tag{2}$$

[4] Whereas Estrella and Mishkin construct a monthly coincident index of nominal activity, we consider results for industrial production and real GDP.

where f_t^M and f_t^U are the h-step-ahead forecasts of π using either money growth or the unemployment rate models estimated through time t.

A value of λ close to zero means that the forecast based on money growth adds no predictive power beyond that based on the standard Phillips curve specification. As in Stock and Watson, evidence of a role for money is inconsistent, although it seems to have more predictive power in the post-1984 period.

The bottom four rows of Table 2 report the same statistics testing the Phillips curve forecast against a forecast based on money growth and the funds rate. Adding the funds rate improves the forecast performance of money based on both measures in the latter sample, but increases the out-of-sample prediction error in the first half of the sample.

In-sample tests tend to find that the role of money in predicting output and inflation has diminished over time. Money does not appear to matter after 1982. Out-of-sample forecasts of inflation, however, seem to be improved by including money growth. Money matters after 1983. These reduced-form tests do not offer much guidance about the role of money in monetary policy. They also do not capture the role of money in the transmission of policy since this requires an identified model. As Estrella and Mishkin (p. 292) note, "[T]he insignificance [of money for]...nominal income growth and inflation... might be attributable to their use in smoothing fluctuations in those variables." Thus the authors suggest that "a more careful analysis...could proceed by formulating and estimating a policy reaction function."

3. Econometric Approach

This section sketches the identified VAR methodology used in the rest of the paper to estimate private and policy behavior.

Actual policy behavior is a complicated function of a high-dimensional vector of variables. Policy makers choose an interest rate instrument, R_t, as a function of their information set, Ω_t. Actual policy is a function g such that

$$R_t = g(\Omega_t). \tag{3}$$

We assume that private agents are not privy to the details of the policy makers' decision problems, including the policy makers' incentives and constraints. Agents observe the information set $S_t \subset \Omega_t$. They perceive that policy is composed of a regular response to the state of the economy that they observe at t, S_t, and a random part, ε_t^P. The econometric model of policy is

$$R_t = f(S_t) + \varepsilon_t^P, \tag{4}$$

where we take f to be linear and ε_t^P to be exogenous to the model.

The econometric model embeds (4) in a system of equations describing private behavior. If y_t is an $(m \times 1)$ vector of time series, the structural model is

$$\sum_{s=0}^{\infty} A_t y_{t-s} = \varepsilon_t, \tag{5}$$

where ε_t is a vector of exogenous *i.i.d.* behavioral disturbances, including policy and non-policy shocks. To use the structural model for policy prediction, we require that ε_t^P be uncorrelated with all the non-policy disturbances [Marschak (1953)]. The errors are Gaussian with

$$E\left(\varepsilon_t \varepsilon_t' \,|y_{t-s}, s > 0\right) = I, \qquad E\left(\varepsilon_t \,|y_{t-s}, s > 0\right) = 0, \qquad all\ t. \tag{6}$$

Assuming the matrix of contemporaneous coefficients, A_0, is non-singular, there is a representation of y in terms of the impulse response functions:

$$y_t = \sum_{s=0}^{\infty} C_s \varepsilon_{t-s} + E_0 y_t. \tag{7}$$

The elements of C_s report how each variable in y responds over time to the behavioral disturbances in ε. $E_0 y_t$ is the projection of y_t conditional on initial conditions. The reduced form of (5) is

$$\sum_{s=0}^{p} B_s y_{t-s} = u_t, \tag{8}$$

with $B_0 = I$ and the covariance of the reduced-form error, u, is $\Sigma = A_0^{-1} A_0^{-1\prime}$.

Expressions (5) and (8) imply a linear mapping from the reduced-form errors to the behavioral disturbances:

$$u_t = A_0^{-1} \varepsilon_t, \tag{9}$$

Identification of the structural model follows from imposing sufficient restrictions on A_0 so that there are no more than $m(m-1)/2$ free parameters in A_0. No restrictions are imposed on lags, except in section 6.3.

In the estimates that follow all variables are logged except the unemployment rate, the Federal funds rate, and the own rate of return on M2, which enter as percentage points. Therefore, all interest rate elasticities are semi-elasticities. Identified models are estimated using Sims and Zha’s (1998) Bayesian methods. We assume a lag length of 13 months throughout.

4. Economic Evidence: Models that Omit Money

We start with an economic specification in the spirit of recent theoretical work in which the money market is not modeled. Ours is an expanded version of Rotemberg and Woodford's (1997) three-variable VAR model. The money stock is excluded from the model and policy obeys a Taylor rule. As in a standard New Keynesian model, policy is not transmitted through the money stock.

Table 3 describes the identification of the model without money—the A_0 matrix. Sectors of the economy are depicted as columns and variables as rows. The sectors are **P** (product market), **I** (information), and **MP** (monetary policy). Y is real GDP, C is real personal consumption expenditures, U is the unemployment rate, P is the personal consumption expenditures implicit price deflator, CP is commodity prices, and R is the Federal funds rate. An $\times$ denotes a freely estimated parameter and a blank denotes a zero restriction. Product market variables are inertial, responding only to their own disturbances within the month.[5] Information variables—commodity prices—are determined in auction markets and respond to all news instantaneously. Monetary policy follows a Taylor rule, adjusting the funds rate in response to current inflation and output.[6] Appendix B reports the estimated coefficients in the Taylor rule.

Figure 2 reports responses to an exogenous monetary contraction for a system estimated over the full sample period, 1959:1-2001:6. The solid line is the maximum likelihood estimate and the dashed lines report the 68% probability band.[7] The funds rate rises initially and stays well above its original level for 2 years. Output and consumption decline smoothly, reaching their troughs after about 18 months, while unemployment rises and doesn't peak for about 2 years. The model exhibits a small price puzzle, with the price level very likely to be higher for at least 6 months. After 6 months, the upper bound of the error bands lies on zero; any deflationary effects of a monetary contraction are very imprecisely estimated.

Appendix C reports impacts of a policy contraction over four sub-periods: 1959:1-2001:6 (solid); 1959:1-1979:9 (dashed); 1959:1-1982:12 (dotted); 1959:1-2001:6, excluding 1979:10-1982:12 (solid-dotted). Qualitatively, responses of real variables are stable over time, though they are somewhat larger in the 59-79 sub-period. Price level impacts exhibit substantial instability, and they all display a small price puzzle in the short run, consistent with Hanson (2002). The 59-79 and 59-01 (excluding 79-82) periods have chronic puzzles, with a policy contraction permanently raising the price level.

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[5] Sims (1998b, 2001) discusses why product markets may be inertial.

[6] This is a generalized Taylor rule that imposes no restrictions on lags.

[7] We use Sims and Zha's (1999) procedure for computing error bands with a Gibbs sampler algorithm based on 300,000 draws [Waggoner and Zha (2003a,b)].

Table 6 reports that for the 1959-2001 period the model's overidentifying restrictions are rejected by both a likelihood ratio test and the Akaike information criterion (AIC). Data slightly favor the unrestricted model by the Schwarz criterion (SC). This pattern holds across most sub-periods, except that the SC favors the restricted model. The recent period, 1983:1-2001:6, which is discussed in section 9, is different: the restrictions are not rejected by any test.

This model includes past, but not current, commodity prices in the policy rule. Following Hall's (1996) suggestion, we can allow commodity prices to enter the rule contemporaneously, but with a "soft zero" restriction. Soft zeros are a prior on CP with a zero mean, but a non-degenerative distribution, so if the data strongly support a response of policy to CP, the posterior parameters will reflect it. Doing this tends to resolve the anomalous response of prices, but the real effects of policy become much smaller and more transitory.

Although commodity prices may help resolve an empirical puzzle—though see Hanson's (2002) careful analysis for a different conclusion—it raises the theoretical puzzle of exactly what role information about commodity prices is playing in policy choices. Sims (1992) argues commodity prices provide the Fed with information about future inflation, possibly generated by real disturbances, but there is little direct evidence establishing that link. Moreover, the role of commodity prices has not been well worked out in theoretical models. For these reasons, we are not very satisfied with giving commodity prices a prominent role in identifying monetary policy behavior.

We turn now to modeling money market behavior and find that this resolves the two key empirical anomalies mentioned in the introduction without the contrivance of commodity prices.

5. Economic Evidence: Models with Money

In the previous model with a Taylor rule for policy, the money stock imposes no restrictions on the estimates of policy impacts. Implicitly, the model assumes money is supplied elastically to clear the money market at prevailing prices. Rather than impose money supply is infinitely elastic with respect to the interest rate, this section models money market behavior and estimates supply and demand elasticities directly.

5.1. **Why Include Money?** There are several reasons why money may not be redundant, given interest rates. Although Rotemberg and Woodford (1999) show that a Taylor (1993) rule is nearly optimal in the context of a standard New Keynesian model, Collard and Dellas (Undated) and Canova (2000) suggest this result may not be robust. Those papers find that a policy rule that incompletely accommodates money demand shocks yields somewhat higher welfare than does a Taylor rule. Moreover, if volatile real money balances—or a volatile financial sector more generally—are costly to society, it is not likely that setting the interest rate independently of money growth will be even nearly optimal. Ireland (2001a,b) finds empirical support for including money growth in the interest rate rule for policy. Using maximum likelihood to estimate a standard New Keynesian model, he finds that U.S. data favor having both inflation and money growth enter the interest rate rule. This finding holds for both pre-1979 and post-1979 samples of data. In this case, money plays an informational role by helping to forecast future nominal interest rates.

Practical considerations also suggest including money in the Fed's policy rule. If the Fed does not have contemporaneous information on inflation and output, but it does have observations on the money stock, then money may help the Fed infer current values of the variables it cares about directly. Coenen, Levin, and Wieland (2001) show that when output and price data are measured with error and subject to revision, money can help to predict current realizations of these variables. These points are particularly relevant in small empirical models, which approximate the Fed's information set with a short list of variables.

Nelson (2002) offers an alternative role for money. He posits that money demand depends on a long-term interest rate. Because long rates matter for aggregate demand, the presence of a long rate in money demand amplifies the effects of changes in the stock of money on real aggregate demand. Nelson's specification of the Fed's interest rate rule is a dynamic generalization of the conventional Taylor rule—money is excluded. Money now has a direct effect that is independent of the short-term interest rate, an effect that Nelson argues U.S. data support.

5.2. **A Model of the Money Market.** As long as money enters the Fed's policy rule, it is crucial to model the interaction of policy and money demand in order to identify the transmission mechanism of policy. This leads to simultaneity between money and interest rates [Gordon and Leeper (1994), Leeper and Zha (2001)]. We posit a simple form for the simultaneity. Table 4 summarizes the contemporaneous restrictions in A_0. To the model in Table 3 we add money demand behavior, **MD**, and another information variable, the own rate of return on money. As before, product markets are inertial and respond with a one-month lag to shocks from information or monetary sectors.

For compactness, we forego modeling the details that link markets for reserves and broad monetary aggregates. Demand for nominal M2 depends, as it does in many general equilibrium models, on consumption and the price level. It also depends on the opportunity cost of M2, which we take to be the spread between the funds rate and the own return on M2, R^M. An $\times_1$ in Table 4 denotes a linear restriction on the relevant coefficients: $R - R^M$ enters the money demand function with a single free coefficient. Monetary policy responds only to the money stock contemporaneously, even though the Fed also has current information on commodity prices. This limits simultaneity in the money market to that between money and interest rates. Appendix B reports the estimated coefficients on money demand and the policy rule.

Figure 3 reports the dynamic impacts of an exogenous monetary contraction. On impact the funds rate rises and the money stock falls substantially: a 25 basis-point increase in R is associated with a 2.7% annual rate decrease in money growth. The liquidity effect is short-lived, however, lasting only 8 months; within 18 months, the funds rate is significantly lower. An expected inflation effect that dominates the liquidity effect is a feature of this model that is completely absent from the model that omits money. The money stock continues to decline smoothly over the 4-year horizon.

There is no price puzzle. After the imposed one-period delay, the price level declines and continues to decline over the horizon; it is significantly lower within about 8 months. Price impacts are very precisely estimated, with the 68% band below 0 throughout. This path seems consistent with the brief liquidity effect followed by a dominant expected inflation effect that the funds rate exhibits.

Qualitatively the real effects are similar to those in the model that omits money. But the quantitative impacts are substantially larger, as section 6 explores.

Appendix D reports policy impacts over four sub-periods. Responses of variables are qualitatively similar across time with the exception of the own rate of return on $M2$ in 59-79, a period when the own rate was not market determined. As in Appendix C, 59-79 exhibits somewhat larger impacts.

A likelihood ratio test rejects the overidentifying restrictions with $p = .005$ (Table 6). The SC favors the restricted model, while the AIC prefers the unrestricted model. A similar pattern holds in other sample periods, except for 1983:1-2001:6, where the restrictions are not rejected by any test.

6. A Joint Role for 'M' and 'R'

This section lays out detailed evidence that money and interest rates jointly transmit policy. It starts by contrasting the quantitative results from the models with and without money, drawing implications for currently popular theoretical monetary models.[8] We then turn to the importance of assumptions about contemporaneous interactions in the money market, controlling for lagged money effects. We compare a variety of models that differ only in terms of the restrictions they impose on the interest elasticities of money demand and money supply. Finally the section looks at the dynamic role of money by examining the effects of selective exclusion of past money market variables, while allowing unrestricted contemporaneous interactions in the money market.

[8] Section 7 considers versions of the policy rules that are nested.

6.1. **Models With and Without Money.** Table 7 extracts some key quantitative implications from the model without money (Table 3) and the model with money (Table 4). For a standardized exogenous policy shift that raises the funds rate by 25 basis points, the table reports the maximum effects over 4 years on output, consumption, unemployment, inflation, and the ex-post real interest rate.[9] It also reports the effects on the price level and the money stock after 4 years. Looking first at the full sample period, with the important exception of the real interest rate, the model in which both M and R transmit policy generates real effects 2 to 3 times bigger and inflation effects more than 4 times larger. After 4 years, the price level is 9 times lower when the money market is modeled than when behavior in the market is left unspecified.

The pattern that effects from the model with money are substantially larger than from the model without money holds across sub-periods of the data.[10] Differences are less marked for the recent period, 1983:1-2001:6, a topic we revisit in section 9.

An important reason for the differences between the two models lies with money demand. Figure 4 reports responses to exogenous increases in money demand. The demand shock has a very small effect on the money stock, but raises the funds rate and the own rate of return dramatically. Both rates remain high for an extended period. The demand shock also predicts significantly higher prices for a time. The positive correlation between interest rates and future inflation, which Figure 1 reports, gets attributed to money demand disturbances in this model. In contrast, in the model that omits money, the correlation is attributed to monetary policy shocks, creating the price puzzle. This evidence suggests that the model that omits money may confound monetary policy and money demand shocks. Demand shocks also produce non-trivial movements in output, consumption, and especially unemployment. Evidently, money demand disturbances are an important source of variation for which models that omit money cannot explicitly account.

That increases in money demand should raise the price level runs counter to textbook analyses when the money stock is exogenous. But it is commonplace in models with interest rate rules for policy. Consider a policy rule of the sort that Ireland (2001b) estimates: $R_t = \alpha_\pi \pi_t + \alpha_\mu \frac{M_t}{M_{t-1}}$, where the coefficients are positive and $\alpha_\pi + \alpha_\mu > 1$. Embedding this rule in a New Keynesian model with a conventional calibration of parameters, an exogenous increase in money demand raises the real interest rate briefly, but then lowers it. Because output depends on the entire future

[9]The ex-post real rate is computed as $r_t = R_t - \pi_t$. Maximum effects are restricted to those that are "correctly" signed, meaning that a contraction lowers y, c, p and M and raises U. A zero entry means the entire impulse response function was anomalous.

[10]In the period 1959:1-1979:9 the maximum effect on the real rate of the model with money is twice that of the model without money. But this arises from a single month, rather than from a persistently higher real rate.

path of real rates, output falls initially and then rises. The price level, which depends on the entire path of the output gap, rises to a new higher level.

Figure 5 compares the impacts of policy contractions in the two models. The contractions are normalized to raise the funds rate 25 basis points initially. Responses for the model with money appear in the solid and dashed lines (68% error bands) and responses for the model that omits money appear in the dotted solid lines. Exogenous shifts in policy produce a striking pattern of results following a policy contraction: the real interest rate paths (labeled r) are nearly identical across the two models, but the model with money has effects on real quantities and the price level that are substantially larger over the four-year horizon. The paths of the funds rate itself also differ across the models. When money is absent, the policy shock generates a persistent liquidity effect and no expected inflation effect. In the model with money, in contrast, the liquidity effect lasts well under a year and the expected inflation effect becomes important after 18 months.

If money enters the policy rule, as it does in the model with money, then these results present a challenge to monetary theorists. They are inconsistent with theoretical models now in wide use for monetary policy analysis [Clarida, Gali, and Gertler (1999), Rotemberg and Woodford (1999)]. The evidence appears to contradict the prevalent monetary transmission mechanism in which the real interest rate is the sole channel by which policy affects real quantities and inflation.

6.2. **Alternative Models of Money Market Behavior.** The above section compares two extremes: a model which allows for nearly unrestricted contemporaneous and lagged money effects; and a model in which money is omitted entirely. We now focus more narrowly on four alternative models of money market behavior, controlling for lagged money effects.

The benchmark is the model with money described in Table 4, whose policy impacts appear in Figure 3. Three other models, which are drawn from existing literature, are identical to the benchmark except in their assumptions about short-run money demand and monetary policy behavior. Table 5 repeats the description of the benchmark, model A, and describes the other models. The three models, which differ in their interest elasticities, include: infinitely elastic money supply, model B [Taylor (1993)]; inelastic money demand, model C [some models in Leeper, Sims, and Zha (1996) and Sims (1998a)]; inelastic money supply, model D [Cochrane (1994)]. The four models have identical lagged coefficients and identical restrictions in all equations except monetary policy and money demand.

The four models imply four different pairs of interest elasticities of supply and demand—some estimated, some imposed. The four elasticity pairs produce four sets of dynamic impacts of a monetary policy shock, normalized to raise the funds rate

25 basis points on impact. Table 8 summarizes those impacts across various subperiods. Model A estimates interest semi-elasticities of supply and demand, while models B-D make different extreme assumptions about elasticities. Benchmark model A consistently finds short-run (monthly) semi-elasticities of demand that are negative and of supply that are positive. The demand semi-elasticity is smallest in the 1983:1-2001:6 period, which is where the supply semi-elasticity is the largest.

When an infinite supply elasticity is imposed (model B), estimates of demand elasticities tend to fall by more than an order of magnitude relative to their estimates in model A. Tiny demand elasticities produce tiny liquidity effects from exogenous shifts in policy under interest rate rules. If money demand is assumed to be interest inelastic (model C), supply elasticities are consistently negative and, by assumption, the liquidity effect is zero. The biggest demand elasticities emerge when supply is inelastic (model D).

The size of the policy impacts, recorded in columns 2-8, are monotonically increasing in the magnitude of the response of money supply to the normalized policy disturbance. And the money supply response is increasing in the estimated interest elasticity of money demand. The biggest impacts come from model D, where supply is inelastic, and the smallest come from model C, where demand is inelastic. Policy effects under a Taylor rule (model B) are modest, lying near those when demand is inelastic. Benchmark model A generates effects that are several times larger than models B and C, but substantially smaller than model D.

Figure 6 makes clear the divergence of policy impacts in the benchmark and the Taylor rule models (A and B), estimated over the full sample. Solid and dashed lines pertain to model A; solid-dotted lines to model B. Effects on output, consumption, and unemployment are much larger in model A, with model B's responses often lying fully outside the 68% error bands. Price effects under a Taylor rule are tiny; except for the first few periods, they also lie well outside the error band for the benchmark model. Indeed, it is two years before a policy contraction has any discernible effect on prices, a result consistent with several models that Christiano, Eichenbaum, and Evans (1999) report. Small price effects of monetary policy disturbances are also consistent with findings in estimated New Keynesian models [Ireland (2001b), Cho and Moreno (2002)]. Impacts under a Taylor rule are remarkably close to those in the model that omits money entirely (see Table 7 and Figure 2). This underscores the crucial role played by assumptions about contemporaneous interactions in the money market.

One of the more frequently cited facts to emerge from identified VARs is that inflation exhibits substantial inertia following a policy shock—far more inertia than is present in monetary models with the sticky price mechanisms proposed by Taylor (1980), Rotemberg (1982), or Calvo (1983). As reflected in Figure 6, inflation is very inertial under the Taylor rule specification, but moves quite rapidly in the benchmark model. Even though inflation is not permitted to respond instantly to a policy shock, it falls significantly just two months after the shock.[11] Inflation behavior appears to be a particularly non-robust feature of identified VARs.

It is difficult to reconcile this pattern of results with the view that money is redundant given the nominal interest rate. Moreover, if any of models B-D, which impose elasticities, were consistent with the data, model A, which estimates supply and demand elasticities jointly, should recover estimates close to the imposed values. This doesn't happen in any sample periods.

Table 6 shows that model A (the benchmark) and model D (inelastic money supply) are slightly favored by the data, compared with the models that impose infinitely elastic supply or inelastic demand for money. But the differences are not too striking and the SC consistently favors all the restricted models over the unrestricted ones.

6.3. **Selective Exclusion of M and R^M from Lags.** Section 6.2 contrasted four models that differ only in their assumptions about contemporaneous interactions in the money market (the elements of A_0 associated with monetary policy and money demand). This section contrasts models that differ only in whether lagged values of money market variables—M and R^M—enter various product market equations. Whereas section 6.2 focused on impact effects on monetary policy, this section concentrates on lagged effects of M and R^M in transmitting policy. Each model imposes identical identifying restrictions—those in the benchmark model (Table 4).

Table 9 reports the impacts of a policy contraction that raises the funds rate by 25 basis points in four models: the benchmark, where no exclusion restrictions are imposed on lags of M and R^M; a model that excludes M and R^M from the price level equation; a model that excludes the variables from the real variables' equations—output, consumption, and unemployment; and a model that excludes M and R^M from all product market equations. With only a few exceptions, real and inflation impacts fall by a factor of about three when M and R^M are excluded from the Y, C, and U equations. The cumulative effects on the price level and money stock fall by 2 to 3 times when M and R^M are excluded from the entire product market. These patterns hold across sub-periods, though they are less pronounced in recent data.

The importance of lagged money market variables in transmitting policy shocks seems at odds with reduced-form evidence. Equation-by-equation F tests in Table 1 display no consistent pattern in whether money growth predicts output and inflation. In contrast, the multivariate results in Table 9 suggest that past money market variables play a consistent and non-trivial role in transmitting policy.[12]

[11] The 68% error band for inflation that is implied by Figure 6 lies entirely below zero from 2-48 months after the shock.

[12] Because the Bayesian prior allows for unit roots and cointegration, the VAR could estimate a cointegrating relation linking a stationary velocity process to a linear combination of money growth, inflation, and output growth, even though the variables enter the VAR in log levels.

Taken together, results in sections 6.2 and 6.3 paint a complex picture of the transmission mechanism. Joint movements in M and R constitute the initial impact of a policy shock and their lagged values jointly propagate policy to product market variables.

7. Some Nested Monetary Models

We showed in sections 5 and 6 that models in which money enters the policy rule, so that money and interest rates are determined simultaneously, consistently imply substantially larger impacts of monetary policy shocks than do models that omit money all together or treat money as determined recursively after output, inflation, and the nominal interest rate are determined. Because the models discussed above are not nested, it is difficult to discern whether it is the simultaneous determination of money and interest rates *per se*, or merely the different interest rate rules that produce the larger estimated policy impacts.

In this section we compare three models of the money market: models A and B of Table 5 and a third model that nests those two. The third model differs from A and B only by generalizing the policy rule to allow the nominal rate to respond to output, the price level, and the money stock. Model A restricts the general model by zeroing out Y and P; model B restricts it by zeroing out M. Table 10 reports these restrictions.

Figure 7 reports the responses to a monetary policy shock that raises the funds rate by 25 basis points initially for the model with the generalized policy rule (solid line with dashed error bands). Superimposed on those responses are the impacts in model B, which excludes M from the policy rule (dotted solid line). Supply and demand behavior are not well identified under the generalized policy rule: even the short-run impacts of policy on the funds rate are very imprecisely estimated and all the error bands are substantially wider than in model A in Figure 3. Nonetheless, the maximum likelihood estimates in model B are much smaller than under the generalized rule. The price level effects are so much smaller in model B that they lie outside the error bands. Model B's extremely inertial inflation does not hold up under the generalized policy rule.

Figure 8 shows the impacts of a policy shock for model A, which used the policy rule $R = f(M)$, along with responses for the model with the generalized rule (dotted solid lines). These two models produce quantitatively similar policy impacts, with the point estimates under the generalized rule frequently within the error bands for model A. If anything, the generalized rule implies still larger impacts of policy disturbances. Including money in the policy rule consistently amplifies the effects of policy shocks and makes the response of inflation much less inertial.

Taken together the two figures support our focus on model A, rather than on the model with the generalized rule. Policy impacts are very close in the two models, and both are substantially different from the model that excludes M from the policy rule. In addition, behavior in model A is more sharply identified and the dynamic impacts are more precisely estimated.

8. Correlations Among Exogenous Shocks

A maintained assumption in the structural models we estimate is that the exogenous shocks are mutually uncorrelated [see equation (6)]. Because the models are overidentified, there is no guarantee this assumption holds in the estimates. We use a small-sample procedure to assess the assumption. For each draw from the posterior distribution of the model's parameters, we compute the sequence of exogenous disturbances implied by the data; then we calculate the correlation matrix for the sequences. Table 11 reports 68% probability intervals for correlations between **MP** and **MD** shocks and other shocks for the model without money (section 4) and the model with money (section 5).

Over the full sample, both models violate the maintained assumption. Monetary policy and money demand shocks are correlated with product market disturbances in both models.[13] In the period that excludes 79:10-82:12, policy shocks in the model with money are uncorrelated with all non-policy shocks. Money demand disturbances continue to be correlated with product market shocks, but the probability interval is substantially narrower and closer to including zero. The model without money does not perform any better when the period of reserves targeting is omitted.

Identification problems plague both models, though monetary policy seems better identified in the model that includes money. Money demand, which plays a key role in differentiating the two models, appears to contain a cyclical component that is not captured by conventional money demand specifications, even when lagged variables enter in an unrestricted manner.

9. The Recent Period

Although many economists have strong prior beliefs about the stability of monetary policy behavior over time, we believe the issue is unsettled. Bernanke and Mihov (1998a,b) test the stability of the reduced-form coefficients and residual covariances in VARs and conclude the coefficients are stable but the covariances exhibit breaks in late 1979/early 1980 and between early 1982 and early 1988. Sims's (1999) regime-switching reaction function estimates confirm this: most of the improvement in fit from parameter variation comes from variation in the size of the errors in the policy rule, rather than from variation in the coefficients of the rule. Also in a VAR framework, Hanson (2001) finds significant change in the variance of policy shocks

[13]Because separate behavioral relations in product markets are not identified, we can conclude only that the money market disturbances are correlated with some linear combination of behavioral disturbances in the product market.

before and after the Volcker period. But he finds little evidence that the policy rule has changed. Sims and Zha (2002) fit an identified VAR, allowing for certain types of parameter variation over time. They find no evidence of permanent changes in monetary policy regime of the kind Clarida, Gali, and Gertler (2000) and Taylor (1999) emphasize in their single-equation estimates of Taylor rules.[14] Sims and Zha conclude: "The story that policy has changed drastically between the 60-78 period and the 83-2000 period does not seem to be borne out (p. 13)." Significant differences in inference about the stability of policy behavior can emerge from multivariate and single-equation analyses.

Despite this multivariate evidence that post-82 policy behavior has not been wholly different from pre-79 behavior, in this section we focus on the sub-period 1983:1-2001:6. There is good reason to be skeptical of inferences about policy behavior drawn solely from this sub-period. Because the data are not very informative, it is difficult to identify and estimate money market behavior.

Figure 9 superimposes responses for the model without money (dotted solid lines) over responses for the benchmark model with money, along with the monetary model's 68% error bands (solid and dashed lines). Maximum likelihood estimates of policy impacts on output in the model with money are at some points nearly twice as large as those in the model without money, but the price level impacts are only slightly larger. However, all the impacts on product market variables and nominal and real interest rates when money is omitted lie within the monetary model's error bands, indicating that the effects of policy may not be well identified by either model.

It is disturbing that both models exhibit small price puzzles, a problem that didn't arise in the model with money in other sub-periods. This is another symptom of identification problems. Importantly, the price puzzle in the model with money is associated with a substantially smaller liquidity effect and a smaller estimated elasticity of money demand (model A in Table 8) than in other sub-periods.

A further indicator that behavior is not well identified lies in the correlations among shocks in this sub-period. Monetary policy shocks for the model without money are positively correlated with errors in the equations for consumption and unemployment. In the model with money, policy disturbances are positively correlated with errors in the unemployment and price level equations, while money demand shocks are negatively correlated with unemployment errors.

Conventional tests of fit, reported in Table 6 cannot reject any of the restricted models over this period. Evidently, sampling error is sufficient to make statistical criteria for model selection unhelpful. While we do not dismiss the possibility that post-1983 constitutes a distinct policy regime, it is clear that it is extraordinarily difficult to reliably estimate policy effects from that period.

[14]Lubik and Schorfheide (2002) use maximum likelihood to estimate a New Keynesian model and find important shifts in Taylor rules of the sort Clarida, Gali, and Gertler report.

10. Interpreting History

Interpretations of economic history and policy's role in it depend on how money is modeled. Comparing the model without money to the model with money, which freely estimates money demand and supply elasticities, yields important differences in the estimated real and nominal effects of policy.

Figure 10 plots realized inflation (the solid line) against the implied path of inflation after extracting the effects of shocks to monetary policy or money demand (the dotted line).[15] The gap between the actual and implied series represents the effects on inflation of current and past exogenous policy or money demand shocks.[16] During the run-up in inflation in the late 1970's, both the model with money (top panel) and the model without money (bottom panel) attribute part of the rise in inflation to the effects of exogenous monetary policy, with the magnitude of the effect somewhat greater in the model with money. The implication is that, had the monetary authorities at the time acted in a manner consistent with their average behavior historically, inflation would have been as much as 2 percentage points lower. The models diverge, however, in how they account for the decline in inflation beginning in the early 1980's. Whereas the model with money shows exogenous policy to have had a substantial disinflationary effect, the model without money ascribes little of the decline to exogenous policy.

Many of the differences between the policy impacts in the two models are explained by the contributions of exogenous shifts in money demand in the model with money (middle panel of Figure 10). From 1964-1974 money demand shocks steadily contributed to lower inflation rates; the model without money attributes the lower inflation to monetary policy shocks. Similar results obtain around the 1980 peak of inflation.

It appears likely that when money is omitted, monetary policy and money demand shocks are confounded. This interpretation is consistent with the pattern of correlations among shocks reported in Table 11: correlation with the shock from the unemployment equation is attributed to money demand in the model with money and to monetary policy in the model without money.

Differences between the two models also emerge in the most recent period. In the model with money, policy shocks pushed inflation higher in the 1990's and, to a lesser extent, in 2000 and 2001. The model without money shows that policy shocks had smaller positive contributions through 1998 and then brought inflation down through

[15] To extract the effects of policy, we performed a historical decomposition of each estimated model assuming information known at the beginning of the sample. At each point in time we subtract the cumulative effects of the series of implied policy shocks up to that point.

[16] Because we are subtracting out the cumulative effects, it is inappropriate to characterize policy as tight or loose at a given point in time based on the gap between the lines.

the end of the sample. These differences arise even though money demand shocks appear to have had little effect on inflation in the recent period.

Substantial differences across the models arise about the effects of policy on unemployment during the period from around 1975 to the early 1990's (Figure 11). While exogenous policy was effective in helping to lower unemployment by more than 1 percentage point in the late 1970's according to the model without money, it had little effect in the model with money. At the peak rate of unemployment in 1984, the model without money estimates exogenous policy to have contributed nearly 2 percentage points to unemployment, whereas the model with money shows little influence.

11. Concluding Remarks

This paper has presented a variety of evidence that the money stock and the short-term nominal interest rate jointly transmit monetary policy in the United States. Although reduced-form evidence tells no consistent story about the role of money in monetary policy, the tale that multivariate structural evidence weaves is clear. A short-run liquidity effect—even one lasting less than a year—is the essential initial stage of the transmission process. When a monetary contraction that raises the Federal funds rate does not also generate a substantial contemporaneous decline in the money stock—a liquidity puzzle—there is also a tendency for the price level to rise for a time—a price puzzle. Our findings link the two puzzles: a significant liquidity effect involving the funds rate and a sufficiently broad monetary aggregate resolve the price puzzle. Moreover, when monetary policy generates significant joint movements in money and the interest rate, real and inflation impacts of policy are larger than when money's response is small. The findings also carry an important challenge for currently fashionable theoretical models of monetary policy: some impacts of monetary policy on economic activity are not captured by the path of the real interest rate.

We obtain these results from modeling supply and demand in the money market and freely estimating interest elasticities in that market. This approach contrasts with other empirical specifications, such as Taylor rules and many identified VARs, which impose one elasticity and estimate the other. Those imposed elasticities could have been recovered by our estimates. They were not.

Careful modeling of the money market interactions—a subject that has received little attention in the identified VAR literature—is crucial to our understanding of the dynamic effects of monetary policy. We can learn nothing about these interactions from further attempts to estimate monetary policy and money demand separately.

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Appendix A. Data

All data are monthly from 1959:1-2001:6. All series except interest rates and commodity prices are seasonally adjusted.

Y : real GDP interpolated using procedure Leeper, Sims, and Zha (1996) describe or industrial production (source: Federal Reserve Board);

C : personal consumption expenditures deflated by PCE implicit price deflator (source: Bureau of Economic Analysis);

U : civilian unemployment rate (source: Bureau of Labor Statistics)

$hours$: non-farm employee hours (source: Bureau of Labor Statistics)

P : personal consumption expenditures implicit price deflator (source: Bureau of Economic Analysis) or consumer price index, all items (source: Bureau of Labor Statistics) or CPI (all urban consumer price index ; source: Bureau of Labor Statistics)

CP : KR-CRB spot commodity price index, raw industrials (source: Commodity Research Bureau);

M : M2 money stock (source: Federal Reserve Board);

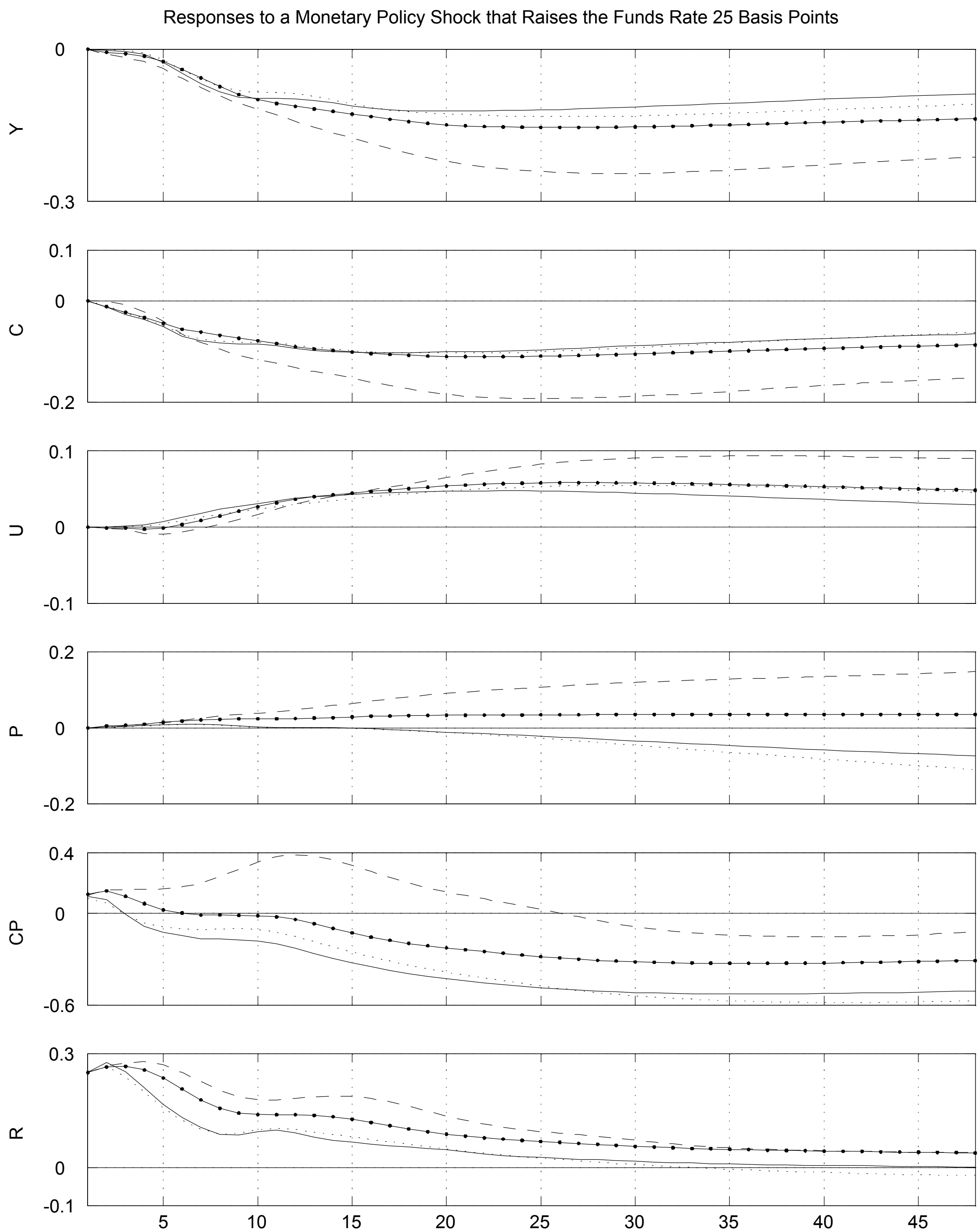
R^M : deposit-weighted own rate of return on M2 (source: Federal Reserve Board);

R : Federal funds rate, effective rate (source: Federal Reserve Board).

Appendix B. Estimates of A_0 : Models With and Without Money

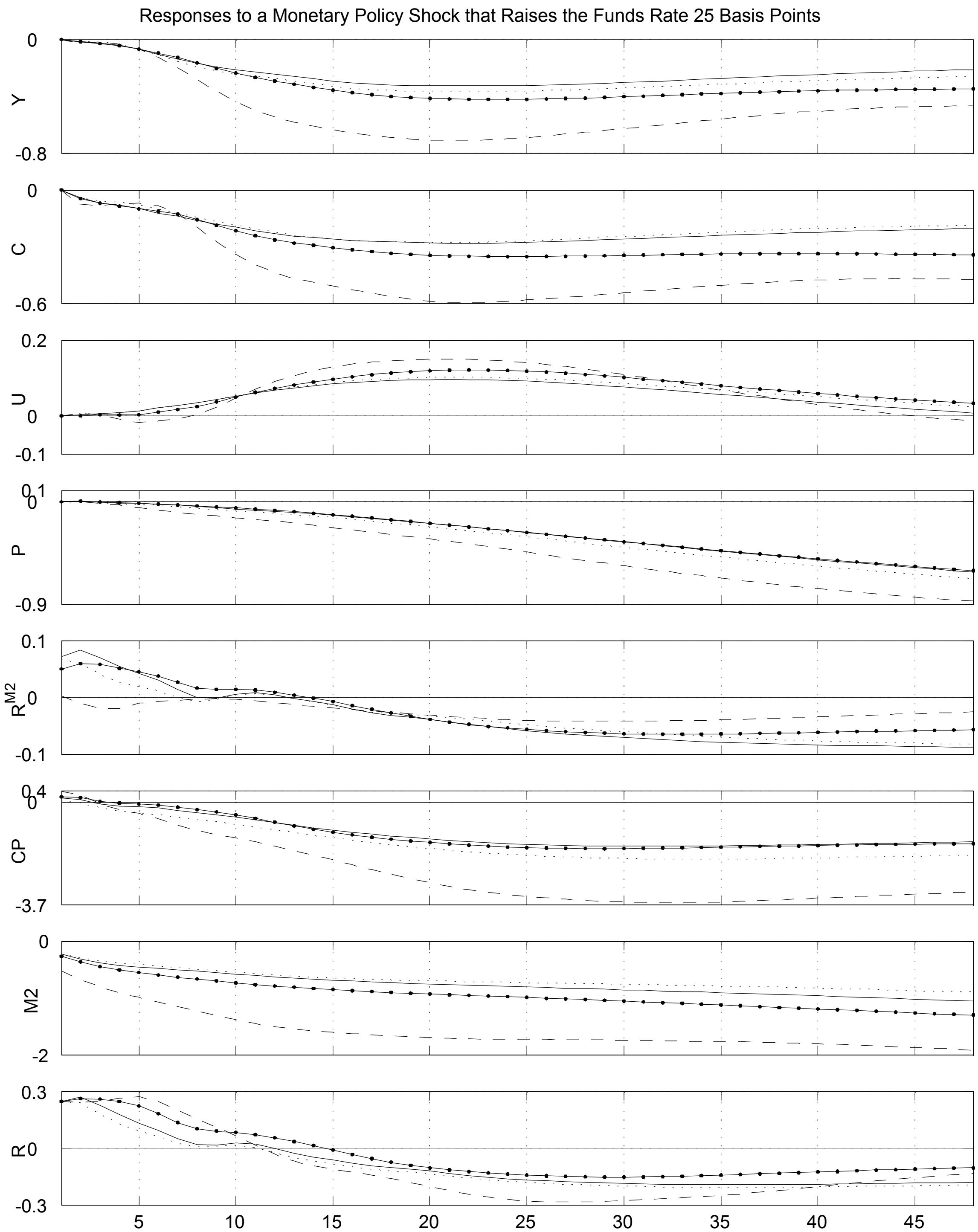
Model With Money
$\underset{(321.89,480.91)}{441.16M} - \underset{(-131.38,6.95)}{61.51R} = \varepsilon^{MP}$
$\underset{(23.60,5.87)}{15.67C} - \underset{(-47.44,-39.55)}{46.78P} - \underset{(-261.58,-184.30)}{239.95(R-R^M)} - \underset{(-345.82,-34.68)}{189.45M} = \varepsilon^{MD}$
Model Without Money
$\underset{(-11.81,-34.13)}{-23.03Y} + \underset{(53.30,-10.80)}{20.87P} + \underset{(188.59,200.86)}{194.68R} = \varepsilon^{MP}$
Maximum likelihood estimates; .68 probability intervals in parentheses.
ε^{MP} : monetary policy shock; ε^{MD} : money demand shock

Appendix C. Sub-Sample Stability in Model Without Money



59:1-01:6 (solid line); 59:1-79:9 (dashed line); 59:1-82:12 (dotted line); 59:1-01:6, excl. 79:10-82:12 (dotted solid line)

Appendix D. Sub-Sample Stability in Model With Money



59:1-01:6 (solid line); 59:1-79:9 (dashed line); 59:1-82:12 (dotted line); 59:1-01:6, excl. 79:10-82:12 (dotted solid line)

Table 1. In-Sample Tests of Role for Money

Granger Causality Tests for Predictive Power of Money			$(g,\pi,\mu)^1$		$(g,\pi,R,\mu)^1$	
			p	R^2	p	R^2
1959:01 - 2001:6	Output Growth	RGDP	0.023	0.400	0.131	0.430
		IP	0.001	0.258	0.001	0.280
	Inflation	PCE	0.482	0.876	0.242	0.881
		CPI	0.463	0.824	0.136	0.838
	Funds Rate	RGDP/PCE			0.413	0.995
		IP/CPI			0.306	0.995
1979:10-2001:6	Output Growth	RGDP	0.255	0.403	0.083	0.498
		IP	0.414	0.216	0.075	0.280
	Inflation	PCE	0.223	0.836	0.332	0.843
		CPI	0.258	0.801	0.277	0.823
	Funds Rate	RGDP/PCE			0.047	0.998
		IP/CPI			0.039	0.998
1983:1-2001:6	Output Growth	RGDP	0.607	0.477	0.738	0.497
		IP	0.891	0.271	0.971	0.317
	Inflation	PCE	0.365	0.782	0.123	0.808
		CPI	0.386	0.780	0.317	0.795
	Funds Rate	RGDP/PCE			0.275	0.999
		IP/CPI			0.198	0.999
1990:1-2001:6	Output Growth	RGDP	0.292	0.627	0.426	0.650
		IP	0.539	0.382	0.572	0.459
	Inflation	PCE	0.015	0.747	0.001	0.781
		CPI	0.120	0.815	0.063	0.838
	Funds Rate	RGDP/PCE			0.199	0.999
		IP/CPI			0.007	1.000
1959:1 - 2001:6 (ex. 79:10-82:12)	Output Growth	RGDP	0.008	0.429	0.040	0.447
		IP	0.001	0.276	0.006	0.326
	Inflation	PCE	0.200	0.853	0.040	0.864
		CPI	0.342	0.782	0.036	0.802
	Funds Rate	RGDP/PCE			0.012	0.998
		IP/CPI			0.017	0.998

p-values correspond to the F-statistic testing that lags of money growth are zero in the output growth, inflation, (and in the last two columns) funds rate equations from VAR(9) model. R^2 statistics are for the unrestricted equations. Systems based on M2 and either real GDP (RGDP) and the personal consumption expenditure deflator (PCE) or industrial production (IP) and the consumer price index (CPI).

[1] $g = \ln(Y_t/Y_{t-1}); \pi = \ln(P_t/P_{t-1}); \mu = \ln(M_t/M_{t-1})$; R= Federal Funds Rate

Table 2. Out-of-Sample Tests of Role for Money

Forecasting Inflation						
	1970-2001:6		**1970-1983**		**1984-2001:6**	
	Rel. MSE[1]	$\boldsymbol{\lambda}^2$	**Rel. MSE**[1]	$\boldsymbol{\lambda}^2$	**Rel. MSE**[1]	$\boldsymbol{\lambda}^2$
(U, CPI)	1.18	0.17	1.23	0.0018	1.08	0.39
	(0.10)	(0.15)	(0.13)	(0.22)	(0.10)	(0.14)
$(hours, CPI)$	1.16	0.21	1.22	0.04	1.04	0.44
	(0.10)	(0.15)	(0.12)	(0.21)	(0.11)	(0.15)
(U, PCE)	1.21	0.15	1.27	0.02	1.10	0.34
	(0.10)	(0.12)	(0.13)	(0.18)	(0.09)	(0.12)
$(hours, PCE)$	1.21	0.13	1.30	-0.06	1.05	0.42
	(0.10)	(0.13)	(0.14)	(0.19)	(0.08)	(0.13)
(U, CPI, R)	1.25	0.15	1.41	0.08	0.97	0.63
	(0.20)	(0.17)	(0.32)	(0.19)	(0.06)	(0.26)
$(hours, CPI, R)$	1.28	0.10	1.47	0.005	0.96	0.65
	(0.23)	(0.16)	(0.37)	(0.17)	(0.05)	(0.19)
(U, PCE, R)	1.18	0.21	1.30	-0.001	0.95	0.57
	(0.13)	(0.14)	(0.18)	(0.17)	(0.09)	(0.13)
$(hours, PCE, R)$	1.18	0.22	1.34	0.001	0.91	0.66
	(0.14)	(0.15)	(0.21)	(0.16)	(0.08)	(0.12)

The Relative MSE and λ statistics compare inflation forecast performances based on alternative k_t in the following regression: $f_t^k : \pi_{t+12} - \pi_t = \alpha + B(L)k_t + G(L)\pi_t + \varepsilon_{t+12}$. Inflation is measured with either the CPI or PCE-deflator. In the bottom four forecast specifications, the current and lagged funds rate are also included as right-hand-side variables. Standard errors in parentheses are heteroskedastic and serial-correlation robust estimates.

[1] Rel. MSE is the ratio of the MSE based on money growth, $k_t = \ln(M2_t/M2_{t-1})$ and the MSE based on the the standard Phillips curve, $k_t = \mathrm{U}_t$, or the log difference in hours worked.

[2] λ is estimated from a regression of the realized annual change in inflation on two alternative out of sample forecasts: $\pi_{t+h} - \pi_t = \lambda f_t^{M2} + (1-\lambda) f_t^x + \varepsilon_{t+h}$,where $x = U_t$, or the log difference in hours

TABLE 3. Identifying Restrictions in Model Without Money

	P	**P**	**P**	**P**	**I**	**MP**
Y	×	×	×	×	×	×
C		×	×	×	×	
U			×	×	×	
P				×	×	×
CP					×	
R					×	×

TABLE 4. Identifying Restrictions in Model With Money

	P	**P**	**P**	**P**	**I**	**I**	**MD**	**MP**
Y	×	×	×	×	×	×		
C		×	×	×	×	×	×	
U			×	×	×	×		
P				×	×	×	×	
R^M					×	×	$\times_1$	
CP						×		
M					×	×	×	×
R					×	×	$\times_1$	×

TABLE 5. Alternative Models of Money Market Behavior

	A		**B**		**C**		**D**	
	MD	**MP**	**MD**	**MP**	**MD**	**MP**	**MD**	**MP**
Y				×				×
C	×		×		×		×	
U								
P	×		×	×	×		×	×
R^M	$\times_1$		$\times_1$				$\times_1$	
CP								
M	×	×	×		×	×	×	
R	$\times_1$	×	$\times_1$	×		×	$\times_1$	×

Table 6. Tests of Overidentifying Restrictions

Model		1959:1-2001:6	1959:1-2001:6 (ex. 79:9-82:12)	1959:1-1979:9	1959:1-1982:12	1983:1-2001:6
No Money[1]	S	12.578	10.598	8.7182	8.5203	3.9629
	SC	12.45	12.28	10.99	11.28	10.75
	LR	.0019	.0050	.0128	.0141	.1379
	AIC	4	4	4	4	4
A[2]	S	16.995	12.852	8.3803	10.636	5.9146
	SC	31.13	30.72	27.51	28.24	26.92
	LR	.0045	.0248	.1365	.0591	.3146
	AIC	10	10	10	10	10
B[2]	S	18.559	15.002	9.4069	11.582	3.8982
	SC	24.91	24.58	22.01	22.60	21.54
	LR	.0010	.0047	.0517	.0207	.4200
	AIC	8	8	8	8	8
C[2]	S	24.526	16.004	9.4901	15.148	8.7202
	SC	37.36	36.87	33.01	33.90	32.31
	LR	.0004	.0137	.1478	.0191	.1899
	AIC	12	12	12	12	12
D[2]	S	17.04	12.807	8.3482	10.622	6.5458
	SC	24.91	24.58	22.01	22.60	21.54
	LR	.0297	.1187	.0049	.2241	.5863
	AIC	8	8	8	8	8

Rows report test statistics and criteria for tests of overidentifying restrictions: S: test statistic $= 2*(\ln ML(unrestricted) - \ln ML(restricted))$; SC: Schwarz Criterion $= k*\ln(T)$; k=no. of overidentifying restrictions; T sample size; LR: p-value from $\chi^2(k)$ for likelihood ratio test; AIC: Akaike Information Criterion = 2* k.

[1] Model without money: Does not model money market behavior. M and R^M excluded from the model. Policy: $R = f(P, Y)$.

[2] Models A-D differ only in their models of money market behavior; lagged coefficients identical across models. The models are:

A: Policy: $R = f(M)$; money demand: $M = g(P, C, R - R^M)$.

B: Policy: $R = f(P, Y)$; money demand: $M = g(P, C, R - R^M)$.

C: Policy: $R = f(M)$; money demand: $M = g(P, C)$.

D: Policy: $M = f(P, Y)$; money demand: $M = g(P, C, R - R^M)$.

Table 7. Comparing Models With and Without Money

Impacts of Policy Contraction that Raises Funds Rate by 25 Basis Points						
Sample period	*Maximum effect over 4 years on*[1,2]					*Total effect after 4 years on*[2]
Model	Y	C	U	π^3	r^4	P
1959:1-2001:6						
Without Money	-.12	-.10	.05	-.04	.25	-.07
With Money	-.33	-.28	.10	-.20	.29	-.62
1959:1-2001:6 excl. 79:10-82:12						
Without Money	-.15	-.11	.06	-.00	.25	.04
With Money	-.42	-.35	.12	-.20	.34	-.61
1959:1-1979:9						
Without Money	-.25	-.19	.10	0	.25	.15
With Money	-.71	-.59	.15	-.29	.54	-.87
1959:1-1982:12						
Without Money	-.13	-.10	.06	-.05	.25	-.11
With Money	-.36	-.28	.10	-.22	.29	-.67
1983:1-2001:6						
Without Money	-.25	-.26	.06	-.10	.41	-.14
With Money	-.43	-.47	.09	-.12	.45	-.24

Without Money: Does not model money market behavior. M and R^M excluded from the model. Policy: $R = f(P, Y)$.

With Money: Policy responds to the money stock $R = f(M)$ and money demand is $M = g(P, C, R - R^M)$.

[1] Maximum "correct-signed" response.

[2] In percent for Y, C, P, π, and in percentage points for U, r.

[3] π is monthly inflation at an annual rate.

[4] r is the annual real interest rate, $r_t = R_t - \pi_t$.

Table 8. Alternative Models of Money Market Behavior

Impacts of Policy Contraction that Raises Funds Rate by 25 Basis Points									
Sample period	Maximum effect over 4 years on[1,2]					Total effect after 4 years on[2]		Short-run interest elasticity of money[3]	
Model	Y	C	U	π^4	$\dot{M}^4$	P	M	demand	supply
1959:1-2001:6									
A	-.33	-.28	.10	-.20	-2.70	-.62	-1.05	-.0127	.0014
B	-.14	-.11	.05	-.04	-.32	-.08	-.07	-.0008	∞
C	-.13	-.10	.05	-.03	-.26	-.05	-.002	0	-.0298
D	-.77	-.68	.20	-.58	-8.58	-1.86	-3.33	-.0484	0
1959:1-2001:6 excl. 79:10-82:12									
A	-.42	-.35	.12	-.20	-3.15	-.61	-1.30	-.0132	.0035
B	-.20	-.14	.08	-.03	-.38	-.04	-.14	-.0011	∞
C	-.18	-.12	.07	-.01	-.33	.02	-.03	0	-.0482
D	-1.25	-1.23	.30	-.85	-13.98	-2.75	-5.66	-.0773	0
1959:1-1979:9									
A	-.71	-.59	.15	-.29	-6.31	-.87	-1.91	-.0213	.0010
B	-.29	-.23	.11	0	-.46	.15	-.15	-.0006	∞
C	-.28	-.22	.11	0	-.43	.17	-.10	0	-.0582
D	-1.51	-1.25	.30	-.87	-17.25	-2.68	-5.04	-.0562	0
1959:1-1982:12									
A	-.36	-.28	.10	-.22	-2.60	-.67	-.89	-.0118	.0005
B	-.15	-.11	.06	-.05	-.27	-.13	-.12	-.0009	∞
C	-.13	-.10	.06	-.04	-.22	-.08	-.06	0	-.0140
D	-.51	-.39	.14	-.34	-4.16	-1.03	-1.39	-.0195	0
1983:1-2001:6									
A	-.43	-.47	.09	-.12	-1.86	-.24	-.81	-.0086	.0112
B	-.26	-.27	.07	-.10	-.69	-.08	-.23	-.0013	∞
C	-.22	-.23	.07	-.10	-.65	-.05	-.12	0	-.0750
D	-2.42	-2.77	.23	-.69	-19.59	-2.04	-7.46	-.2746	0

Models A-D differ only in their models of money market behavior; lagged coefficients identical across models. The models are:

A: Policy: $R = f(M)$; money demand: $M = g(P, C, R - R^M)$.

B: Policy: $R = f(P, Y)$; money demand: $M = g(P, C, R - R^M)$.

C: Policy: $R = f(M)$; money demand: $M = g(P, C)$.

D: Policy: $M = f(P, Y)$; money demand: $M = g(P, C, R - R^M)$.

[1] Maximum "correct-signed" response.

[2] In percent for $Y, C, P, M, \pi, \dot{M}$, and in percentage points for U.

[3] Short-run elasticity is the monthly contemporaneous semi-elasticity.

[4] π and $\dot{M}$ are monthly inflation and money growth at annual rates.

Table 9. Excluding Monetary Variables from Various Equations

Impacts of Policy Contraction that Raises Funds Rate by 25 Basis Points When Lagged M and R_M are Excluded from Various Equations

Sample period / Model	Maximum effect over 4 years on[1,2]							Total effect after 4 years on[2]	
	Y	C	U	π^3	$\dot{M}^3$	R	r^4	P	M
1959:1-2001:6									
No exclusions	-.33	-.28	.10	-.20	-2.70	.27	.29	-.62	-1.05
Excluded from P	-.37	-.34	.11	-.13	-2.70	.27	.25	-.35	-1.00
Excluded from Y, C, U	-.11	-.07	.04	-.17	-2.70	.27	.30	-.52	-.82
Excluded from Y, C, U, P	-.12	-.09	.05	-.07	-2.70	.27	.25	-.17	-.72
1959:1-2001:6 ex. 79:10-82:12									
No exclusions	-.42	-.35	.12	-.20	-3.15	.26	.34	-.61	-1.30
Excluded from P	-.47	-.41	.15	-.13	-3.15	.26	.25	-.32	-1.22
Excluded from Y, C, U	-.13	-.07	.05	-.18	-3.15	.27	.35	-.52	-1.01
Excluded from Y, C, U, P	-.14	-.09	.06	-.07	-3.15	.27	.25	-.13	-.86
1959:1-1979:9									
No exclusions	-.71	-.59	.15	-.29	-6.31	.28	.54	-.87	-1.91
Excluded from P	-.84	-.71	.20	-.34	-6.31	.29	.28	-.80	-1.86
Excluded from Y, C, U	-.23	-.13	.09	-.26	-6.31	.28	.53	-.55	-1.54
Excluded from Y, C, U, P	-.21	-.12	.09	-.18	-6.31	.29	.28	-.40	-1.43
1959:1-1982:12									
No exclusions	-.36	-.28	.10	-.22	-2.60	.25	.29	-.67	-.89
Excluded from P	-.38	-.31	.11	-.18	-2.60	.25	.25	-.49	-.81
Excluded from Y, C, U	-.11	-.07	.05	-.17	-2.60	.25	.31	-.56	-.76
Excluded from Y, C, U, P	-.10	-.07	.05	-.12	-2.60	.25	.25	-.33	-.65
1983:1-2001:6									
No exclusions	-.43	-.47	.09	-.12	-1.86	.33	.45	-.24	-.81
Excluded from P	-.43	-.48	.09	-.10	-1.86	.33	.43	-.20	-.83
Excluded from Y, C, U	-.30	-.32	.06	-.11	-1.86	.34	.44	-.20	-.67
Excluded from Y, C, U, P	-.30	-.32	.07	-.10	-1.86	.34	.43	-.15	-.69

Models differ only in whether lags of M and R^M are excluded from various equations in the product market. Interactions in the money market identical across models; policy: $R = f(M)$; money demand: $M = g(P, C, R - R^M)$.

[1] Maximum "correct-signed" response.
[2] In percent for $Y, C, P, M, \pi, \dot{M}$, and in percentage points for U, R, r.
[3] π and $\dot{\mathrm{M}}$ are monthly inflation and money growth at annual rates.
[4] r is the annual real interest rate, $r_t = R_t - \pi_t$.

TABLE 10. Some Nested Models of Money Market Behavior

	A		**B**		**Generalized**	
	MD	**MP**	**MD**	**MP**	**MD**	**MP**
Y				$\times$		$\times$
C	$\times$		$\times$		$\times$	
U						
P	$\times$		$\times$	$\times$	$\times$	$\times$
R^M	$\times_1$		$\times_1$		$\times_1$	
CP						
M	$\times$	$\times$	$\times$		$\times$	$\times$
R	$\times_1$	$\times$	$\times_1$	$\times$	$\times_1$	$\times$

TABLE 11. Behavioral Error Correlations Implied by Alternative Models

	1959:1-2001:6			1959:1-2001:6 (excl. 79:10-82:12)		
	Money[1]		No Money[2]	Money[1]		No Money[2]
	ε(MP)	ε(MD)	ε(MP)	ε(MP)	ε(MD)	ε(MP)
ε(Y)	(-.038,.049)	(-.007,.062)	(-.051,.039)	(-.038,.023)	(-.060,.014)	(-.041,.052)
ε(C)	(.014,.052)	(-.015,.052)	(-.022,.010)	(-.061,.030)	(-.061,.014)	(.064,.096)
ε(U)	(-.074,.066)	(.136,.176)	(.138,.168)	(-.076,.097)	(.010,.159)	(.111,.141)
ε(P)	(-.031,.004)	(-.038,.051)	(-.044,.046)	(-.021,.024)	(-.032,.062)	(-.029,.065)
ε(R^M)	(-.039,.050)	(-.020,.070)	—	(-.040,.051)	(-.036,.056)	—
ε(CP)	(-.048,.038)	(-.037,.050)	(-.052,.036)	(-.046,.044)	(-.041,.049)	(-.051,.040)
ε(MD)	(-.042,.053)	1	—	(-.033,.069)	1	—
ε(MP)	1	(-.042,.053)	1	1	(-.032,.069)	1

68% error bands for correlation between the monetary policy or money demand shock and other shocks in system. Based on 300,000 draws.

[1] Model with money: Policy: $R = f(M)$ and money demand is $M = g(P, C, R - R^M)$.

[2] Model without money: Does not model money market behavior. M and R^M excluded from the model. Policy: $R = f(P, Y)$.

FIGURE 1. Dynamic Correlations From 15-Year Moving Window of Data. Solid lines are 1 year, 6 months, or 0 months; dashed lines are 2 years, 1 year, or 6 months ahead.

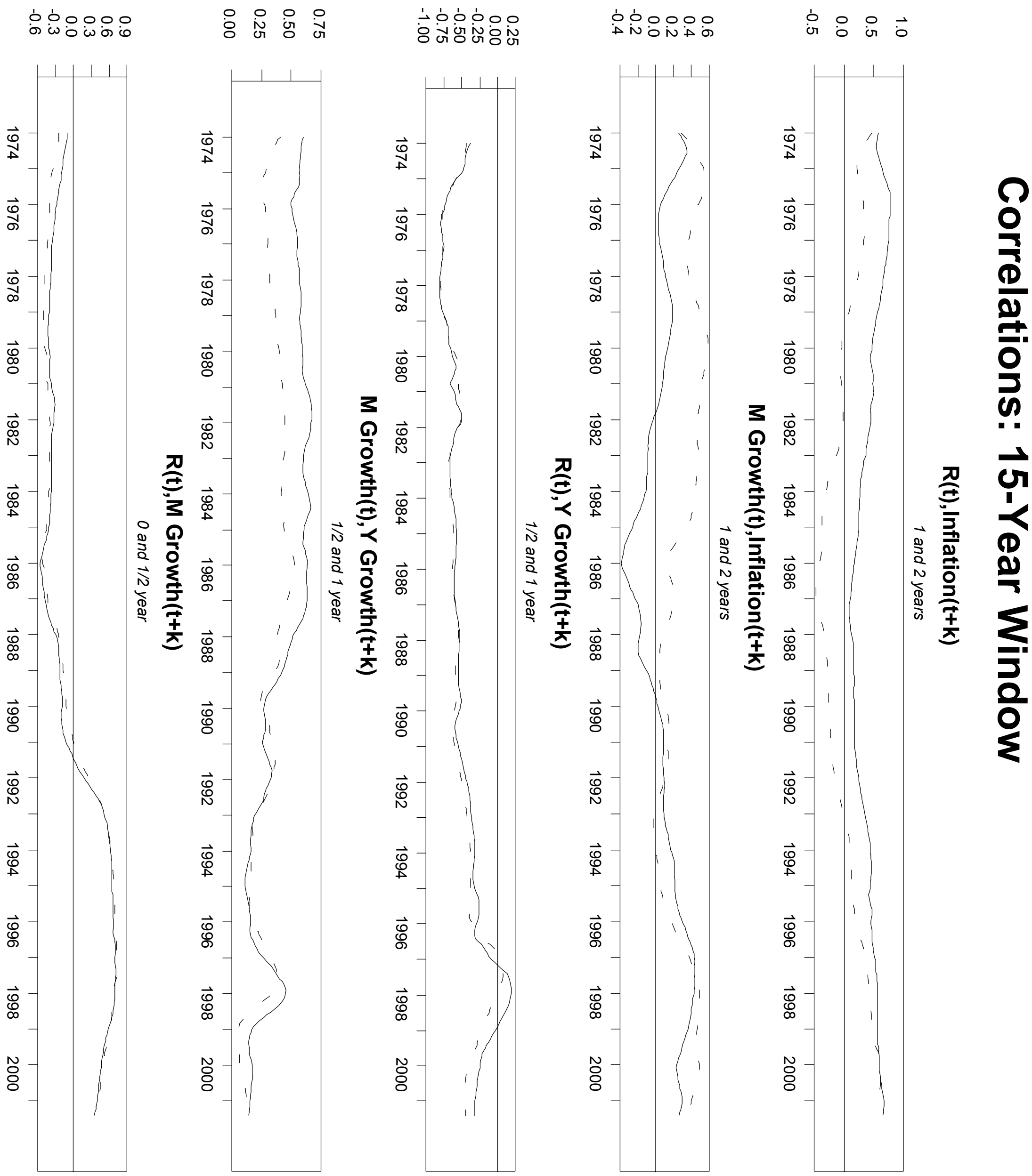


FIGURE 2. Impacts of Policy Contraction in Model Without Money: 1959-2001

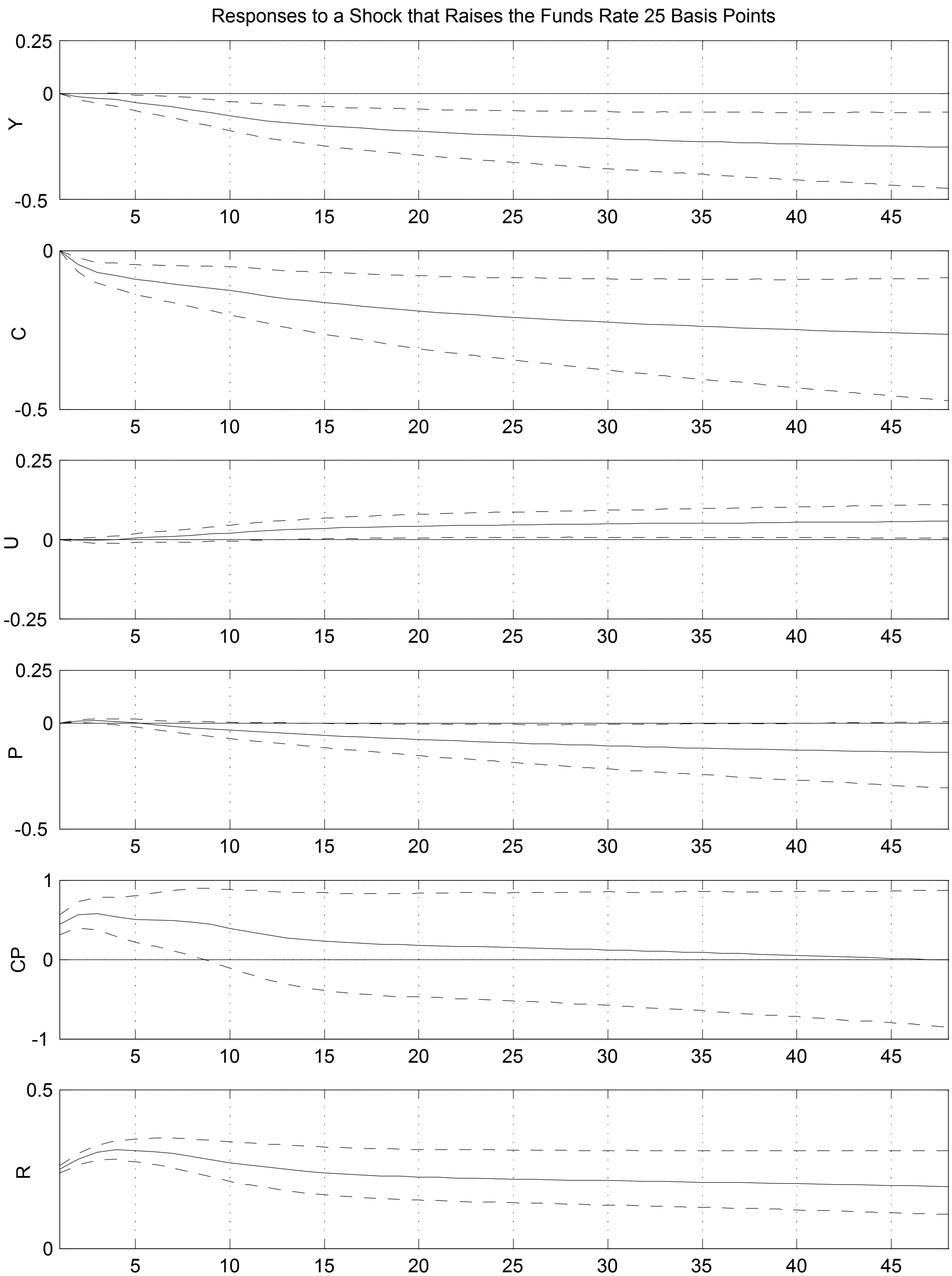


FIGURE 3. Impacts of Policy Contraction in Model With Money: 1959-2001

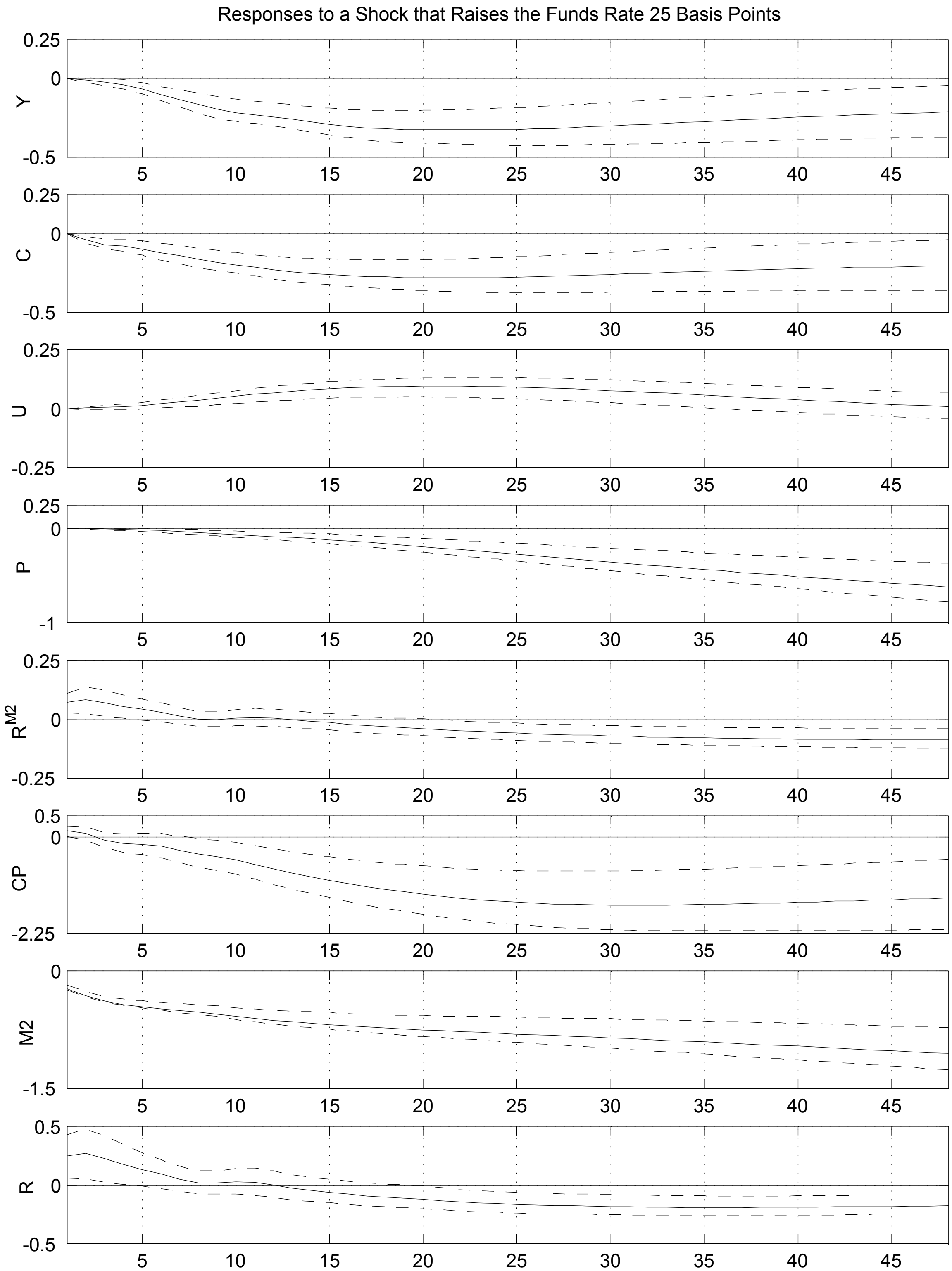


FIGURE 4. Impacts of Money Demand Increase: 1959-2001

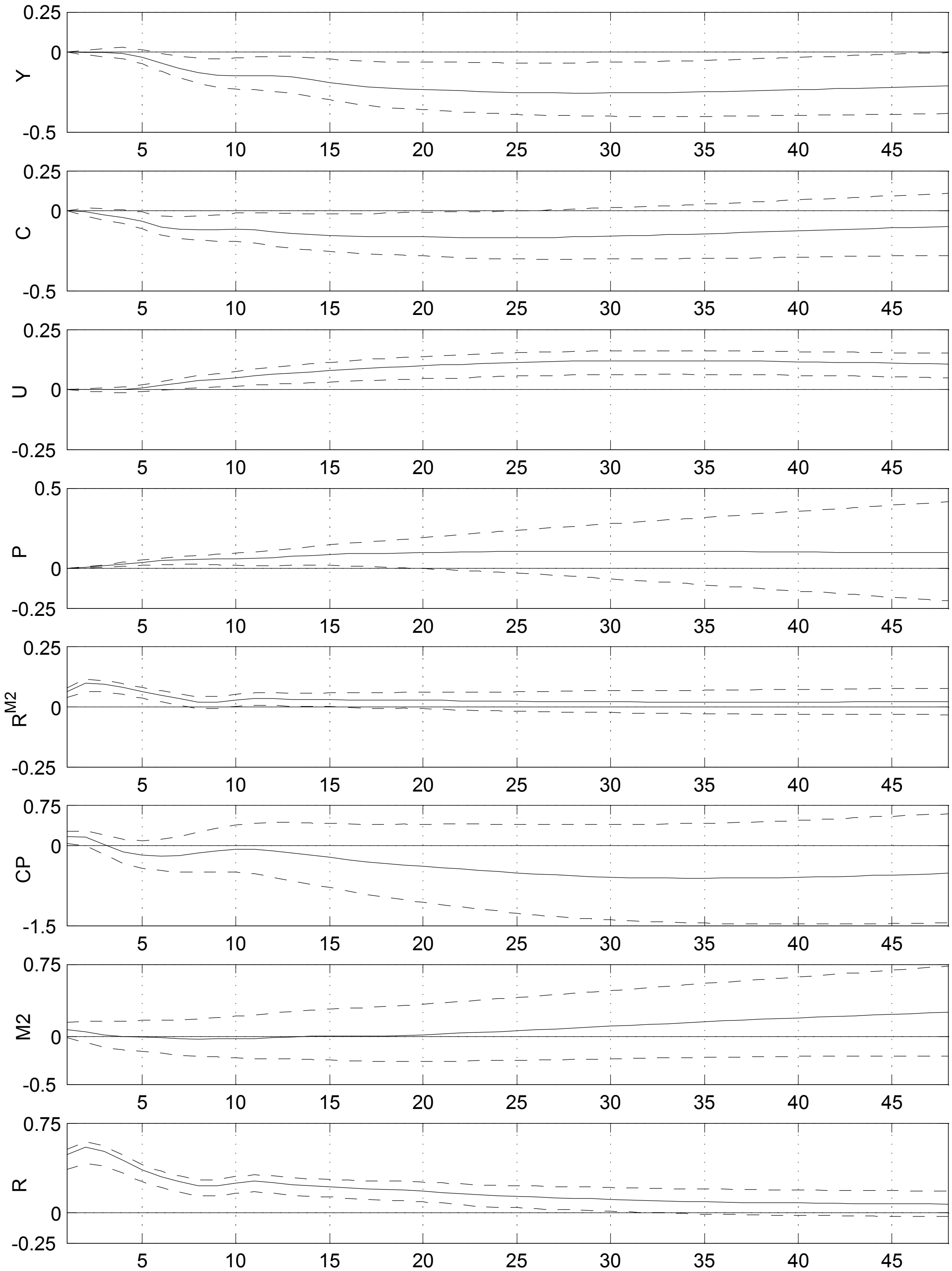


FIGURE 5. Impacts of Policy Contraction in Models With and Without Money. Dotted solid line, model without money; solid line. model with money; dashed lines, 68% bands model with money.

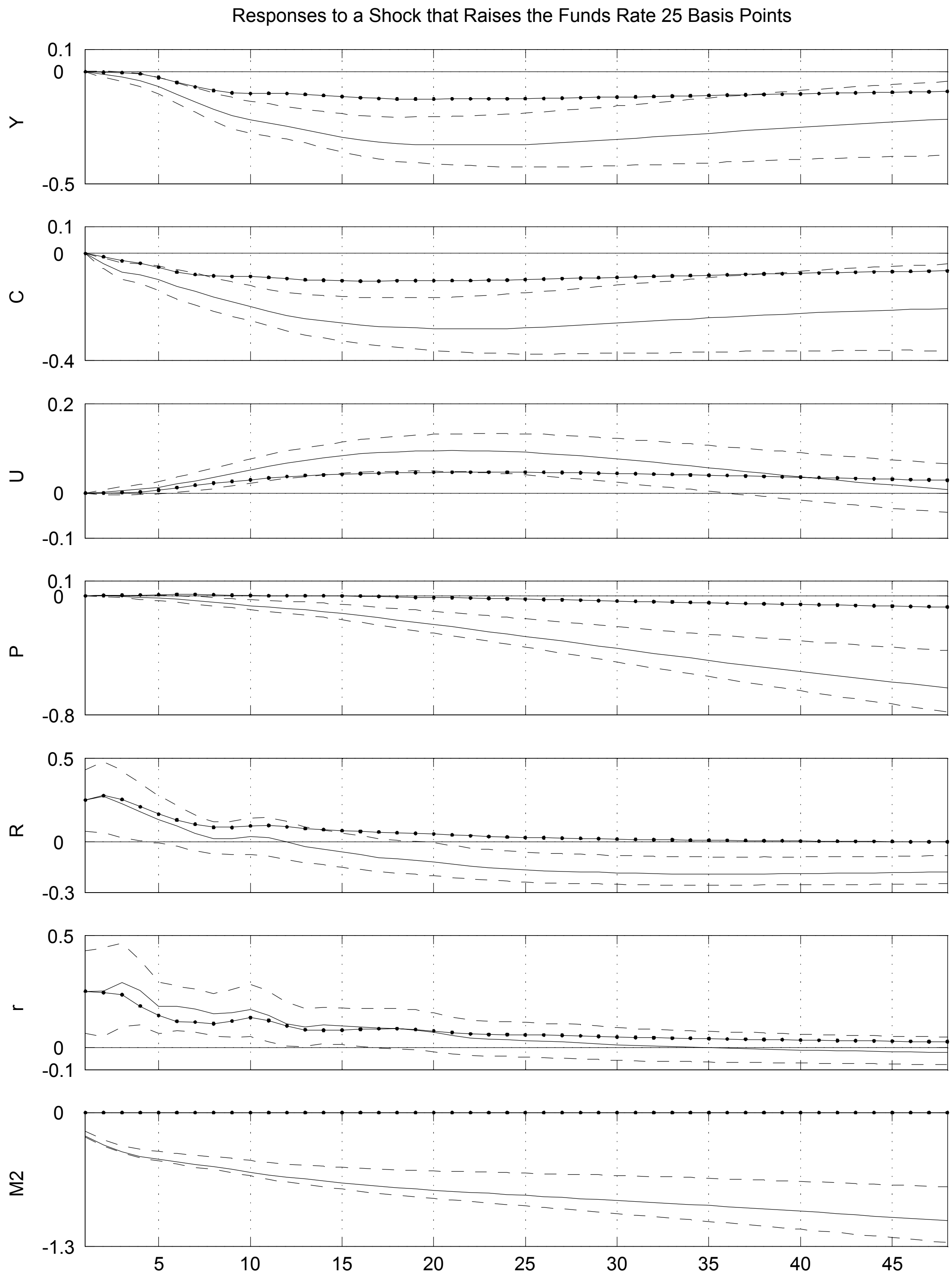


FIGURE 6. Impacts of Policy Contraction in Models A and B With Money. Solid line is A; dashed lines 68% bands for A; dotted solid line is B. Policy in A: $R = f(M)$; policy in B: $R = f(Y, P)$.

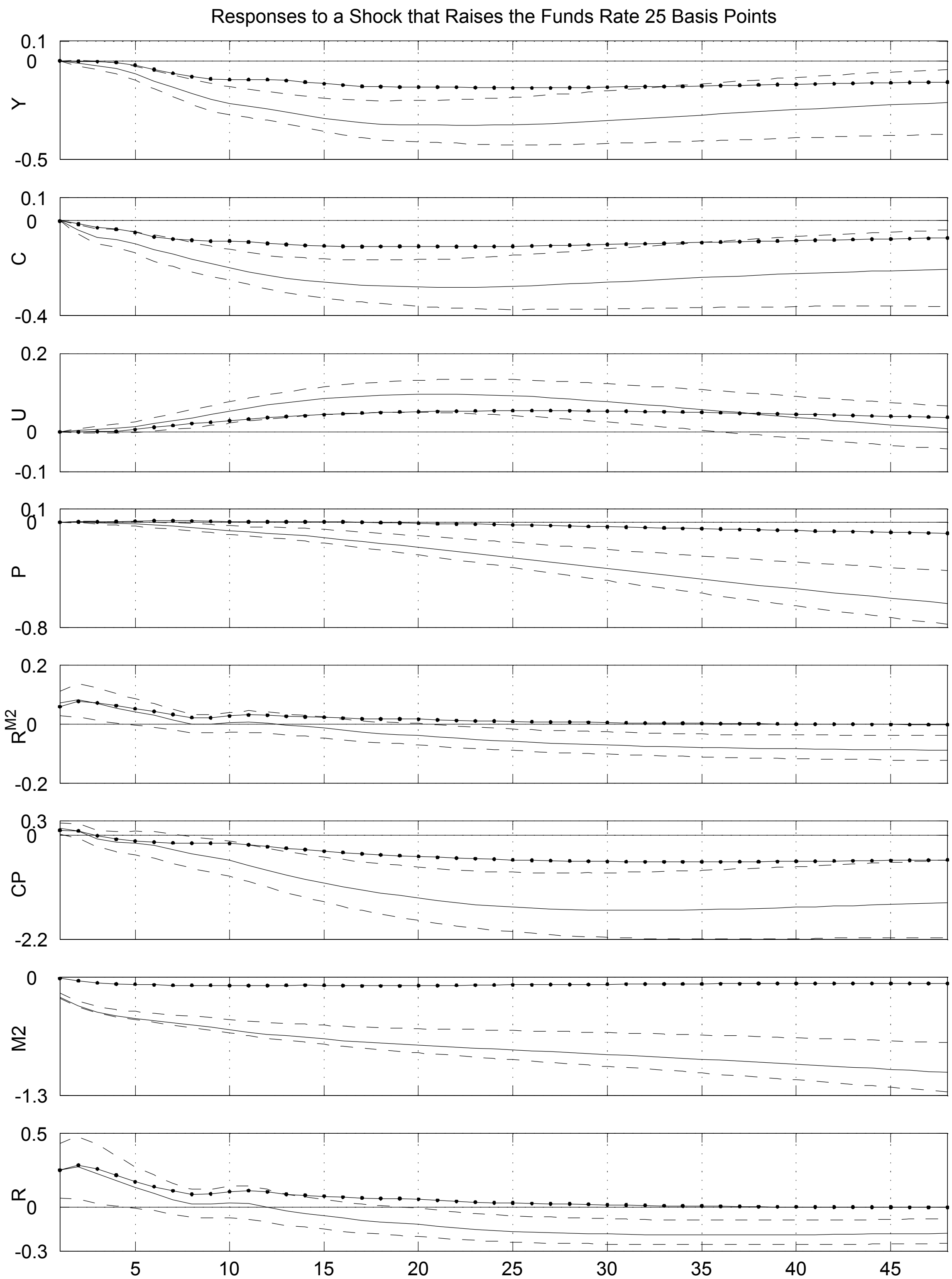


FIGURE 7. Nested Models: $R = f(P, Y, M)$, solid and dashed lines; $R = f(P, Y)$, dotted lines.

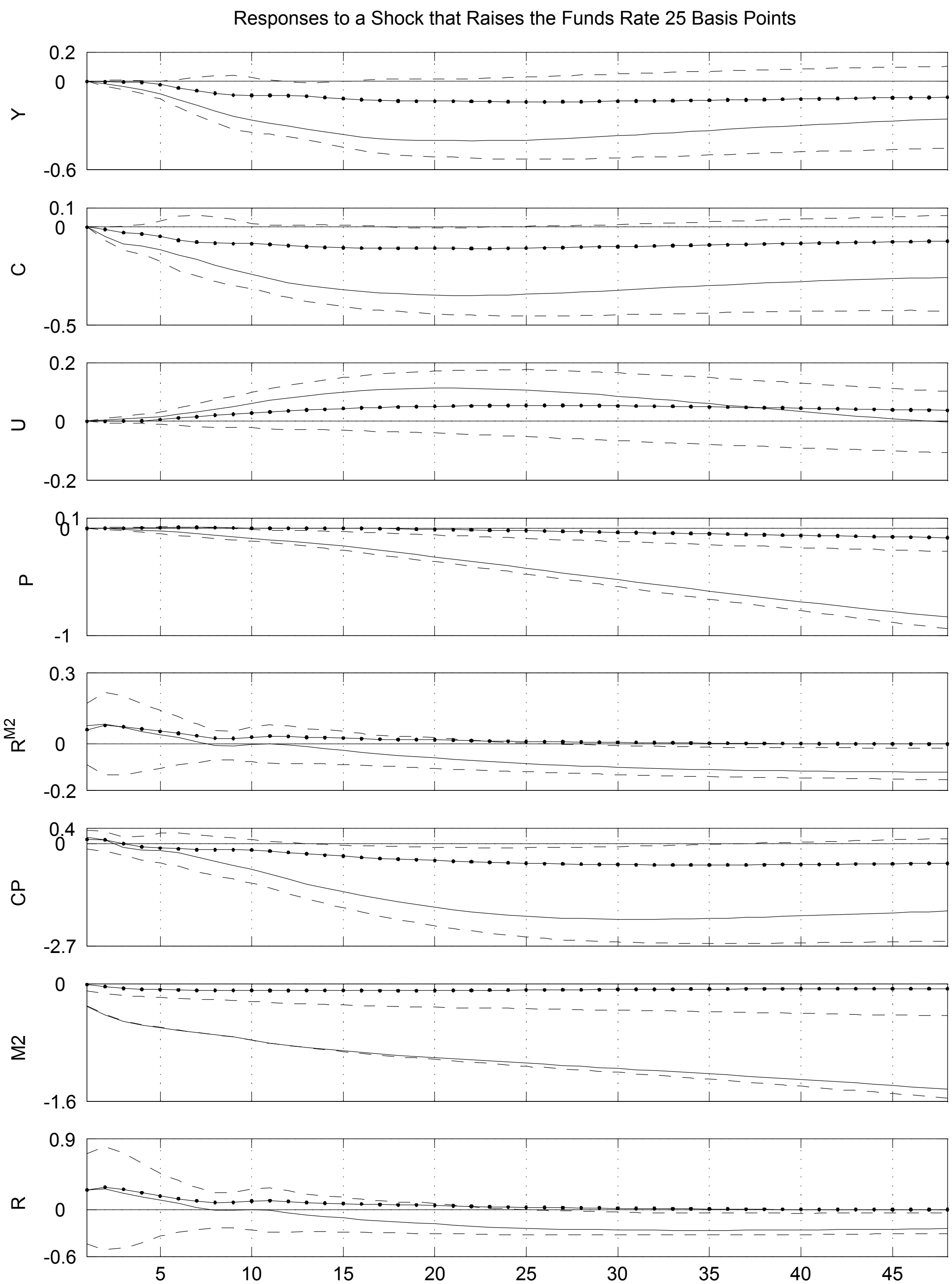


FIGURE 8. Nested Models: $R = f(M)$, solid and dashed lines; $R = f(P, Y, M)$, dotted lines.

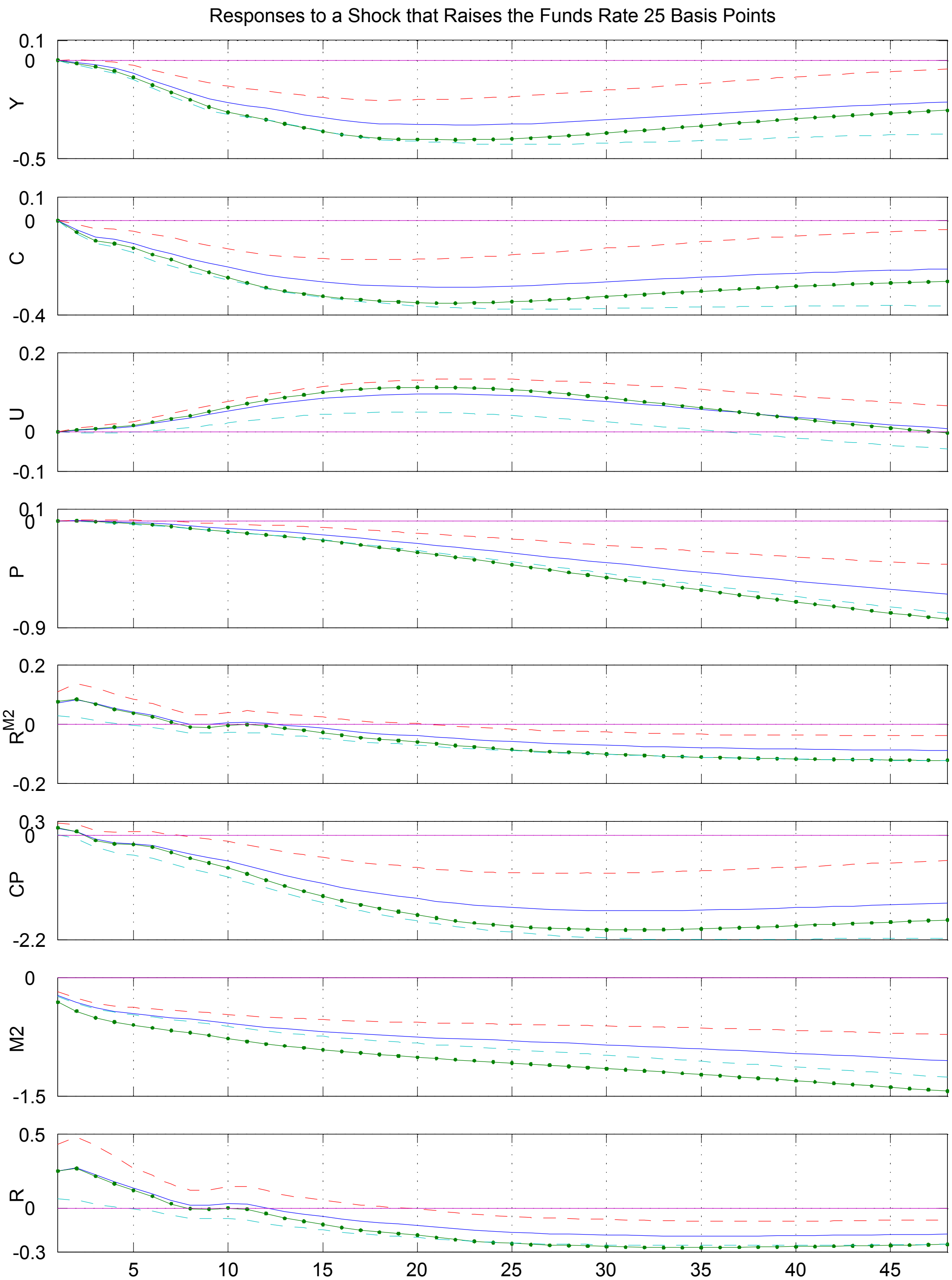


FIGURE 9. Impacts of Policy Contraction in Models With and Without Money: 1983-2001. Dotted solid line, model without money; solid line, model with money; dashed lines 68% bands, model with money.

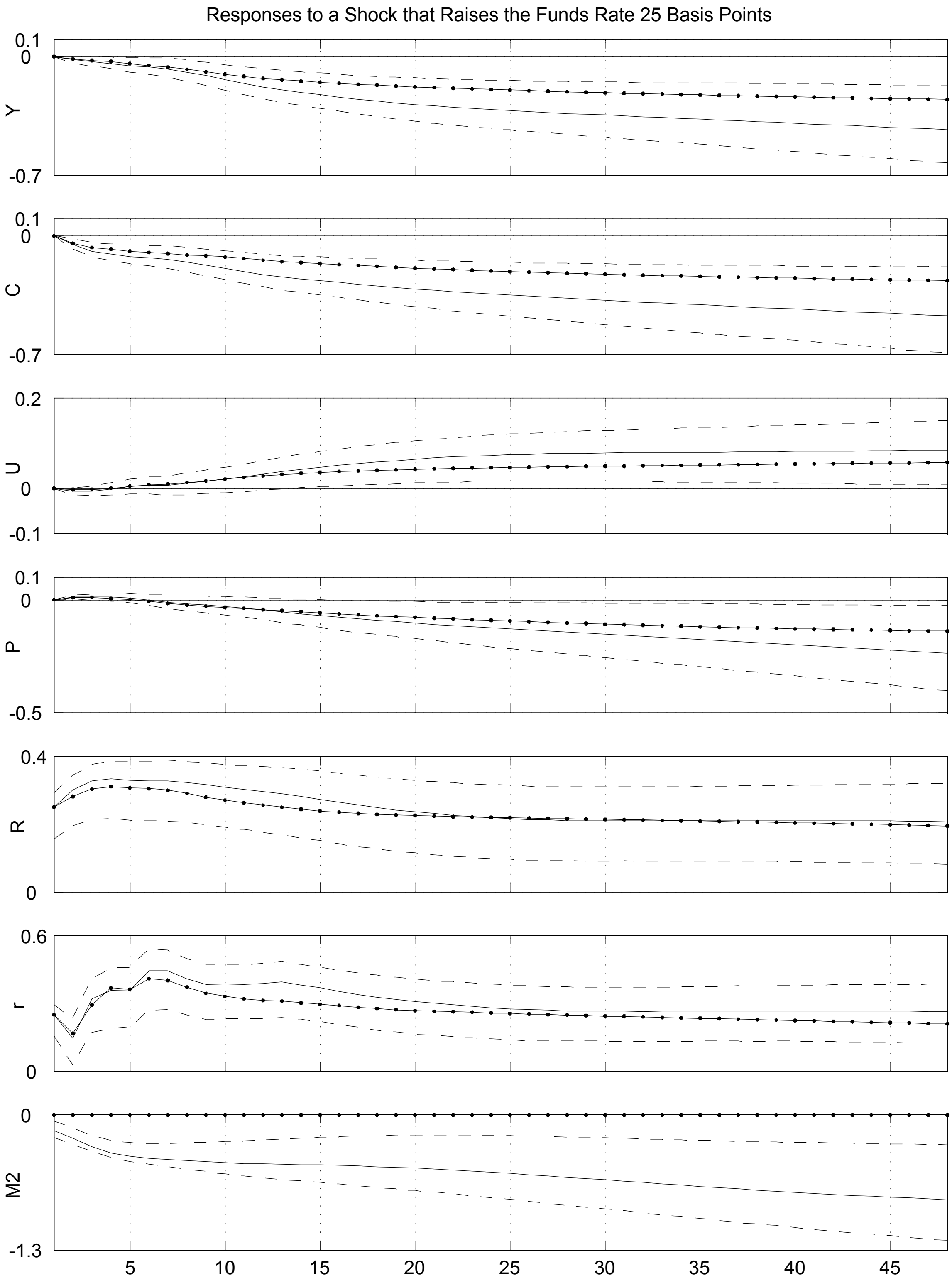


Figure 10. Inflation: Actual and Without Policy Shocks

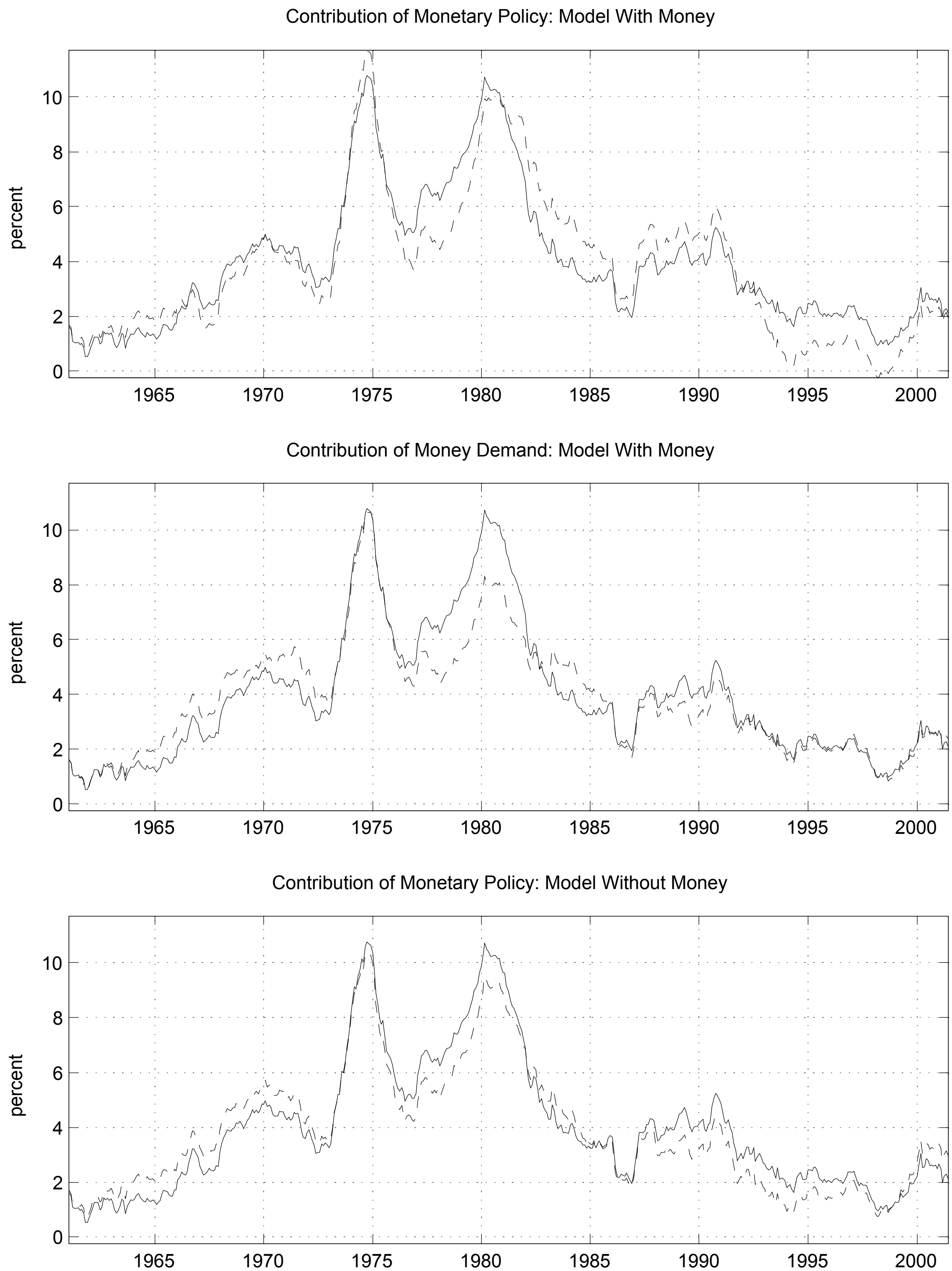


FIGURE 11. Unemployment: Actual and Without Policy Shocks