Putting "M" Back in Monetary Policy

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Money demand and the stock of money have all but disappeared from monetary policy analyses. Remarkably, it is more common for empirical work on monetary policy to include commodity prices than to include money. This paper establishes and explores the empirical fact that whether money enters a model and how it enters matters for inferences about policy impacts. The way money is modeled significantly changes the size of output and inflation effects, and the degree of inertia that inflation exhibits following a policy shock. We offer a simple and conventional economic interpretation of these empirical facts.

MONEY DEMAND and the stock of money have all but disappeared from monetary policy analyses. Reasons for the disappearance range from the declining correlations between conventional money measures and economic activity to the frustrating instability of empirical money demand specifications. The near-universal adoption of interest rate instruments by central banks, coupled with a recent focus on modeling central bank behavior 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). In these 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. 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, 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. Reduced-form studies often find

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no role for money growth in predicting output and inflation, but without identifying money market behavior it is difficult to interpret those findings as having implications for money's role in determining monetary policy impacts (Estrella and Mishkin, 1997, Stock and Watson, 1999).

Two persistent 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 the narrative approach of Romer and Romer (1989) and 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 nonborrowed 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.)

Remarkably, empirical work on monetary policy has reached the point where many people find it more natural to put commodity prices than money in VARs. Commodity prices gained popularity because VARs with commodity prices produce policy impacts that better accord with views about what monetary policy does.

Data on commodity prices and monetary aggregates share some appealing features. Both are available to the Fed in real time at the frequency of FOMC meetings, and both are more or less consistently linked to subsequent economic activity. This paper explores whether money can also help to resolve puzzles in empirical studies of monetary policy. Money does resolve puzzles and in some ways it works better than commodity prices.

This paper consists of two components. The first is a statement about empirical facts: whether money enters an econometric model and how it enters matter for inferences about the impacts of policy. The second component offers a simple and conventional interpretation of how money enters the model and what role it plays in determining the impacts of policy. Importantly, one can accept that money matters for inferences about policy without accepting our particular interpretation.

In this paper, we estimate a range of identified VAR models of monetary policy based on different assumptions about the role of money. Comparing results across models, we find that a policy shock that generates the same initial change in the

Federal funds rate yields significantly different output and price effects, depending on how money enters the model. The way that money is modeled also determines how inertial is the response of inflation to a policy disturbance. These findings hold across time, even in the face of significant financial innovation and instability in short-run money demand. The pattern of results suggests that the funds rate is not sufficient to identify the quantitative effects of monetary policy in small empirical models.

We begin with an extreme comparison between a model that excludes money entirely and a model that allows money to enter relatively unrestricted. The model without money is an expanded version of Rotemberg and Woodford's (1997) three-variable VAR model in which policy obeys a Taylor rule. In the model with money, we allow simultaneity between money and the funds rate. The model without money estimates significantly smaller output and price effects despite the fact that the models predict essentially the same path for the real interest rate. There is an important qualitative difference as well: the model without money exhibits a price puzzle while the model with money does not.

These results raise a host of questions. What role is money playing? Does money provide information of the type that Sims (1992) argues commodity prices contain—information that helps separate an exogenous policy shock from endogenous policy responses to higher expected inflation? Or does money play a causal role in the transmission of policy? These are important and difficult questions that cannot be addressed by empirical work alone. This paper tackles the logically prior empirical question: Do inferences about monetary policy impacts depend on assumptions about how money enters the empirical model?

We examine the implications of allowing money to enter the model in different ways. First, we consider alternative recursive specifications of money and the funds rate and compare those to simultaneous determination of the two money market variables. Restrictions on the contemporaneous interactions between money and the funds rate have large and significant effects on the estimated real and nominal effects of policy. With a recursive ordering, output and price responses to a monetary policy shock are half as large. And the impacts are related to the size of the short-run liquidity effect: the smaller the contemporaneous negative response of money associated with a given initial increase in the funds rate, the smaller the total effect on output and prices. In addition, the price puzzle emerges whenever money and the funds rate are determined recursively.

Next, we examine the effects of selectively restricting lagged money market variables from various real and nominal variable equations, leaving contemporaneous interactions between money and the funds rate unrestricted. In contrast to results from reduced-form Granger causality tests, restrictions on the dynamic role of money generate significant effects.[1] Dynamic restrictions on the role of money produce consistently smaller policy effects on output and prices.

The empirical facts point to the conclusion that money provides information important to identifying monetary policy—information that is not contained in the Federal funds rate.

The paper offers an interpretation of the empirical fact that how money is modeled affects inferences about monetary policy impacts. The size of the liquidity effect and the impacts of policy shocks on output and inflation vary depending on how money is modeled. Our interpretation is straightforward: as simple theory predicts, policy effects depend on the interest elasticities of money demand and money supply. In our models, the Fed adjusts the funds rate in response to the contemporaneous money stock, perhaps because the money stock contains useful and timely information about the current state of the economy.[2] The Fed need not care about money directly. This policy behavior is coupled with a conventional money demand function where the opportunity cost of money is the spread between the funds rate and the own rate of return of M2. This specification of money market behavior assumes that the correlation between money and the funds rate is jointly determined by interactions of supply and demand: money and the funds rate are determined simultaneously. When we estimate these elasticities jointly, we find different policy impacts from when either supply is assumed to be infinitely interest elastic or money demand is assumed to be interest inelastic.

It is tempting to take our interpretation to mean money plays a purely informational role in the sense that Sims argues commodity prices do. Although that meaning is consistent with the empirical facts, the identifications cannot distinguish the informational role from some causal role money may play. Addressing this deeper issue requires more detailed identification schemes than we employ.

Finally, we apply this interpretation to movements in inflation and unemployment over the post-World War II period. Inferences about the role monetary policy played over time vary considerably depending on whether one uses the lens of a model with or without money. Thus, any lessons we might hope to draw for monetary policy from the historical record depend critically on whether and how we include money in the analysis.

1. WHY INCLUDE MONEY?

There are a number of 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. Their 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, 2001b) 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 Ireland's model, money unambiguously plays an informational—rather than a causal—role by helping to forecast future nominal interest rates.

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, which excludes money. Money now has a direct effect that is independent of the short-term interest rate, an effect that Nelson argues U.S. data support.

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.[3] 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.

Goodfriend (1999, p. 414) argues that money plays a critical role even under an interest rate policy because "...credibility for a price-path objective stems from a central bank's power to manage the stock of money, if need be, to enforce that objective." In equilibrium, money is not playing a causal role, yet it is essential for establishing the credibility that allows the central bank to determine expected inflation at every point in time. Goodfriend calls for exploration of models in which "monetary aggregates play a role in transmitting monetary policy independently of interest rate policy" (p. 415).

Lastly, but not exhaustively, an explicit FOMC target for monetary aggregates is not a necessary condition for money to play a role in monetary policy. Financial market conditions may warrant attention by policy makers to quantity measures whether or not precise control of aggregates is possible. In fact, Greenbook and Bluebook documents prepared by Fed staff in preparation for FOMC meetings contain large sections reviewing current money aggregates and bank credit conditions.[4] Further, transcripts from FOMC meetings document lengthy policy discussions of both money aggregates and credit market conditions.[5] A reasonable explanation for continued policy attention to quantity measures under an interest rate targeting regime is the recognition that the transmission of policy actions to the macro economy depends on more than just the short-term interest rate.

2. ECONOMETRIC APPROACH

This section sketches the identified VAR methodology we use 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

$$R_t = g(\Omega_t)\,. \tag{1}$$

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

$$R_t = f(S_t) + \varepsilon_t^P\,, \tag{2}$$

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

The econometric model embeds Equation (2) in a system of equations describing private behavior. If y_t is an $(m \times 1)$ vector of time series, the structural model is

$$\sum_{s=0}^{\infty} A_t y_{t-s} = \varepsilon_t\,, \tag{3}$$

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

$$E(\varepsilon_t \varepsilon'_t \,|\, y_{t-s}, s > 0) = I, \quad E(\varepsilon_t \,|\, y_{t-s}, s > 0) = 0, \quad \text{for all } t\,. \tag{4}$$

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

$$y_t = \sum_{s=0}^{\infty} C_s \varepsilon_{t-s} + E_0 y_t\,. \tag{5}$$

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 Equation (3) is

$$\sum_{s=0}^{p} B_s y_{t-s} = u_t\,, \tag{6}$$

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

Equations (3) and (6) imply a linear mapping from the reduced-form errors to the behavioral disturbances:

$$u_t = A_0^{-1} \varepsilon_t\,. \tag{7}$$

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 4.3.

The common data set from which we draw includes monthly data from 1959:1 to 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.[6] 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 semielasticities. Identified models are estimated using Sims and Zha's (1998) Bayesian methods. We assume a lag length of 13 months throughout.

3. EXTREME ASSUMPTIONS ABOUT THE ROLE OF MONEY

3.1 A Model that Omits 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 1 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 × 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.[7] 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 prices and output.[8] Appendix B reports the estimated coefficients in the Taylor rule.

Figure 1 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.[9] 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

TABLE 1
IDENTIFYING RESTRICTIONS IN MODEL WITHOUT MONEY

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

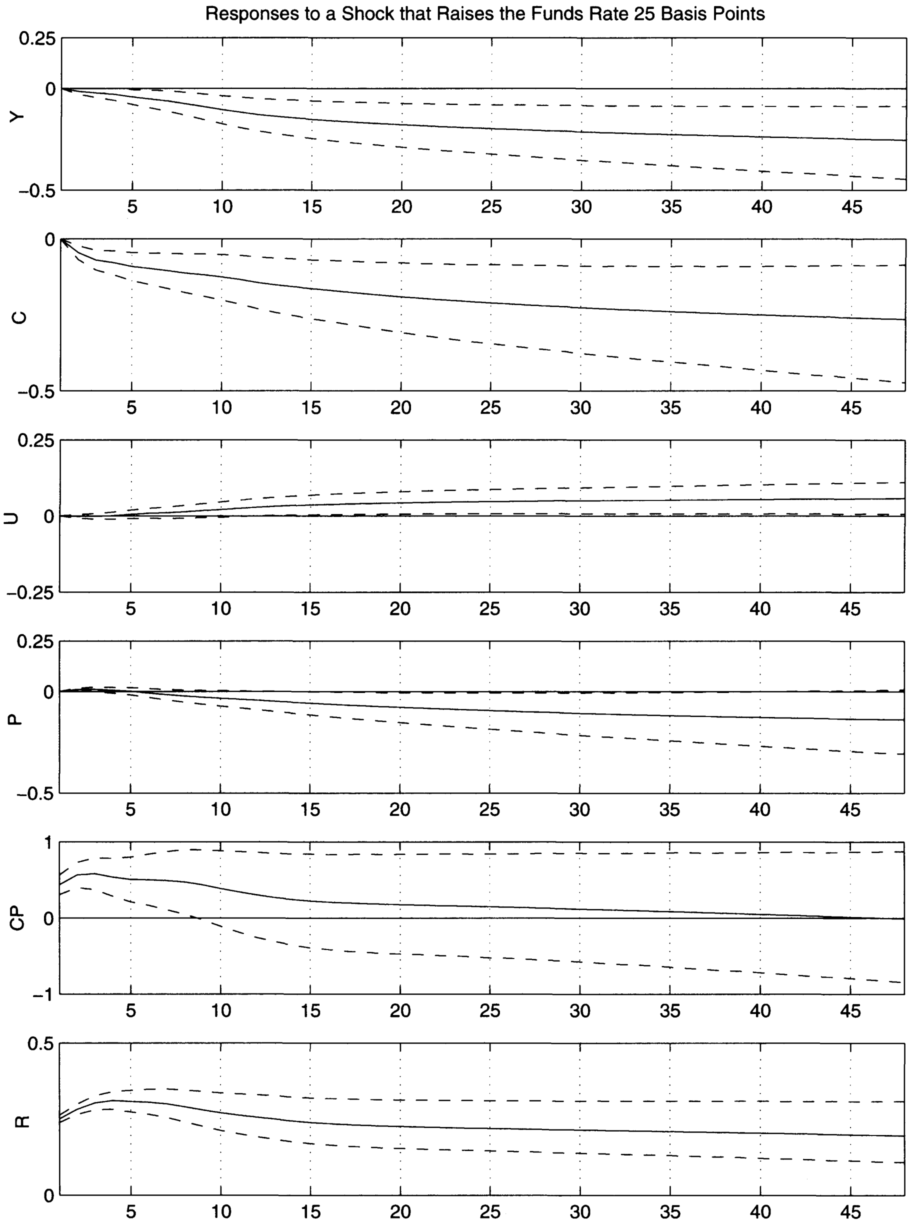


FIG. 1. Impacts of policy contraction in model without money: 1959–2001

months, while unemployment rises and does not peak for about 4 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 subperiods: 1959:1–2001:6 (solid); 1959:1–1979:9 (dashed); 1959:1–1982:12 (dotted); and 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 1959–79 subperiod. Price level impacts exhibit substantial instability, and they all display a small price puzzle in the short run, consistent with Hanson (2002). The 1959–79 and 1959–2001 (excluding 1979–82) periods have chronic puzzles, with a policy contraction permanently raising the price level.

Table 4 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 subperiods, except that the SC favors the restricted model. The recent period, 1983:1–2001:6, which is discussed in Section 5, is different: the restrictions are not rejected by any test. Monetary policy shocks violate the maintained assumption that they are uncorrelated with nonpolicy disturbances, as Appendix E reports. Over both the full sample and the full sample excluding 1979:10–1982:12, the policy shock is correlated with disturbances to goods market equations.

We turn now to a model that includes money and find that this resolves the two empirical anomalies stressed in the introduction.

3.2 Economic Evidence: A Model 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, so it has no effect on output and prices beyond that captured in the short-term interest rate. We now consider a model that allows money to enter in a minimally restricted manner: we allow money and the funds rate to interact simultaneously, and money to enter goods market equations at all lags.

We posit a simple form for the simultaneity between money and the funds rate.[10] Table 2 summarizes the contemporaneous restrictions in A_0. To the model in Table 1 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 1-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 define as the spread between the funds rate and the own return on M2, R^M. An $\times_1$ in Table 2 denotes a linear restriction on the relevant coefficients: $R - R^M$ enters the money demand function with a single

TABLE 2

Tests of Overidentifying Restrictions

Model		1959:1–2001:6	1959:1–2001:6 (excl. 1979:9–1982:12)	1959:1–1979:9	1959:1–1982:12	1983:1–2001:6
No money[a]	S	12.578	10.598	8.7182	8.5203	3.9629
	SC	12.45	12.28	10.99	11.28	10.75
	LR	0.0019	0.0050	0.0128	0.0141	0.1379
	AIC	4	4	4	4	4
A[b]	S	16.995	12.852	8.3803	10.636	5.9146
	SC	31.13	30.72	27.51	28.24	26.92
	LR	0.0045	0.0248	0.1365	0.0591	0.3146
	AIC	10	10	10	10	10
B[b]	S	18.559	15.002	9.4069	11.582	3.8982
	SC	24.91	24.58	22.01	22.60	21.54
	LR	0.0010	0.0047	0.0517	0.0207	0.4200
	AIC	8	8	8	8	8
C[b]	S	24.526	16.004	9.4901	15.148	8.7202
	SC	37.36	36.87	33.01	33.90	32.31
	LR	0.0004	0.0137	0.1478	0.0191	0.1899
	AIC	12	12	12	12	12
D[b]	S	17.04	12.807	8.3482	10.622	6.5458
	SC	24.91	24.58	22.01	22.60	21.54
	LR	0.0297	0.1187	0.0049	0.2241	0.5863
	AIC	8	8	8	8	8

Notes: 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 $\chi2(k)$ for likelihood ratio test; AIC: Akaike Information Criterion = $2k$. [a]Model without money: Does not model money market behavior. M and R^M excluded from the model. Policy: $R = f(P, Y)$. [b]Models A–D differ only in their models of money market behavior; lagged coefficients identical across models. The models are as follows. 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: $M = g(P, C, R - R^M)$.

free coefficient. Monetary policy responds only to the money stock contemporaneously.[11] Our objective is to explore the implications of simultaneously determining money and the interest rate. The money demand and monetary policy specifications are stripped to their bare essentials to limit simultaneity in the model to between money and interest rates. Appendix B reports the estimated coefficients on money demand and the policy rule.

Figure 2 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 interest rate 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% error 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.

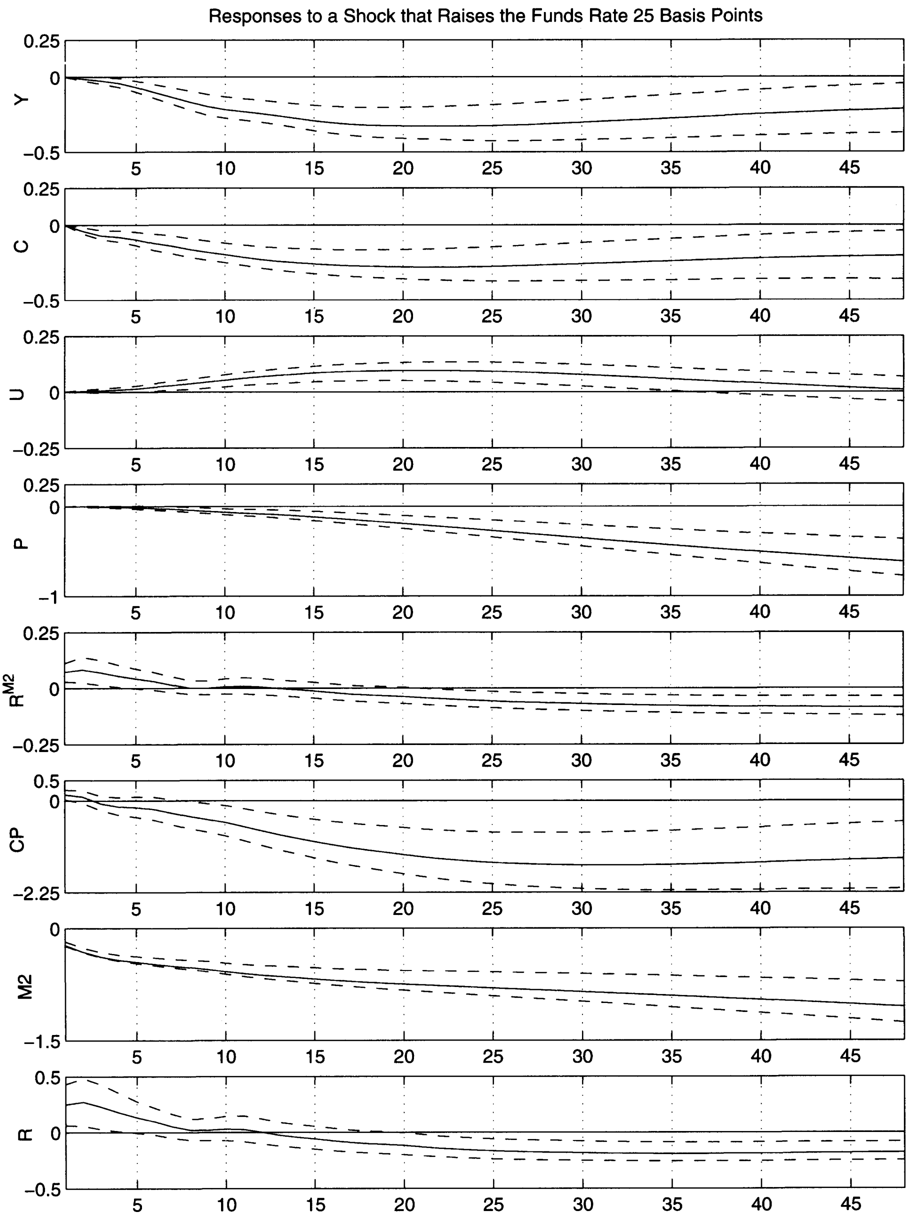


FIG. 2. Impacts of policy contraction in model with money: 1959–2001

TABLE 3

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					×	×	$\times_1$	×

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

Appendix D reports policy impacts over four subperiods. Responses of variables are qualitatively similar across time with the exception of the own rate of return on M2 in 1959–79, a period when the own rate was not market determined. As in Appendix C, 1959–79 exhibits somewhat larger impacts.

A likelihood ratio test rejects the overidentifying restrictions with $p = 0.005$ (Table 4). The SC favors the restricted model, while the AIC prefers the unrestricted

TABLE 4

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[a,b]					Total effect after 4 years on[b]
Model	Y	C	U	π^c	r^d	P
1959:1–2001:6						
Without money	−0.12	−0.10	0.05	−0.04	0.25	−0.07
With money	−0.33	−0.28	0.10	−0.20	0.29	−0.62
1959:1–2001:6 excl. 1979:10–1982:12						
Without money	−0.15	−0.11	0.06	−0.00	0.25	0.04
With money	−0.42	−0.35	0.12	−0.20	0.34	−0.61
1959:1–1979:9						
Without money	−0.25	−0.19	0.10	0	0.25	0.15
With money	−0.71	−0.59	0.15	−0.29	0.54	−0.87
1959:1–1982:12						
Without money	−0.13	−0.10	0.06	−0.05	0.25	−0.11
With money	−0.36	−0.28	0.10	−0.22	0.29	−0.67
1983:1–2001:6						
Without money	−0.25	−0.26	0.06	−0.10	0.41	−0.14
With money	−0.43	−0.47	0.09	−0.12	0.45	−0.24

NOTES: 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 $M = g(P, C, R - R^M)$. [a]Maximum "correct-signed" response. [b]In percent for Y, C, P, π, and in percentage points for U, r. [c]π is monthly inflation at an annual rate. [d]r is the annual real interest rate, $r_t = R_t - \pi_t$.

model. A similar pattern holds in other sample periods, except for 1983:1–2001:6, where the restrictions are not rejected by any test. The monetary policy shock is correlated with nonpolicy disturbances over the full sample, but is uncorrelated with all the shocks when the period 1979:10–1982:12 is excluded from the sample (Appendix E).

3.3 Comparing the Models with and without Money

Table 5 extracts some key quantitative implications from the model without money (Table 1) and the model with money (Table 2). 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.[12] 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,[13] the model with money generates real effects two to three times larger, and inflation effects more than four times larger. After 4 years, the price level is nine times lower in the model with money. The pattern that effects from the model with money are substantially larger than from the model without money holds across subperiods of the data. Differences are less marked for the recent period, 1983:1–2001:6, a topic we revisit in Section 5.

Figure 3 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 4-year horizon. The paths of the funds rate itself also differ across the models. When money is absent, the policy shock

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	$\times_1$	×	$\times_1$	×		×	$\times_1$	

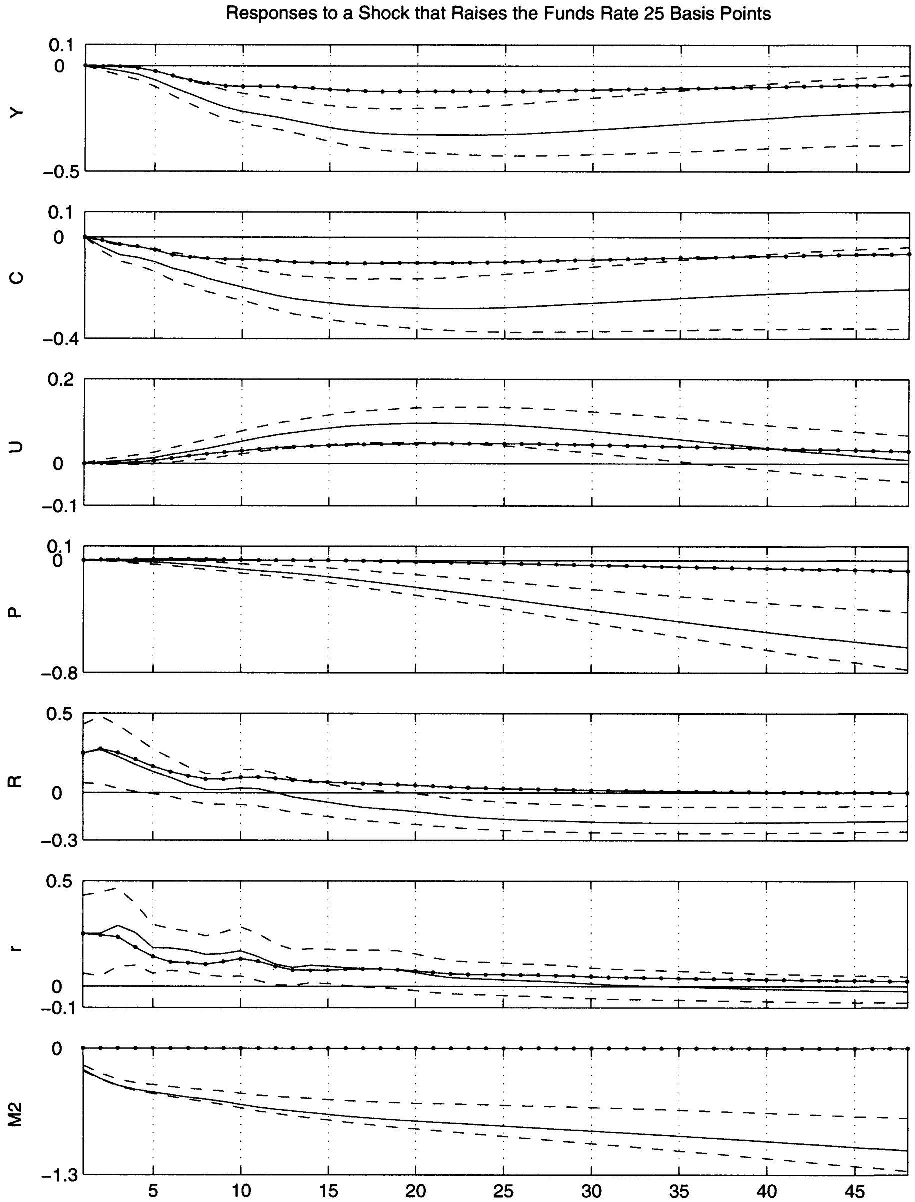


FIG. 3. Impacts of policy contraction in models with and without money. Dotted solid line, model without money; solid line, model with money; dashed lines, 68% bands model with money

generates a persistent increase in the funds rate; the liquidity effect dominates the expected inflation effect. In the model with money, in contrast, the increase in the funds rate lasts well under a year and the expected inflation effect becomes dominant after 18 months.

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.

4. NARROWING THE FIELD

The above section compares two extremes: a model that loosely restricts money and a model that omits money entirely. This comparison is informative, but it does not provide specific information about the empirical role that money plays. We now explore that issue.

4.1 Alternative Models of Contemporaneous Interactions between M and R

We now focus more narrowly on assumptions about contemporaneous interactions between M and R by comparing four alternative models of money market behavior. The four models treat lagged money effects identically and differ only in terms of their specification of short-run money demand and monetary policy behavior. We classify each according to its respective demand or supply interest elasticity assumptions, but we can also think of them in terms of their respective recursive assumptions about policy and private behavior as functions of the money stock and the funds rate.

The benchmark is the model with money described in Table 2, whose policy impacts appear in Figure 2. Three other models are drawn from existing literature. Table 3 repeats the description of the benchmark, model A, and describes the other three models, including: infinitely elastic money supply, model B (Taylor 1993); inelastic money demand, model C (some models in Leeper, Sims, and Zha, 1996, Sims, 1998a); and inelastic money supply, model D (Cochrane 1994).

The four models imply four different pairs of interest elasticities of supply and demand—some estimated, some imposed. Model A assumes M and R are simultaneous and estimates interest semielasticities of supply and demand, while models B–D make different recursive assumptions about the interaction between M and R by imposing a zero (or infinite) elasticity of demand or supply. 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 6 summarizes those impacts across various subperiods and presents the estimated elasticities.

Benchmark model A consistently finds short-run (monthly) semielasticities of demand that are negative and of supply that are positive. The demand semielasticity is smallest in the 1983:1–2001:6 period, which is where the supply semielasticity is the largest. When an infinite supply elasticity is imposed (model B), estimates of

TABLE 6

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[a,b]					Total effect after 4 years on[b]		Short-run interest elasticity of money[c]	
Model	Y	C	U	π^d	$\dot{M}^d$	P	M	Demand	Supply
1959:1–2001:6									
A	−0.33	−0.28	0.10	−0.20	−2.70	−0.62	−1.05	−0.0127	0.0014
B	−0.14	−0.11	0.05	−0.04	−0.32	−0.08	−0.07	−0.0008	∞
C	−0.13	−0.10	0.05	−0.03	−0.26	−0.05	−0.002	0	−0.0298
D	−0.77	−0.68	0.20	−0.58	−8.58	−1.86	−3.33	−0.0484	0
1959:1–2001:6 excl. 1979:10–1982:12									
A	−0.42	−0.35	0.12	−0.20	−3.15	−0.61	−1.30	−0.0132	0.0035
B	−0.20	−0.14	0.08	−0.03	−0.38	−0.04	−0.14	−0.0011	∞
C	−0.18	−0.12	0.07	−0.01	−0.33	0.02	−0.03	0	−0.0482
D	−1.25	−1.23	0.30	−0.85	−13.98	−2.75	−5.66	−0.0773	0
1959:1–1979:9									
A	−0.71	−0.59	0.15	−0.29	−6.31	−0.87	−1.91	−0.0213	0.0010
B	−0.29	−0.23	0.11	0	−0.46	0.15	−0.15	−0.0006	∞
C	−0.28	−0.22	0.11	0	−0.43	0.17	−0.10	0	−0.0582
D	−1.51	−1.25	0.30	−0.87	−17.25	−2.68	−5.04	−0.0562	0
1959:1–1982:12									
A	−0.36	−0.28	0.10	−0.22	−2.60	−0.67	−0.89	−0.0118	0.0005
B	−0.15	−0.11	0.06	−0.05	−0.27	−0.13	−0.12	−0.0009	∞
C	−0.13	−0.10	0.06	−0.04	−0.22	−0.08	−0.06	0	−0.0140
D	−0.51	−0.39	0.14	−0.34	−4.16	−1.03	−1.39	−0.0195	0
1983:1–2001:6									
A	−0.43	−0.47	0.09	−0.12	−1.86	−0.24	−0.81	−0.0086	0.0112
B	−0.26	−0.27	0.07	−0.10	−0.69	−0.08	−0.23	−0.0013	∞
C	−0.22	−0.23	0.07	−0.10	−0.65	−0.05	−0.12	0	−0.0750
D	−2.42	−2.77	0.23	−0.69	−19.59	−2.04	−7.46	−0.2746	0

NOTES: 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: $M = g(P, C, R - R^M)$. [a]Maximum correct-signed response. [b]In percent for Y, C, P, M, π, $\dot{M}$, and in percentage points for U. [c]Short-run elasticity is the monthly contemporaneous semielasticity. [d]π and $\dot{M}$ are monthly inflation and money growth at annual rates.

demand elasticities tend to fall by more than an order of magnitude relative to their estimates in model A. Tiny demand elasticities produce tiny money responses 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 money response 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 to the normalized policy disturbance, and the money 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 4 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 smaller in model B, with the 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 2 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 5 and Figure 1). 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 5, 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 2 months after the shock. Inflation behavior appears to be a particularly nonrobust feature of identified VARs.

Figure 6 compares the price level responses in the four contemporaneous models. Models B and C exhibit small but persistent price puzzles, while models A and D do not. The same division of models results from a comparison of the size of the money response to a policy shock. When M and R are assumed to be recursive and policy follows an interest rate rule, none of the contemporaneous correlation between the two variables gets attributed to policy shocks. However, when money is allowed to play a role in generating policy shocks—either because M and R are simultaneous (model A) or policy follows a money rule (model D)—larger liquidity effects result and the price puzzle disappears.

This pattern of results contrasts sharply with the view that money is redundant given the nominal interest rate. Moreover, if any of the recursive models (B–D) were consistent with the data, the simultaneous model (A) should recover similar predictions. This does not happen in any sample period. This could be because the simultaneous and recursive models are nonnested. In the next section, we examine a model of monetary policy behavior that nests models A and B and find that the model with simultaneous M and R still does not recover the predictions of the recursive scheme.

Table 4 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

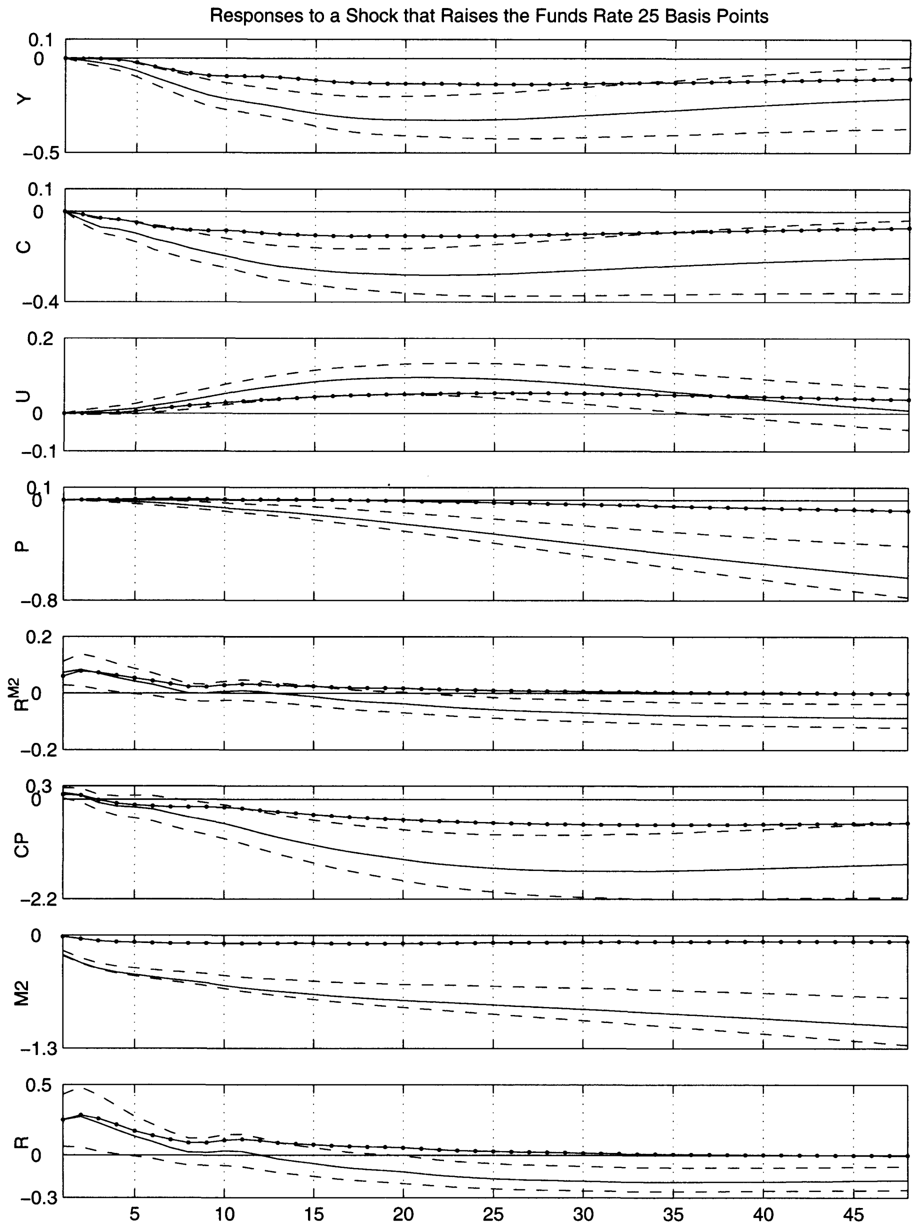


FIG. 4. Impacts of policy contraction in models A and B with money. Solid line is A; dashed lines 68% bands for A; dotted solid line is B. Policy in A: $R = f(M)$; policy in B: $R = f(Y, P)$

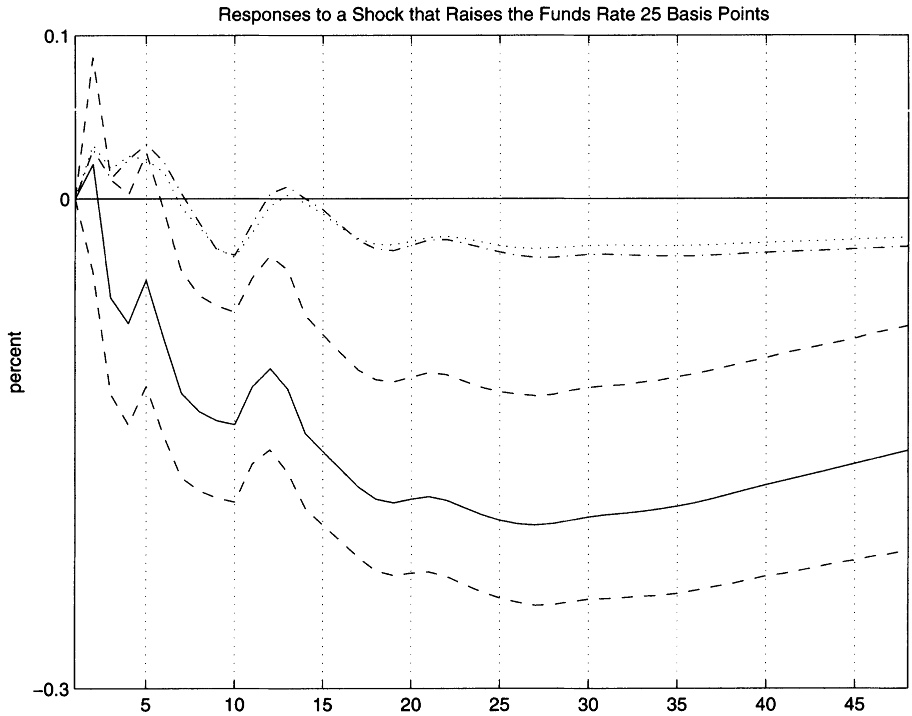


FIG. 5. Impact of policy contraction on annualized inflation. Dotted and dashed line, model B; dotted line, model without money; solid and dashed lines, model A with 68% error bands

too striking, and the SC consistently favors all the restricted models over the unrestricted ones.

4.2 Some Nested Monetary Models

This section compares three models of the money market: models A and B of Table 3 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 8 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

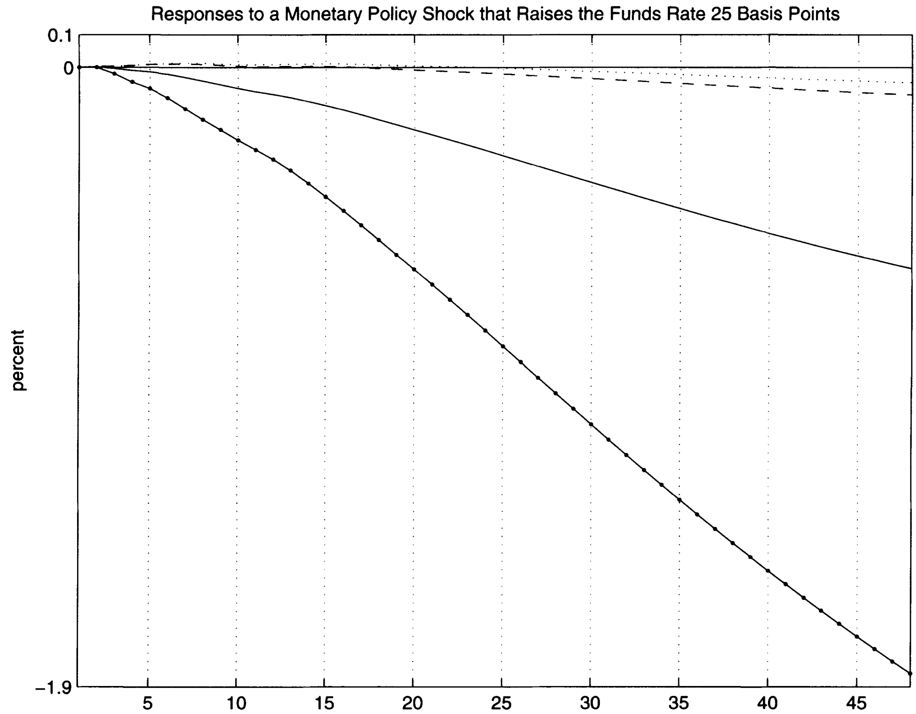


FIG. 6. Impact of policy contraction on price level. Solid line, model A; dashed line, model B; dotted line, model C; dotted solid line, model D

all the error bands are substantially wider than in model A in Figure 2. Nonetheless, the estimated responses in model B are often much smaller than under the generalized rule.[14] Notably, the price level and money stock responses in model B lie entirely outside the error bands of the generalized model. Model B also exhibits a small price puzzle, while the generalized model does not.

Figure 8 highlights the reasoning behind our preference for model A (solid and dashed lines), based on the policy rule $R = f(M)$, over the generalized model (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, however, the impulse responses under model A are much more precisely estimated. This comparison also shows our choice to be conservative: if anything, the generalized rule implies still larger impacts of policy disturbances.

4.3 Selective Exclusion of M and R^M from Lags

Section 4.1 contrasted four models that differ only in their assumptions about contemporaneous interactions in the money market (the elements of A_0 associated

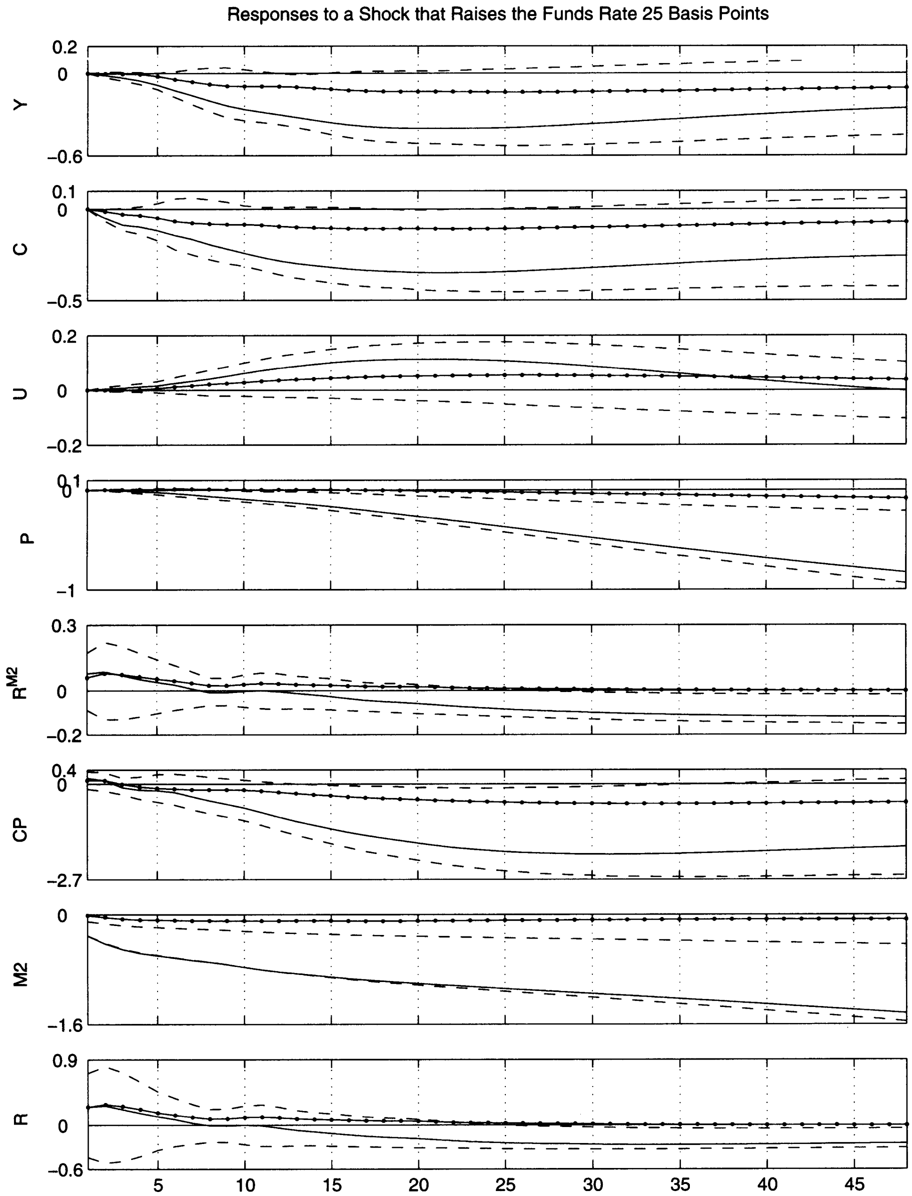


FIG. 7. Impacts of policy contraction in nested models. Solid and dashed lines, $R = f(P, Y, M)$ with 68% error bands; dotted line, $R = f(P, Y)$

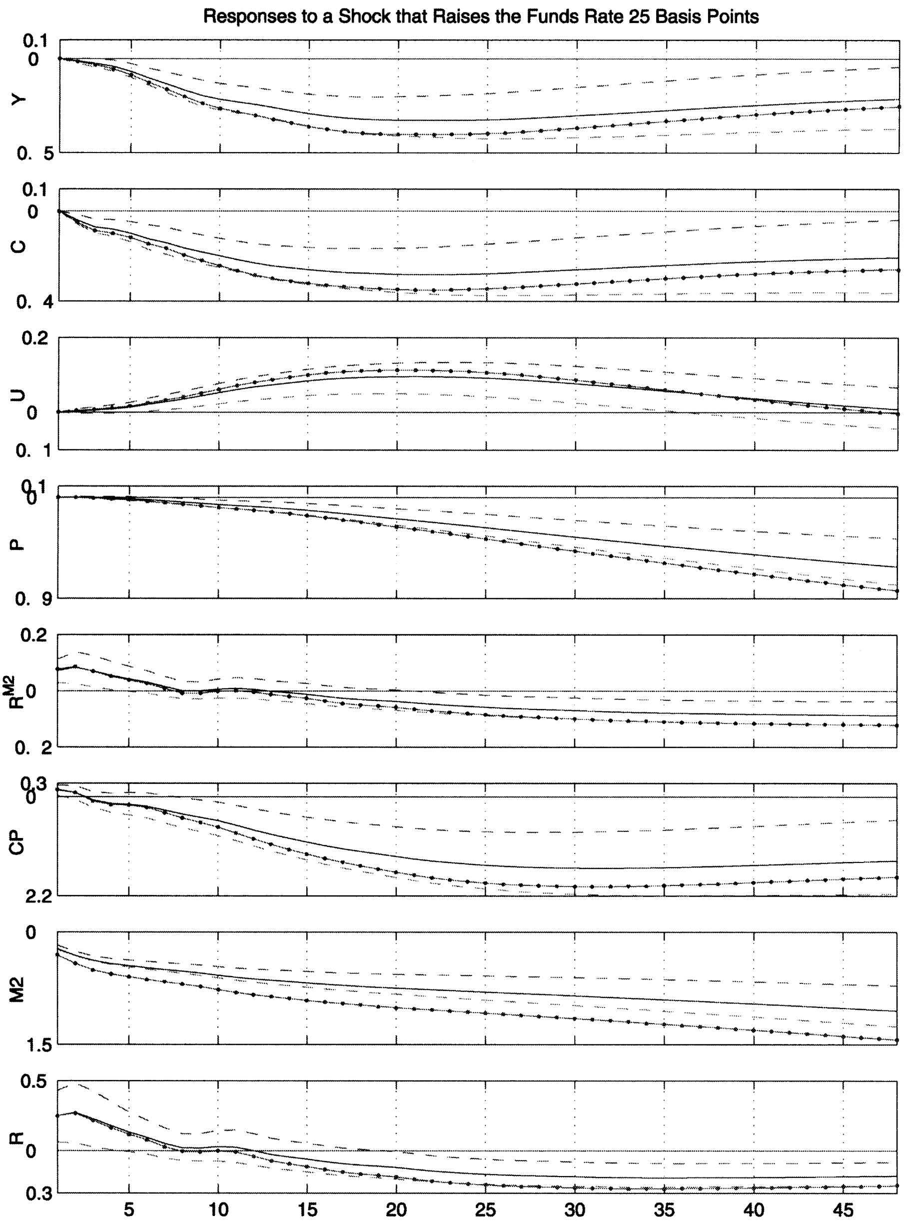


FIG. 8. Impacts of policy contraction in nested models. Solid and dashed lines, $R = f(M)$ with 68% error bands; dotted line, $R = f(P, Y, M)$

with monetary policy and money demand). This section contrasts models that differ only in whether lagged values of money market variables other than the funds rate—M and R^M—enter various product market equations. Whereas Section 4.1 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 2).

Table 7 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 equations for 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 3 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 two to three times when M and R^M are excluded from the entire product market. These patterns hold across subperiods, though they are less pronounced in recent data.

The importance of lagged money market variables in predicting the effect of policy shocks seems at odds with reduced-form evidence. Equation-by-equation F tests in Estrella and Mishkin (1997) and Leeper and Roush (2002) display no consistent pattern in whether money growth predicts output and inflation. In contrast, the multivariate results in Table 7 suggest that past money market variables play a consistent and nontrivial role.

Taken together, results in Sections 4.1 and 4.3 paint a complex picture of the role of money in estimating monetary policy effects. Joint movements in M and R are important for isolating the initial impact of a policy shock; the money stock (and the funds rate) is important for capturing the propagation of policy to product market variables.

TABLE 7

Some Nested Models of Money Market Behavior

	A		B		Generalized	
	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 8

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	Maximum effect over 4 years on[a,b]							Total effect after 4 years on[b]	
Model	Y	C	U	π^3	$\dot{M}^c$	R	r^d	P	M
1959:1–2001:6									
No exclusions	−0.33	−0.28c	0.10	−0.20	−2.70	0.27	0.29	−0.62	−1.05
Excluded from P	−0.37	−0.34	0.11	−0.13	−2.70	0.27	0.25	−0.35	−1.00
Excluded from Y, C, U	−0.11	−0.07	0.04	−0.17	−2.70	0.27	0.30	−0.52	−0.82
Excluded from Y, C, U, P	−0.12	−0.09	0.05	−0.07	−2.70	0.27	0.25	−0.17	−0.72
1959:1–2001:6 excl. 1979:10–1982:12									
No exclusions	−0.42	−0.35	0.12	−0.20	−3.15	0.26	0.34	−0.61	−1.30
Excluded from P	−0.47	−0.41	0.15	−0.13	−3.15	0.26	0.25	−0.32	−1.22
Excluded from Y, C, U	−0.13	−0.07	0.05	−0.18	−3.15	0.27	0.35	−0.52	−1.01
Excluded from Y, C, U, P	−0.14	−0.09	0.06	−0.07	−3.15	0.27	0.25	−0.13	−0.86
1959:1–1979:9									
No exclusions	−0.71	−0.59	0.15	−0.29	−6.31	0.28	0.54	−0.87	−1.91
Excluded from P	−0.84	−0.71	0.20	−0.34	−6.31	0.29	0.28	−0.80	−1.86
Excluded from Y, C, U	−0.23	−0.13	0.09	−0.26	−6.31	0.28	0.53	−0.55	−1.54
Excluded from Y, C, U, P	−0.21	−0.12	0.09	−0.18	−6.31	0.29	0.28	−0.40	−1.43
1959:1–1982:12									
No exclusions	−0.36	−0.28	0.10	−0.22	−2.60	0.25	0.29	−0.67	−0.89
Excluded from P	−0.38	−0.31	0.11	−0.18	−2.60	0.25	0.25	−0.49	−0.81
Excluded from Y, C, U	−0.11	−0.07	0.05	−0.17	−2.60	0.25	0.31	−0.56	−0.76
Excluded from Y, C, U, P	−0.10	−0.07	0.05	−0.12	−2.60	0.25	0.25	−0.33	−0.65
1983:1–2001:6									
No exclusions	−0.43	−0.47	0.09	−0.12	−1.86	0.33	0.45	−0.24	−0.81
Excluded from P	−0.43	−0.48	0.09	−0.10	−1.86	0.33	0.43	−0.20	−0.83
Excluded from Y, C, U	−0.30	−0.32	0.06	−0.11	−1.86	0.34	0.44	−0.20	−0.67
Excluded from Y, C, U, P	−0.30	−0.32	0.07	−0.10	−1.86	0.34	0.43	−0.15	−0.69

NOTES: 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: $M = g(P, C, R - R^M)$. [a]Maximum correct-signed response. [b]In percent for Y, C, P, M, π, $\dot{M}$, and in percentage points for U, R, r. [c]π and $\dot{M}$ are monthly inflation and money growth at annual rates. [d]r is the annual real interest rate, $r_t = R_t - \pi_t$.

5. 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, 1998b) test the stability of the reduced-form coefficients and residual covariances in VARs and conclude that the coefficients are stable, but the covariances exhibit breaks in late 1979/early 1980 and between early 1982 and early 1988. Sims' (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 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.[15] Sims and Zha (2002, p. 13) 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." Significant differences in inference about the stability of policy behavior can emerge from multivariate and single-equation analyses.

Despite this multivariate evidence that post-1982 policy behavior has not been wholly different from pre-1979 behavior, in this section we focus on the subperiod 1983:1–2001:6. There is good reason to be skeptical of inferences about policy drawn solely from this subperiod. 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 did not arise in the model with money in other subperiods. This is potentially 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 6) than in other subperiods.

Conventional tests of fit, reported in Table 4 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.

6. PRICE PUZZLES, LIQUIDITY EFFECTS, AND MONEY DEMAND

The models we estimate include 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.[16] Doing this in the model without money tends to resolve the anomalous response of prices, although the real effects of policy become much smaller and more transitory.

Although commodity prices may help resolve an empirical puzzle—see Hanson's (2002) careful analysis for a different conclusion—this approach raises the theoretical puzzle of exactly what role information about commodity prices is playing in policy

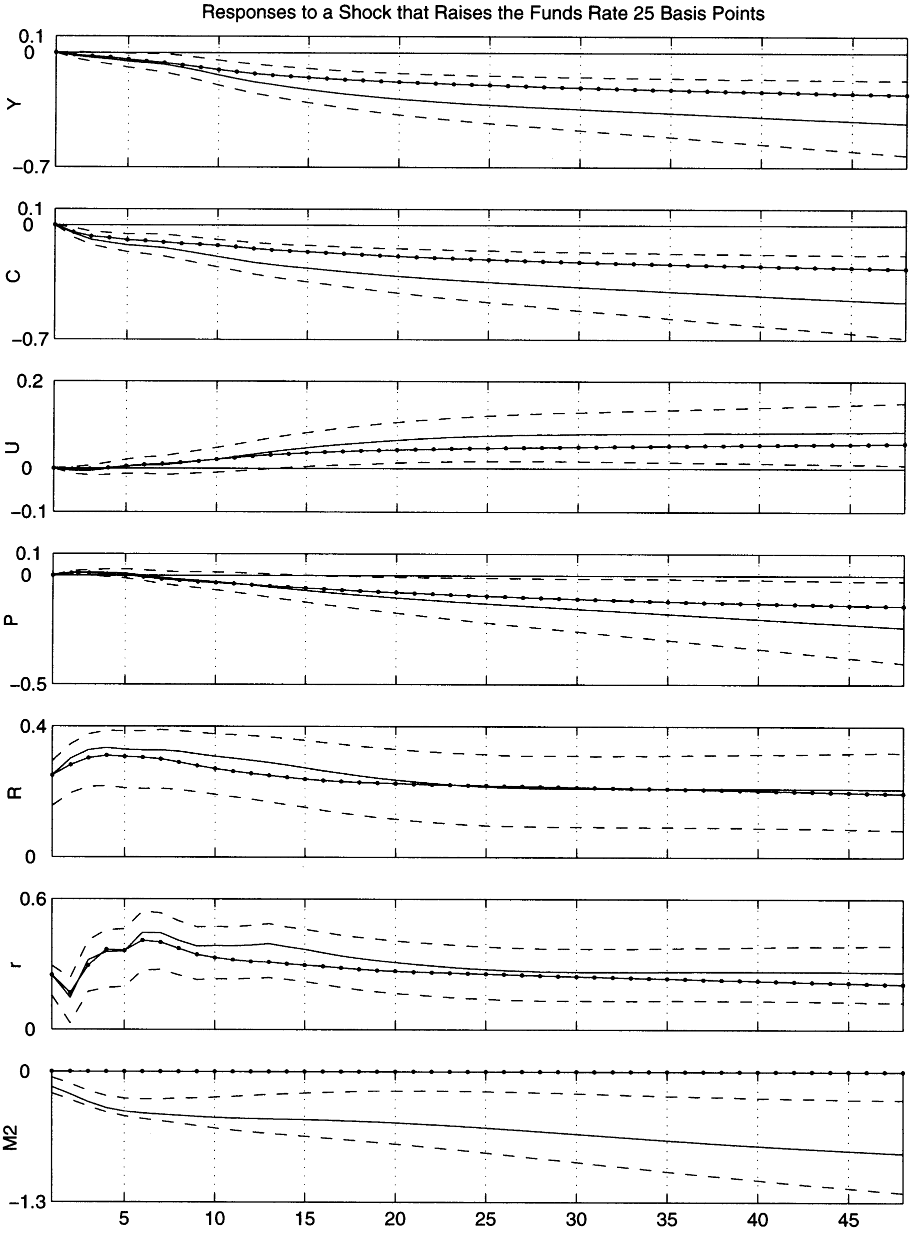


FIG. 9. Impacts of policy contraction in models with and without money: 1983–2001. Dotted solid line, model without money; solid line, model with money; dashed lines 68% bands, model with money

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.[17]

Our results suggest that such contrivances are not necessary. We find that price puzzles are associated with small responses of the money stock to a change in the funds rate induced by policy, or alternatively, that sufficiently large liquidity effects are associated with qualitatively reasonable price responses. One explanation for this association is that liquidity puzzles and price puzzles have a common source: extreme assumptions about the interest elasticities of money demand and money supply.

We believe that money demand lies behind many of the differences among models we estimate. Figure 10 reports responses to the estimated money demand shock in the model with money (baseline model A). 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 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 nontrivial movements in output, consumption, and especially unemployment. Evidently, money demand disturbances are an important source of variation for which models that omit money or do not identify money demand 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:

$$R_t = \alpha_\pi \pi_t + \alpha_m (M_t - M_{t-1}) \,, \tag{8}$$

where the coefficients are positive and $\alpha_\pi + \alpha_m > 1$. Embed this rule in a standard New Keynesian model consisting of an IS equation

$$x_t = -\frac{1}{\sigma}(R_t - E_t\pi_{t+1}) + E_t x_{t+1} \,, \tag{9}$$

where x is the output gap, $\pi_{t+1} = P_{t+1}/P_t$, and $1/\sigma$ is the intertemporal elasticity of substitution; a Phillips curve

$$\pi_t = \lambda x_t + \beta E_t \pi_{t+1} \,, \tag{10}$$

where λ is a reduced-form parameter determining the output-inflation tradeoff; and a money demand function

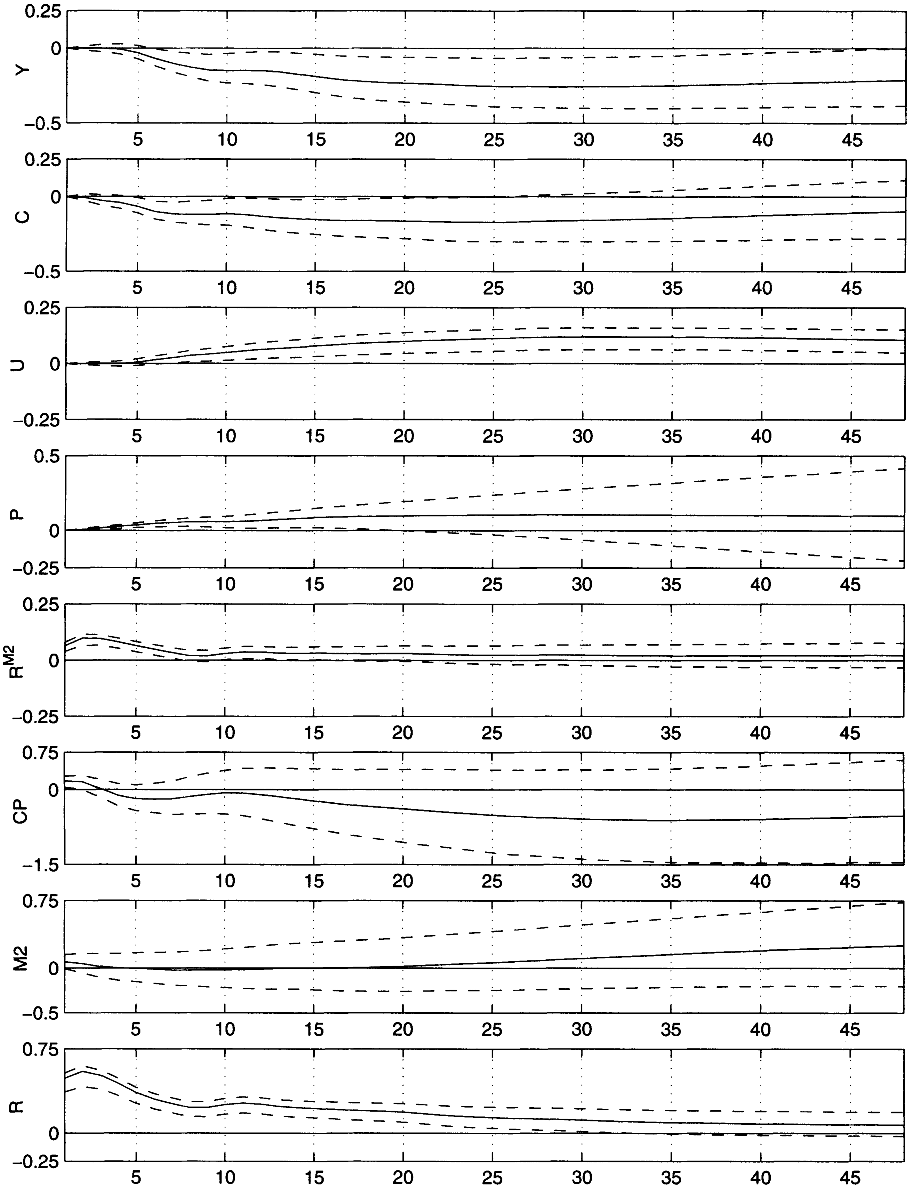


FIG. 10. Impacts of money demand increase: 1959–2001

$$M_t - P_t = -\alpha_R R_t + \alpha_x x_t + \nu_t , \qquad (11)$$

where α_R and α_x are the interest semielasticity and income elasticity, respectively, and ν is an exogenous disturbance to the demand for money. All variables are in logs.

With a conventional calibration of parameters, an exogenous increase in money demand raises the real interest rate briefly, but then lowers it.[18] Because output depends on the entire future 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 11 shows these results. Comparing these results to responses to money demand estimated in the VAR (Figure 10), higher money demand raises the nominal interest rate and the price level, and reduces output in the short run, as in the data.

There are some indications that money demand is not well identified. The VAR does not generate the increase in real money balances that appears in the theory. In addition, exogenous disturbances to money demand are correlated with exogenous shocks to the unemployment equation (Appendix E). These factors argue for a more careful identification of money demand, perhaps through inclusion of long-term interest rates or other asset prices, as Friedman (1956), Tobin (1969), and Brunner and Meltzer (1972) suggest.

Importantly, the New Keynesian model creates a positive correlation between the nominal interest rate and future inflation following a money demand shock. An exogenous monetary policy shock, however, generates a negative correlation. It is

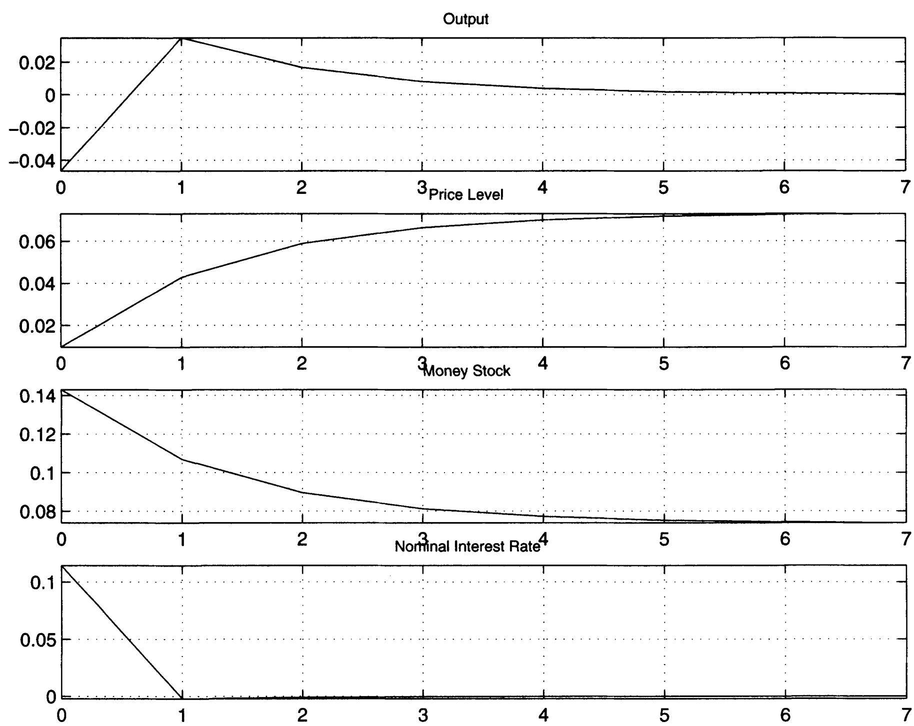


FIG. 11. Impacts of money demand shock in calibrated New Keynesian Model

precisely this decomposition that our baseline VAR models, but recursive identification schemes and models that omit money cannot achieve.

7. 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 yields important differences in the estimated real and nominal effects of policy.

Figure 12 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).[19] The gap between the actual and implied series represents the effects on inflation of current and past exogenous policy or money demand shocks.[20] During the run up in inflation in the late 1970s, 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 1980s. 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 12). From 1964 to 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 Appendix E: 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 1990s 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 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 1990s (Figure 13). While exogenous policy was effective in helping to lower unemployment by more than 1% in the late 1970s according to the model without money, it had little effect

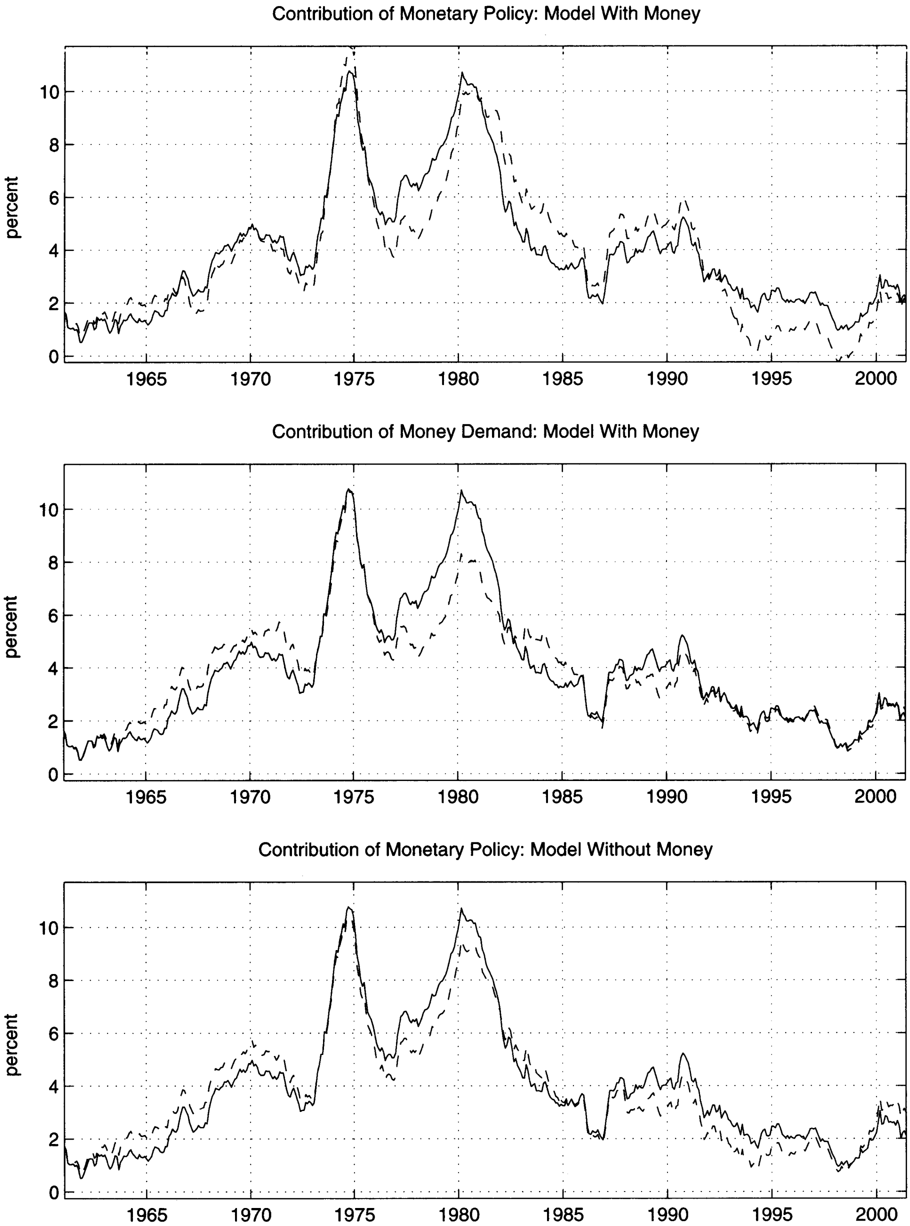


FIG. 12. Inflation: actual and without policy shocks

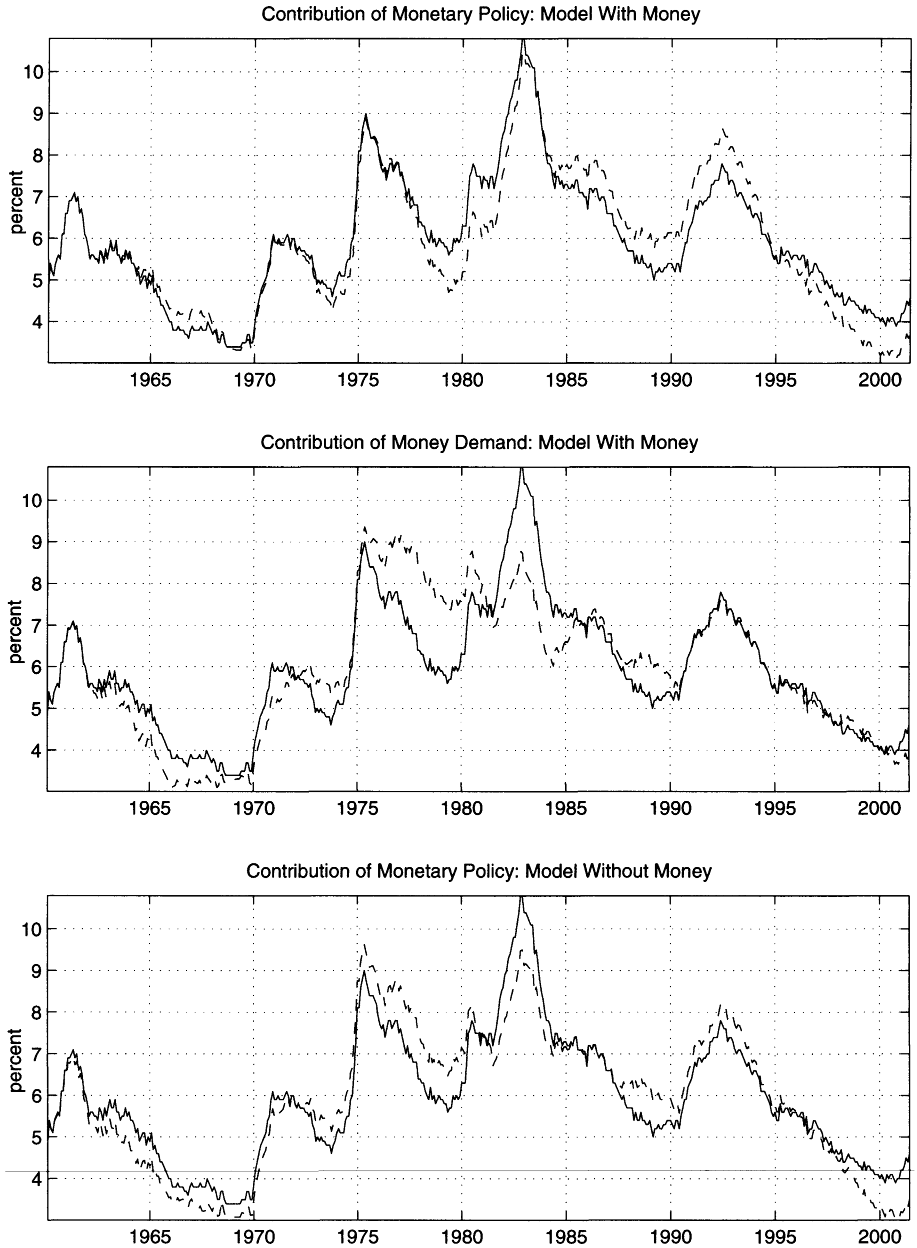


FIG. 13. Unemployment: actual and without policy shocks

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% to unemployment, whereas the model with money shows little influence.

8. CONCLUDING REMARKS

This paper has presented compelling empirical evidence that inferences about the dynamic impacts of monetary policy hinge critically on whether a broad monetary aggregate is included in the model. But merely "adding money" is not sufficient, as our results and the factor analysis VAR of Bernanke, Boivin, and Eliasz (2002) show. It matters how money enters because that determines how contemporaneous money–interest rate correlations get decomposed into parts due to monetary policy and nonpolicy disturbances. Contemporaneous correlations between money and interest rates are important because money is strongly correlated with future output and prices. Recursive identification schemes with, for example, an interest rate rule for policy, take an extreme stand on the decomposition: (1) if money is predetermined for the interest rate, then none of the correlation is attributed to the monetary policy shock; (2) if the interest rate is predetermined for money, then nearly the full correlation is attributed to policy. Simultaneous identification schemes do not impose either of these conditions a priori, though either could be implied by the estimates. We can draw these conclusions about the role of money without claiming to have found the definitive identification of monetary policy and money demand behavior.

The fact that modeling money in certain ways matters is more than an empirical curiosity. We have shown that several important conclusions depend on whether and how money is modeled, including:

1. The magnitude of real and nominal impacts of monetary policy.
2. The absence or presence of liquidity and price puzzles.
3. The degree of inertia exhibited by inflation.
4. The role of monetary policy in influencing observed paths of inflation and unemployment.

The paper offers an economic interpretation of the empirical evidence. We argue that the puzzles that appear in recursive identification schemes may be due to a confounding of monetary policy and money demand disturbances. When the money-interest rate correlation is modeled as emerging from interaction of supply and demand in the money market, we obtain a less contaminated monetary policy shock.

Of course, other interpretations are possible. It is even conceivable that money is proxying for some set of high-frequency data that is central to the Fed's decision process. Identifying that set of data might allow us to avoid the inconvenience of estimating money demand and monetary policy behavior simultaneously.

Given what we now know, we prefer the money market interpretation. It is straightforward and simple. It also has a venerable intellectual history.

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 the procedure that 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: nonfarm 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 Without Money

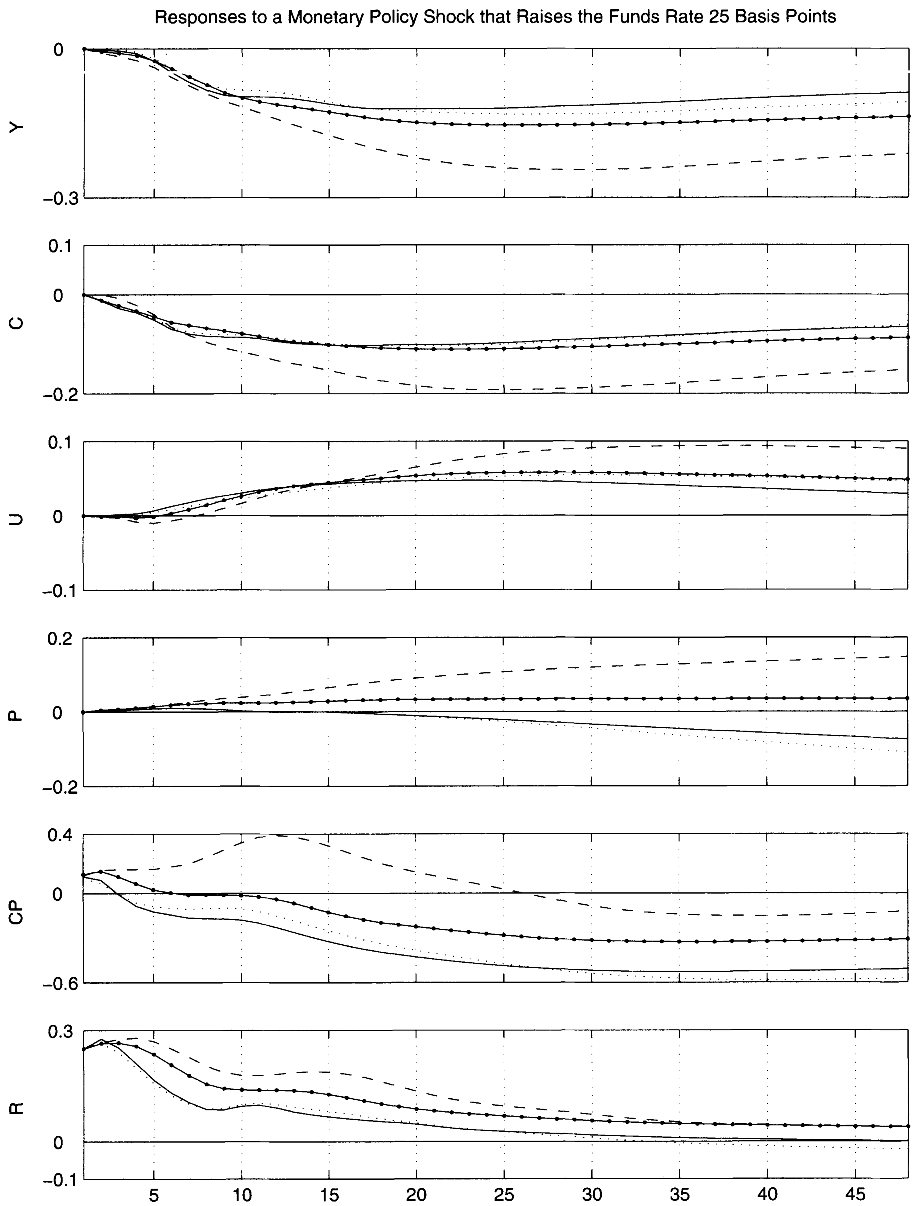
$$\underset{(-11.81,\,-34.13)}{-23.03Y} + \underset{(53.30,\,-10.80)}{20.87P} + \underset{(188.59,200.86)}{194.68R} = \varepsilon^{MP}$$

Model With Money

$$\underset{(321.89,480.91)}{441.16M} - \underset{(-131.38,6.95)}{61.51R} = \varepsilon^{MP}$$

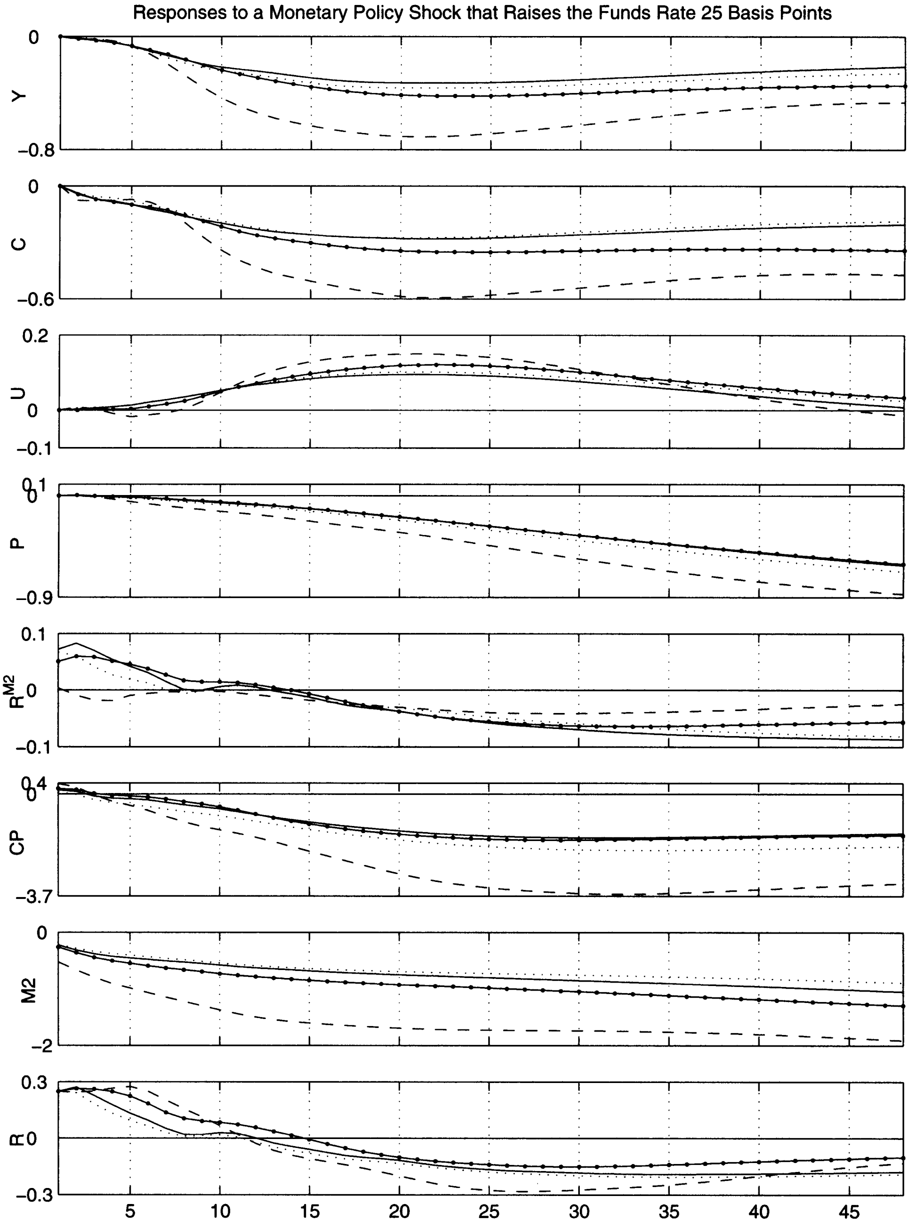
$$\underset{(23.60,5.87)}{15.67C} - \underset{(-47.44,\,-39.55)}{46.78P} - \underset{(-261.58,\,-184.30)}{239.95(R - R^M)} - \underset{(-345.82,\,-34.68)}{189.45M} = \varepsilon^{MD}$$

NOTES: Maximum likelihood estimates; 0.68 probability intervals in parentheses. ε*MP*, monetary policy shock; ε*MD*, money demand shock.



APPENDIX C: SUBSAMPLE STABILITY IN MODEL WITHOUT MONEY

1959:1–2001:6 (solid line); 1959:1–1979:9 (dashed line); 1959:1–1982:12 (dotted line); 1959:1–2001:6, excluding 1979:10–1982:12 (dotted solid line)



APPENDIX D: SUBSAMPLE STABILITY IN MODEL WITH MONEY

1959:1–2001:6 (solid line); 1959:1–1979:9 (dashed line); 1959:1–1982:12 (dotted line); 1959:1–2001:6, excl. 1979:10–1982:12 (dotted solid line)

APPENDIX E:

Correlations Among Structural Shocks

	1959:1–2001:6			1959:1–2001:6 (excl. 1979:10–1982:12)		
	Money[a]		No money[b]	Money[a]		No money[b]
	ε(MP)	ε(MD)	ε(MP)	ε(MP)	ε(MD)	ε(MP)
ε(*Y*)	(−0.038,0.049)	(−0.007,0.062)	(−0.051,0.039)	(−0.038,0.023)	(−0.060,0.014)	(−0.041,0.052)
ε(*C*)	(0.014,0.052)	(−0.015,0.052)	(−0.022,0.010)	(−0.061,0.030)	(−0.061,0.014)	(0.064,0.096)
ε(*U*)	(−0.074,0.066)	(0.136,0.176)	(0.138,0.168)	(−0.076,0.097)	(0.010,0.159)	(0.111,0.141)
ε(*P*)	(−0.031,0.004)	(−0.038,0.051)	(−0.044,0.046)	(−0.021,0.024)	(−0.032,0.062)	(−0.029,0.065)
ε(R^M)	(−0.039,0.050)	(−0.020,0.070)	—	(−0.040,0.051)	(−0.036,0.056)	—
ε(CP)	(−0.048,0.038)	(−0.037,0.050)	(−0.052,0.036)	(−0.046,0.044)	(−0.041,0.049)	(−0.051,0.040)
ε(MD)	(−0.042,0.053)	1	—	(−0.033,0.069)	1	—
ε(MP)	1	(−0.042,0.053)	1	1	(−0.032,0.069)	1

NOTES: 68% error bands for correlation between the monetary policy or money demand shock and other shocks in system. Based on 300,000 draws. [a]Model with money: Policy, $R = f(M)$ and money demand is $M = g(P, C, R - R^M)$. [b]Model without money: does not model money market behavior. M and R^M excluded from the model. Policy: $R = f(P, Y)$.

A maintained assumption in the structural models we estimate is that the exogenous shocks are mutually uncorrelated (see Equation 4). Because the models are overidentified, there is no guarantee that 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. The table reports 68% probability intervals for correlations between MP and MD shocks and other shocks for the model without money (Section 3.1) and the model with money (Section 3.2).

NOTES

1. See, for example, the reduced-form evidence in Estrella and Mishkin (1997). We replicate results from that paper and from Stock and Watson (1999) using our data (Leeper and Roush 2002).
2. The Fed may respond to other current information also.
3. President Meltzer of the St. Louis Fed stated at the February 1992 FOMC meeting, "I think M2 is probably the best indicator we have of concurrent economic activity." (FOMC transcript, p. 44).
4. The FRB Greenbook, the name by which it is commonly referred, is titled "Current Economic and Financial Conditions." The FRB Bluebook is titled "Monetary Policy Alternatives." The general outline of each document follows a predetermined content structure. We looked specifically at the June 1996 editions.
5. See FOMC transcripts for February 4–5, 1992 and February 4–5, 1997 for examples.
6. Appendix A describes the data.
7. Sims (1998b, 2001) discusses why product markets may be inertial.
8. This is a generalized Taylor rule that imposes no restrictions on lags.
9. 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, 2003b).
10. Gordon and Leeper (1994) and Leeper and Zha (2002) consider related forms of simultaneity.
11. In Section 4.2 we also allow current output and prices to enter the policy rule.
12. 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.
13. In the period 1959:1–1979:9 the maximum effect on the real rate in 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.

14. Likelihood ratio tests comparing the Taylor rule (model B) to the generalized policy model for each subsample yielded the following p-values: 1959–2001, $p = 0.20$; 1959–2001 without 1979–82, $p = 0.11$; 1959–79, $p = 0.29$; 1983–2001, $p = 0.73$.

15. 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.

16. Soft zeros are a prior on CP with a zero mean, but a nondegenerative distribution, so if the data strongly support a response of policy to CP, the posterior parameters will reflect it.

17. We found sections on both commodity prices and money aggregates in the Greenbook, but it was not clear to us how to determine which section was more relevant to policy makers. The Bluebook, which dicusses policy alternatives, contains information on money aggregates but not commodity prices. In the June 1996 Bluebook, inflation expectations were discussed in terms of inflations survey data only.

18. Drawing on Clarida, Gali, and Gertler (1999) and Ireland (2001b), we set $\sigma = 1$, $\lambda = 0.5$, $\beta = 0.99$, $\alpha_R = 7$, $\alpha_x = 1.4$, $\gamma_\pi = 0.75$, and $\gamma_m = 0.75$.

19. 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.

20. 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.

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