

MAY/JUNE 1996

# ECONOMIC PERSPECTIVES

A review from the  
Federal Reserve Bank  
of Chicago

**Identification and  
the liquidity effect:  
A case study**

**Soft landings on a  
bumpy runway**

FEDERAL RESERVE BANK  
OF CHICAGO

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## ECONOMIC PERSPECTIVES

May/June 1996 Volume XX, Issue 3

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ISSN 0164-0682

# Identification and the liquidity effect: A case study

Lawrence J. Christiano



Monetary policy continues to be an active subject for debate. This is not surprising. The monetary history of the United States since the found-

ing of the Federal Reserve has not always been easy. In the 1930s, the U.S. experienced by far the worst depression in its history, the severity of which some observers blame on the Fed. Starting in the mid-1960s, the country experienced high inflation for two decades, which was brought to an end only after a wrenching recession. The issues under debate include whether there are changes in the Fed's policy-making framework that would reduce the likelihood of a recurrence of this kind of instability. Various authors, perhaps most notably Milton Friedman, have argued that the Fed should adopt simple rules for the conduct of monetary policy, such as requiring that the Fed hit targets for money growth or expected inflation.<sup>1</sup>

Debate about monetary policy issues requires models.<sup>2</sup> These are needed to make precise the various positions in the debate and to serve as laboratories for comparing the likely operating characteristics of various policy proposals. Supply has expanded to meet the increased demand: Research on constructing empirically plausible macroeconomic models with money has been very active.

To build models that are empirically plausible requires that we know the historical facts about how monetary policy actions affect the economy. If models are to serve persuasively as laboratories for evaluating monetary policies that have never before been tried, then they

must at least be able to reproduce the economic effects of monetary policy actions that have been taken in the past. Before a model's answers to hard questions can be trusted, it should, at a minimum, give the right answers to simple questions.

The purpose of this article is to review some of the issues economists confront in attempting to compile facts about how monetary policy actions affect the economy. The central problem in establishing these facts is that monetary actions often reflect policymakers' responses to nonmonetary developments in the economy. These responses are captured by the notion of a policy *feedback rule*, which expresses policymakers' actions as a function of the state of the economy. To the extent that a policy action is an outcome of the feedback rule, the response of economic variables reflects the combined effects of the action itself and of the variables that policy reacts to. To isolate the effects of Fed policy actions *per se*, one needs to identify the component of those actions that is not reactive to other variables. This is referred

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Lawrence J. Christiano is an economics professor at Northwestern University and a consultant to the Federal Reserve Bank of Chicago. This article surveys joint work with Martin Eichenbaum and Charles Evans (see Christiano and Eichenbaum [1992, 1995], and Christiano, Eichenbaum, and Evans [1996a,b]), and the analysis in Christiano (1995). The author is grateful for innumerable discussions with V.V. Chari and Martin Eichenbaum on the subject of this article. He has also benefited from discussions with John Coleman, Christian Gilles, and Adrian Pagan. The author acknowledges financial support from the National Science Foundation.

to as the exogenous component of a monetary policy action, or, as an exogenous monetary policy *shock*. With this definition, monetary policy actions are the sum of two components: the endogenous part of policy captured by the feedback rule and the exogenous shock. The question, How does the economy respond to a monetary policy action?, is interpreted as, How does the economy respond to an exogenous monetary policy shock?

The answers to such questions depend in part on the assumptions—*identification* assumptions—made to isolate monetary policy shocks. Thus, the persuasiveness of an analysis of monetary policy shocks depends in an important way on how well the researcher defends the underlying identification assumptions.

It is important to distinguish between questions about the economy's response to a monetary policy shock and questions that motivate the quest for a good monetary model in the first place, such as, What is the impact on the economy of a change in the monetary authority's feedback rule? Answering this question would be straightforward if we had data drawn from otherwise identical economies operating under the feedback rules that we are interested in evaluating. We don't. And real world experimentation is not an option. The only place we can perform experiments is in structural models. Giving the right answer to the simple, less directly interesting question is not a sufficient condition for acting on the implications of a given model. However, this test does help narrow the field of choice and gives guidance to the development of models.

This article focuses on the question, What is the *interest rate* effect of a monetary policy shock? Below, I explain why answering this question is not straightforward and requires identifying assumptions. I do this by reviewing the evolution of views on the empirical plausibility of the liquidity effect. This evolution is marked by an increased recognition of the importance of endogeneity in monetary policy. I then describe one set of identification assumptions that I have used in joint work with Martin Eichenbaum and Charles Evans to measure monetary policy shocks. These are used to extract information about monetary policy shocks from data on the nonborrowed reserves (NBR) of banks.<sup>3</sup> Finally, the estimated shocks are used to assess the interest rate effects of monetary policy shocks.

My purpose is not just to convey substantive results about the economic impact of monetary policy shocks, but also to provide a case study motivating the need for identification assumptions, and illustrating one way to go about defending those assumptions.

### **What is the liquidity effect and why care about it?**

An economic model possesses a liquidity effect if it has the following characteristic:<sup>4</sup>

An exogenous, persistent, upward shock in the growth rate of the monetary base engineered by the central bank and not associated with any current or prospective adjustment in distortionary taxes, drives the nominal rate of interest rate down for a significant period of time.

This definition of the liquidity effect can be distinguished from the traditional, partial equilibrium, liquidity effect in the literature. That refers to the fall in the interest rate that is required by a downward-sloped money demand schedule when the money supply increases and there is no change in the price level and level of income. Many existing general equilibrium models that do not possess a liquidity effect in the sense that I define it, do display a partial equilibrium liquidity effect.<sup>5</sup>

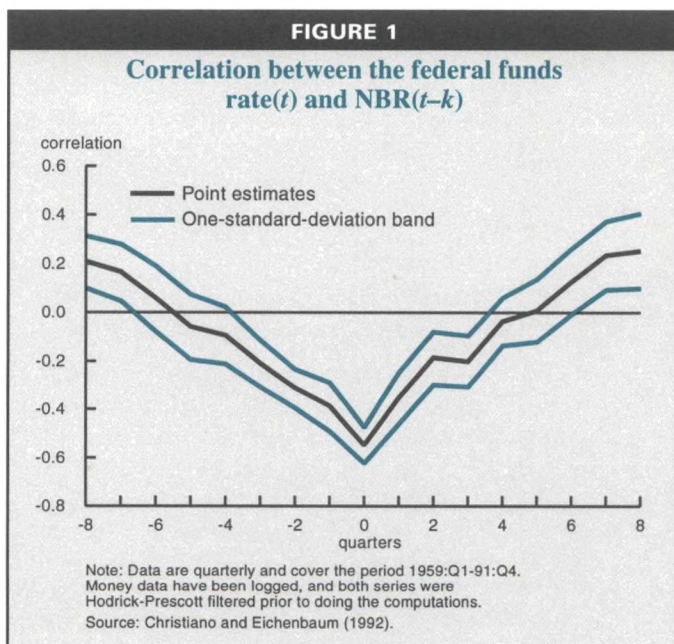
The basic question addressed in the empirical liquidity effect literature is:

What do the data say about the relative plausibility of the following two types of models: models with a liquidity effect, and models with the implication that an exogenous increase in the monetary base drives the nominal rate of interest up?

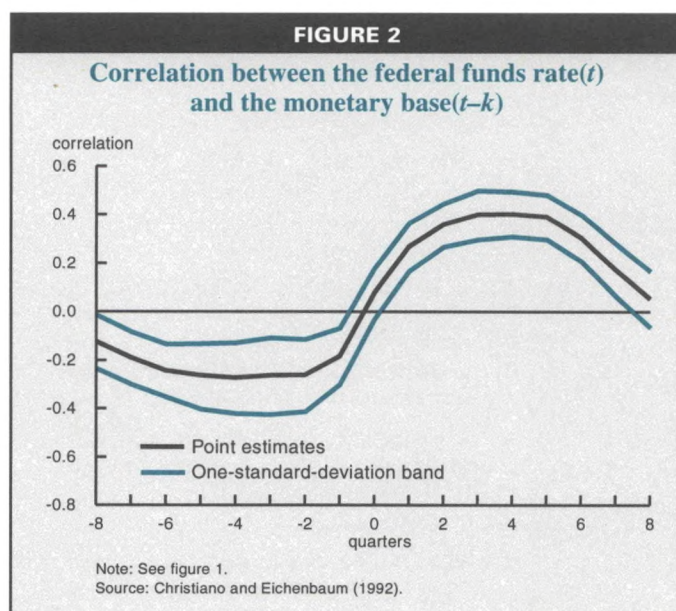
This question is interesting because the answer one selects has important implications for the construction of quantitative macroeconomic models with money. (This is discussed further in Christiano [1991] and Christiano and Eichenbaum [1995].)

### **Evolution of views on the empirical status of the liquidity effect**

Historically, economists have taken the plausibility of the liquidity effect for granted. This is reflected in standard intermediate macroeconomics textbooks, which feature models in which liquidity effects play a key role in the monetary transmission mechanism. However,



when researchers initially attempted to quantify the liquidity effect using data, they came away quite skeptical as to its plausibility. (Examples include Stephen King [1983], Melvin [1983], and Mishkin [1983].) This had an impact on the development of monetary business cycle models. For example, Barro (1987) and Robert King (1991) cite these findings as evidence in support of the first wave of monetized real business cycle models. These models imply that an exogenous increase in

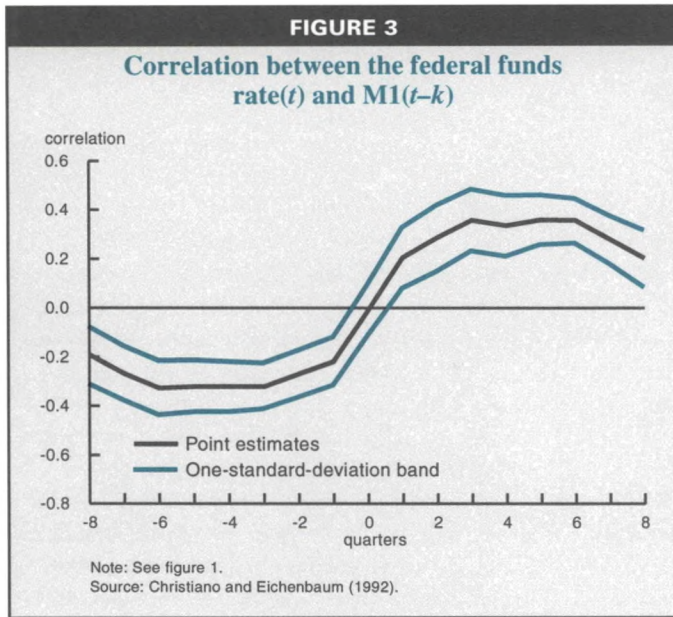


money growth, if persistent, leads to a rise in the nominal rate of interest. Now, as noted by Pagan and Robertson (1995), the consensus has moved back toward the traditional position in favor of liquidity effects.<sup>6</sup> This in turn has sparked efforts to identify frictions which allow monetary models to display a liquidity effect.

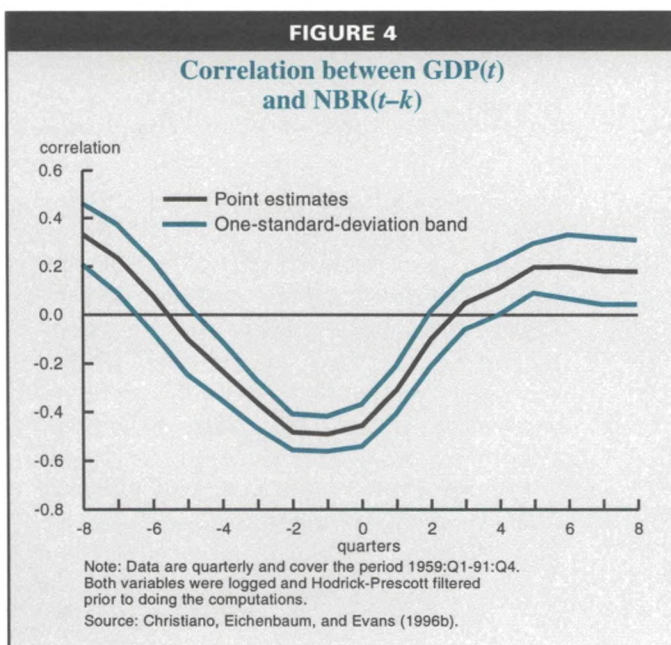
A case can be made that this evolution in thinking reflects early analysts' tendency to focus exclusively on broader monetary aggregates and to ignore the sources of endogeneity in money. Consider the results reported in figures 1-3, taken from Christiano and Eichenbaum (1992). They display the cross-correlation between different monetary aggregates and the federal funds

rate, with plus and minus one-standard-deviation confidence bands. The monetary aggregates examined include nonborrowed reserves (NBR), the monetary base (M0), and M1. (The interest rate and the monetary aggregates were logged and Hodrick-Prescott filtered prior to the computations.)<sup>7</sup> The data display three key features: (1) the broad monetary aggregates covary *positively* with current and future values of the interest rate; (2) they covary *negatively* with past values of the interest rate; and (3) NBR covaries *negatively* with current and future values of the interest rate.

In view of the first feature, it is perhaps not surprising that analysts who assumed the endogenous component of money is small and focused on broader monetary aggregates, arrived at the view that the evidence does not support an important liquidity effect. Early research which recognized the potential role of endogeneity took the view that the Fed conducts monetary policy by targeting the nominal interest rate.<sup>8</sup> Under this view, exogenous innovations in base growth engineered by the central bank are



associated with innovations in the interest rate. Feature two of the data helps explain why these analysts favor the liquidity effect view that an upward revision in the Fed's interest rate target is implemented by engineering a *reduction* in the money supply. Finally, beginning with Thornton (1988), researchers have begun working with NBR. In light of feature three, it is perhaps not surprising that they have tended to conclude that the evidence favors the liquidity effect view.



### Potential pitfalls of ignoring endogeneity in nonborrowed reserves

While the correlations described above go a long way toward explaining why different researchers have reached different conclusions about the empirical status of liquidity effects, they do not tell the whole story. That is because the liquidity effect pertains to the sign (whether positive or negative) of the correlation between the components of interest rates and money that reflect *exogenous* disturbances to monetary policy. Raw correlations, by contrast, reflect the joint movements of interest rates and money arising due to the effects of *all* shocks, not just exogenous monetary policy shocks.

To see why this distinction probably matters, consider the correlation between logged and detrended gross domestic product (GDP) and NBR in figure 4.<sup>9</sup> The fact that the contemporaneous correlation is significantly negative may reflect a policy of "leaning against the wind" at the Fed. If so, then the raw correlation between interest rates and NBR reflects in part the response of both variables to whatever shocks are driving GDP. Such shocks could in principle produce a positive or negative correlation between money and interest rates, independent of whether the liquidity effect is operative.

Coleman, Gilles, and Labadie (1996) present a couple of hypothetical examples that illustrate this and underscore the importance of isolating the exogenous monetary policy component of a monetary indicator variable. They are also useful for illustrating the practical steps researchers take to build confidence that the shocks they have isolated are indeed monetary policy shocks.

One of Coleman et al.'s examples describes an economy in which there is *no* liquidity effect associated with a monetary shock, yet the correlation between non-

borrowed reserves and the interest rate is negative. Suppose the Fed signals policy shifts in advance of actually implementing them, and a signal of an imminent increase in the growth of total reserves produces an immediate rise in the interest rate. Suppose the rise in the interest rate results in an accommodation at the discount window, and the Fed does not wish to see this reflected in a rise in total reserves. This would require the Fed to respond by reducing nonborrowed reserves.<sup>10</sup> Under these circumstances, one would expect a negative correlation between nonborrowed reserves and the interest rate, even though there is no liquidity effect at all. The sign of the correlation simply reflects technical details about how the Fed allocates the different tasks of monetary policy between the discount window and the Federal Open Market Committee (FOMC).

In another of Coleman et al.'s examples, the economy is driven by a single shock,  $\epsilon$ , that is nonmonetary in origin. They assume that the shock drives up the equilibrium nominal rate of interest,  $R$ , and that this produces an accommodation at the Federal Reserve's discount window. The FOMC is assumed to at least partially offset the impact on total bank reserves by undertaking contractionary open market operations which have the effect of reducing  $NBR$ . I will refer to the Fed's presumed perception that the window overreacts to private economy shocks as the *overaccommodation hypothesis*. Under this hypothesis, the Fed partially (or perhaps even fully) offsets the impact on total reserves,  $TR$ , of the surge in discount window borrowing,  $BR$ , that follows a positive realization of  $\epsilon$ . Evidently, under this scenario there could be a negative correlation between  $NBR$  and  $R$ , even though there are no policy shocks at all.

***A formal example of the pitfalls of ignoring endogeneity***

A problem which potentially limits the practical interest of the second example described above is its implication that  $NBR$  and  $TR$  are negatively related. This implication is at variance with the data. But, there is a plausible way around this, which involves incorporating another shock which causes these two variables to move together. Accordingly, let there be an exogenous policy shock to  $TR$ ,  $\mu$ , which also has a positive impact on  $NBR$ . Then it is possible to have  $Cov(TR, NBR) > 0$

and  $Cov(NBR, R) < 0$  simultaneously, as is the case in the data. Most significantly, this pattern of covariances could occur even if a positive, exogenous innovation to total reserves induced by the FOMC (that is, a positive value of  $\mu$ ) led to a rise in  $R$ , that is, even if there were *no* liquidity effect. To make these observations clear, it is necessary to lay the example out formally.

Where relevant, I assume that random variables are independently distributed over time.<sup>11</sup> I also assume that the FOMC's money supply shock,  $\mu$ , and private economy shock,  $\epsilon$ , are mutually uncorrelated. The example has three behavioral equations—two equations describe the policy rules of the FOMC and of the discount window, and the third characterizes the reduced-form relationship between the equilibrium interest rate and the fundamental shocks—and one definitional equation relating  $TR$ ,  $BR$ , and  $NBR$ .

Let the policy rule of the FOMC be:

$$TR = \mu + \epsilon + \upsilon .$$

The shock,  $\upsilon$ , is assumed to be uncorrelated with the other shocks, and is included to capture the possibility that there are exogenous shocks to the reserves emanating from the discount window. These could reflect such things as changes in capital requirements that are exogenous to private economy disturbances, here summarized by  $\epsilon$ . Presumably, most analysts would consider the exogenous component of discount window shocks to be small. However, it is useful to include it here for completeness.

The policy rule of the discount window is:

$$BR = \gamma R + \alpha \upsilon, \alpha, \gamma, > 0.$$

With the exception of the fact that I leave out a role for the discount rate, this specification is pretty standard. Leaving out the discount rate does not detract from the central points I am trying to make.

The reduced-form equation relating the monetary policy shocks,  $\mu$  and  $\upsilon$ , and the private economy shock,  $\epsilon$ , to the equilibrium interest rate,  $R$ , is assumed to be:

$$R = a_1 \mu + a_2 \epsilon + a_3 \upsilon, a_2 > 0.$$

One would want to allow  $a_1 \neq a_3$  since  $\mu$  and  $\nu$  presumably have different dynamic implications for the evolution of total reserves.<sup>12</sup>

The definition of *NBR* implies:

$$NBR \equiv TR - BR = (1 - a_1\gamma)\mu + (1 - a_2\gamma)\varepsilon + (1 - a_3\gamma - \alpha)\nu.$$

Throughout, I will assume  $1 - a_1\gamma > 0$ . This assumption is redundant when  $a_1 < 0$  (that is, there is a liquidity effect), given my assumption  $\gamma > 0$ . In keeping with the spirit of the Coleman et al. example, I assume  $1 - a_3\gamma - \alpha < 0$ , so that the effects of an exogenous increase in reserves supplied at the window are (partially) offset by the FOMC. The overaccommodation hypothesis corresponds to the assumption  $1 - a_2\gamma < 0$ .<sup>13</sup>

It is easily confirmed that:

$$Cov(NBR, R) = a_1(1 - a_1\gamma)\sigma_\mu^2 + a_2(1 - a_2\gamma)\mu_\varepsilon^2 + a_3(1 - a_3\gamma - \alpha)\sigma_\nu^2.$$

$$Cov(NBR, TR) = (1 - a_1\gamma)\sigma_\mu^2 + (1 - a_2\gamma)\sigma_\varepsilon^2 + (1 - a_3\gamma - \alpha)\sigma_\nu^2.$$

A parameterization which implies the right sign pattern of covariances is  $\sigma_\nu = 0.1$ ,  $\sigma_\mu = \sigma_\varepsilon = \gamma = 1$ ,  $a_1 = 0.01$ ,  $a_2 = 1.5$ ,  $a_3 = 1.0$ ,  $\alpha = \gamma$ . In this case,  $Cov(NBR, R) = -0.8$ ,  $Cov(NBR, TR) = 0.39$ . Significantly, in this parameterization there is no liquidity effect, since  $a_1, a_3 > 0$ .

#### *Avoiding the pitfalls in the example*

The preceding example illustrates the principle that one cannot infer anything about the liquidity effect based on the sign pattern of covariances among  $Cov(TR, NBR)$  and  $Cov(NBR, R)$ . Of course, this is not a new principle. Indeed, it is an important theme of the policy shock literature. For example, Christiano and Eichenbaum state that correlations “. . . cannot be taken as evidence of any specific causal mechanism. In particular, they cannot be used to formally infer that unanticipated expansionary monetary policy disturbances cause interest rates to fall. . . .”<sup>14</sup> They argue that to obtain evidence on the liquidity effect “. . . requires identifying assumptions that are sufficiently strong to isolate a measure of monetary policy disturbances.”<sup>15</sup> In the context of the above example, this means the identifying assumptions

have to enable one to isolate the FOMC shock to money,  $\mu$ , or the discount window shock to money,  $\nu$ . Below, I describe the strategy for doing this adopted by Christiano and Eichenbaum (1992, 1995) and Christiano, Evans, and Eichenbaum (1996a,b) (CEE).

#### *Abstracting from discount window shocks*

I first consider the case in which shocks emanating from the discount window,  $\nu$ , are small enough to ignore. To remove the effects of  $\varepsilon$  from *NBR*, CEE make the following identification assumption: that aggregate output,  $y$ , and the aggregate price level,  $p$ , contemporaneously reflect the effects of  $\varepsilon$ , and *not* the effects of  $\mu$ .<sup>16</sup> Their *a priori* reasoning behind this crucial *recursiveness* assumption is that—particularly at the monthly level of time aggregation—it is reasonable to think that monetary policy actions have essentially no contemporaneous impact on aggregate output and the aggregate price level. Below, I review the other efforts made by CEE to check the plausibility of this identifying assumption.

The CEE identifying assumption rationalizes the following two-step procedure for isolating the monetary policy shock,  $\mu$ .<sup>17</sup> First, do an ordinary least squares regression of nonborrowed reserves on  $y$  and  $p$  and treat the residual as something that contains only  $\mu$  and not  $\varepsilon$ . In the second stage, regress the interest rate on the residual. In the example, the residual from the first-stage regression would be  $(1 - a_1\gamma)\mu$  if the data set were large. The coefficients in the regression of the interest rate and of *TR* on the residuals from the first-stage regression are  $a_1/(1 - a_1\gamma)$  and  $1/(1 - a_1\gamma)$ , respectively. Consistent with the sign assumption on  $(1 - a_1\gamma)$  made above, the latter regression coefficient turns out in practice to be positive, so that the sign of the first regression coefficient coincides with that of  $a_1$ . Thus, under the CEE identification assumption, the sign of the regression of the interest rate on the residuals from the first-stage regression constitutes a valid estimate of the sign of the liquidity effect and avoids the pitfalls discussed above.

#### *Taking discount window shocks into account*

The preceding analysis assumes that exogenous discount window shocks,  $\nu$ , are negligible. If they were important, then CEE’s inference



could be distorted. In particular, the contemporaneous interest rate impact of a positive monetary policy shock, measured by CEE's two-stage procedure, is proportional to:

$$a_1(1 - a_1\gamma)\sigma_\mu^2 + a_3(1 - a_3\gamma - \alpha)\sigma_\nu^2.$$

Similarly, the contemporaneous impact on  $TR$  is proportional to:

$$(1 - a_1\gamma)\sigma_\mu^2 + (1 - a_3\gamma - \alpha)\sigma_\nu^2.$$

Once again, the fact that the latter term is positive in the data and our assumption  $1 - a_3\gamma - \alpha < 0$  imply  $1 - a_1\gamma > 0$ . However, now the CEE measure of the interest rate response to a positive money supply shock could be negative, even if  $a_1, a_3 > 0$ , that is, even if there is no liquidity effect; but this requires that  $\sigma_\nu^2$  be large.

This raises the possibility that CEE's measure of monetary policy shocks could be contaminated by  $\nu$ . Under these circumstances, their estimate of a monetary policy shock,  $\mu$ , is actually  $(1 - a_1\gamma)\mu + (1 - a_3\gamma - \alpha)\nu$ .<sup>18</sup> In the extreme case where  $\mu$  is negligible and all monetary policy shocks correspond to  $\nu$ , then if  $(1 - a_3\gamma - \alpha)$  is negative, what they interpret as a positive money supply shock is actually a negative shock.

### Avoiding the pitfalls of endogeneity in practice

The basic problem that must be addressed in estimating the effects of exogenous shocks to monetary policy is how to measure the shocks themselves. In addition, the discussion above highlights the importance of defending the analysis against two potential pitfalls:

(1) the possibility that what is estimated to be a *positive* money supply shock is actually a *negative* money supply shock, and (2) the possibility that what is estimated to be a positive money supply shock is actually some other shock to the private economy. The evidence reported below suggests that the NBR-based procedure for isolating monetary policy shocks avoids these pitfalls.

The key to the CEE strategy for extracting money supply shocks from data on nonborrowed reserves lies in specifying a policy rule for the Fed:

$$NBR_t = f(\Omega_t) + \mu_t,$$

where  $\Omega_t$  is the information set available to the monetary authorities,  $f$  is a linear function, and

$$\Omega_t = \{y_t, p_t, \text{lagged variables}\}.$$

Here,  $p_t$  includes the log of the aggregate price index and of an index of commodity prices, while  $y_t$  is the log of GDP. As before,  $\mu_t$  is the monetary policy shock. The key identifying assumption, aside from the linearity of  $f$  and the specification of  $\Omega_t$ , is:

$$\mu_t \text{ is uncorrelated with the elements in } \Omega_t.$$

As discussed previously, this assumption corresponds to the idea that the relationship between  $p$  and  $y$  on the one hand, and monetary actions on the other, is recursive: Within a given period, the former affect the latter, but the latter have no impact on the former.

Under the recursiveness identifying assumption, the monetary policy shock can be estimated as the residual in the ordinary least squares regression of nonborrowed reserves on  $\Omega_t$ .<sup>19</sup> The dynamic impact on other variables may be obtained from the regression coefficients in a second-stage regression of those variables on current and past values of the estimated residuals. The resulting regression coefficients are referred to as impulse response functions. There is an asymptotically equivalent method for obtaining the impulse response functions based on vector autoregressions. This is the method that was actually used to obtain the impulse response functions displayed in figures 5 and 6. (For technical details on how this was done, see Christiano, Eichenbaum, and Evans [1996a,b].) The results are based on quarterly data and the mnemonics displayed in the figures have the following interpretation. The variable *NBRD* corresponds to minus one times the log of nonborrowed reserves, *FF* corresponds to the federal funds rate, *EMPL* corresponds to the log of employment, *RSALES* corresponds to the level of retail sales, *TRADE PROF* corresponds to the level of profits in the retail trade sector, *NF PROF* corresponds to the level of profits of nonfinancial corporations, and *MFG INV* corresponds to manufacturing inventories. Variables expressed in logs have been multiplied by 100. Units of measure are indicated in the figures.

Consider figure 5, which reports the impact of a contractionary monetary policy shock on monetary and interest rate variables. Panel A of figure 5 indicates that a monetary policy shock corresponds to a persistent drop in the stock of nonborrowed reserves, beginning with a 1.5 percent drop (recall a positive shock to NBRD corresponds to a negative shock to NBR). Interest rates rise for roughly one year, with increases of 30 and 50 basis points in the first two quarters, respectively. Robustness analyses suggest that the reliable result here is the sign of the interest rate response, not its precise magnitude.<sup>20</sup>

As indicated above, there is a need to defend these results against several possibilities. Consider first the possibility that the shock to nonborrowed reserves miscalculates the sign of the monetary shock. This could happen for two reasons. The first of the two Coleman et al. examples suggests the possibility that a negative shock to nonborrowed reserves actually corresponds to a positive *future* shock to the money supply. The second

example suggests the possibility that a negative nonborrowed reserves shock could actually correspond to an overall positive money supply shock emanating from the discount window and partially offset by the FOMC. The plausibility of these hypotheses can be assessed by examining panels B and D of figure 5. These show that total reserves of banks and M1 both drop for one or two years after a negative shock to nonborrowed reserves. Under these circumstances, it seems unlikely that the negative shock to nonborrowed reserves is really a positive shock to current or future total reserves.

Now consider the possibility that the negative shock to nonborrowed reserves really reflects the Fed's reaction to a private economy shock, which drives the interest rate up and leads to an overaccommodation (from the perspective of the FOMC) by the discount window. One possibility is that the private economy shock is a positive shock to money demand by the nonbank public. However, this seems unlikely given the fall in M1. One would expect

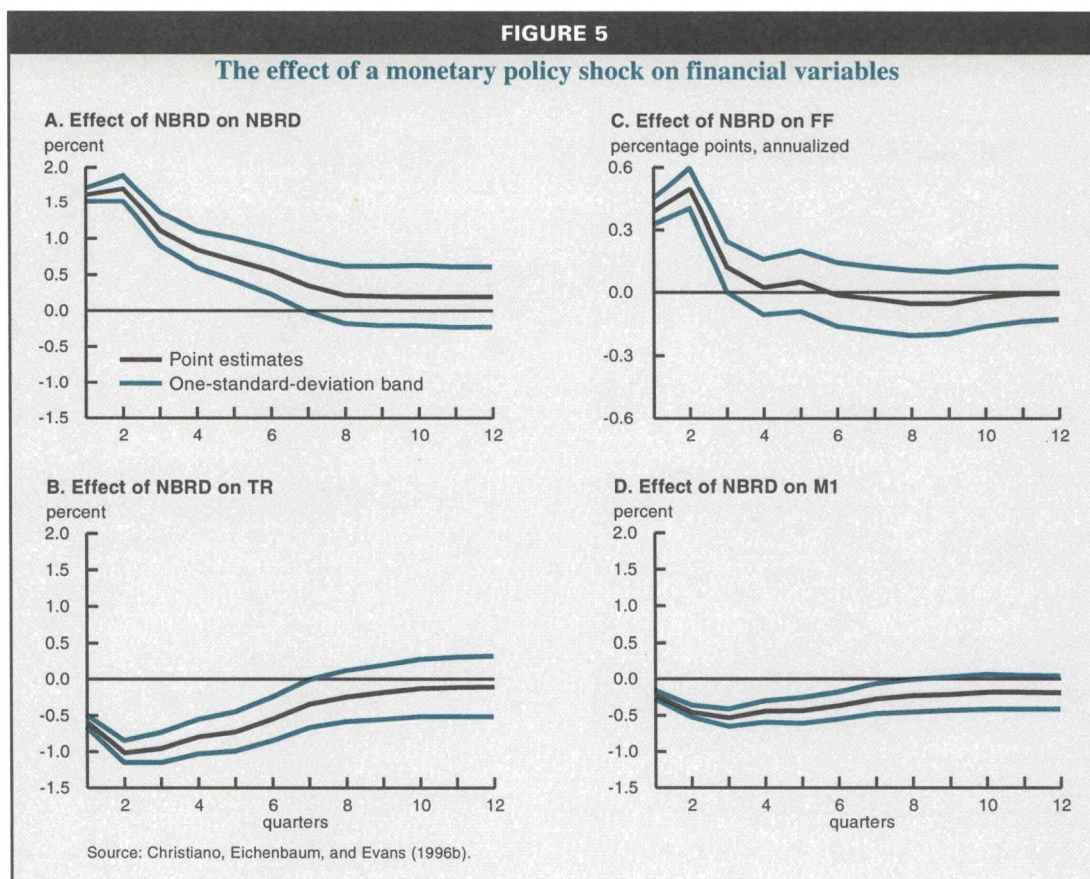
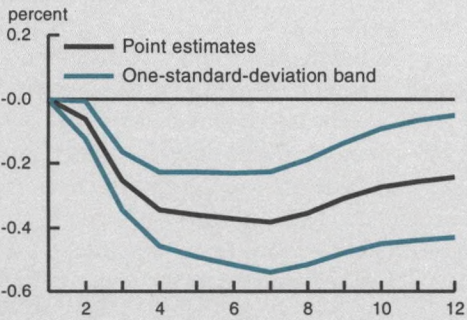


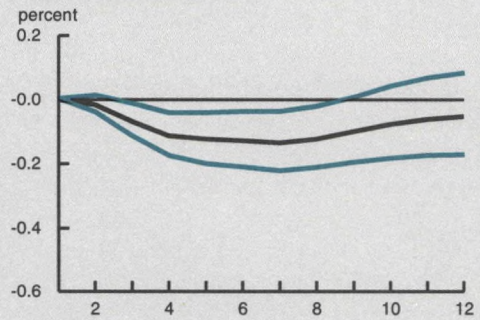
FIGURE 6

The effect of a monetary policy shock on macroeconomic variables

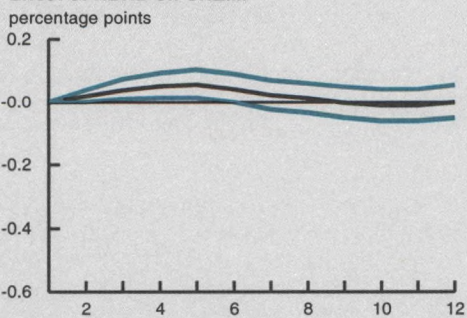
Effect of NBRD on Y



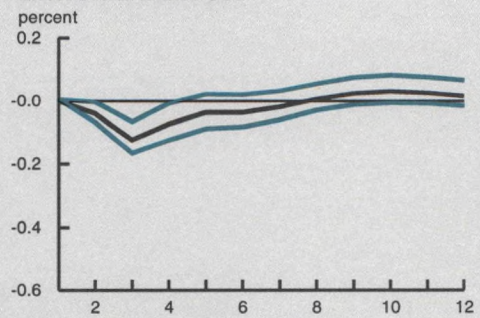
Effect of NBRD on EMPL



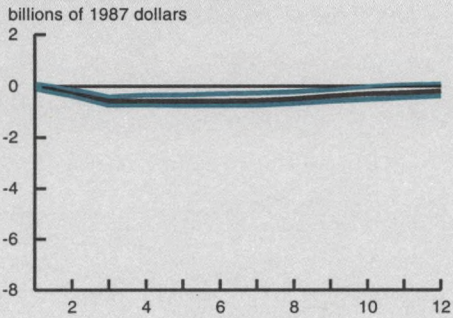
Effect of NBRD on UNEMP



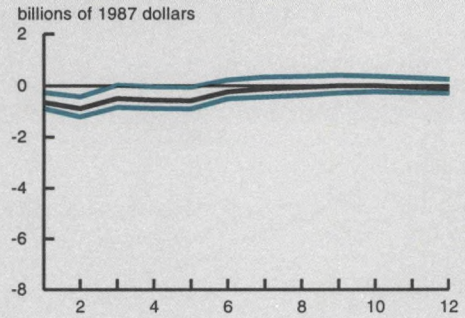
Effect of NBRD on PCOM



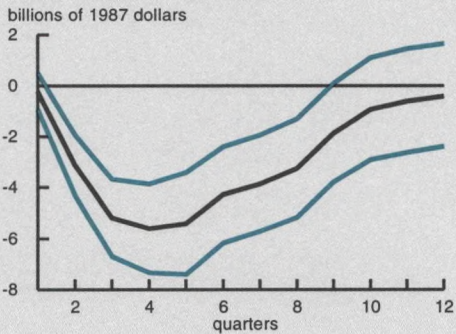
Effect of NBRD on RSALES



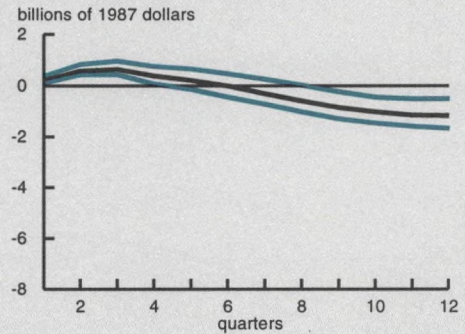
Effect of NBRD on TRADE PROF



Effect of NBRD on NF PROF



Effect of NBRD on MFG INV



Source: Christiano, Eichenbaum, and Evans (1996b).

such a positive money demand shock to raise interest rates and encourage banks to increase the money multiplier. Another possibility is that the positive money demand shock represents an increased demand for reserves by banks; but this seems unlikely given the fall in total reserves. It is hard to see why the Fed would respond to an increased desire for reserves on the part of the banking system by *reducing* the quantity of those reserves.

## Conclusion

This article presented a case study in analyzing the macroeconomic effects of a monetary policy shock. The case study was used to

illustrate the role of identifying assumptions and how, in practice, one can test those identifying assumptions.

The results indicate that contractionary monetary policy actions do not produce an immediate fall in interest rates, as the initial monetized real business cycle models predict. The point estimates suggest that, instead, interest rates rise for about a year after a typical monetary contraction. They also indicate, as seen in figure 6, that output, employment, prices, retail sales, and profits fall, while inventories and unemployment rise.

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## NOTES

<sup>1</sup>For a discussion of a feasible way to target expected inflation, see Friedman's (1992), pp. 227–229, review of Hetzel's (1991) proposal.

<sup>2</sup>The following remarks draw heavily on Christiano, Eichenbaum, and Evans (1996a).

<sup>3</sup>In our work, we also extract monetary policy shocks from interest rate data. I do not survey this work here.

<sup>4</sup>This section and the next draw heavily on the material in Christiano (1995).

<sup>5</sup>This can happen if what earlier writers called the *price* and *income* effects dominate the partial equilibrium liquidity effect, that is, if the positive price and income responses to a money shock exert a sufficiently strong increase in money demand.

<sup>6</sup>There does seem to be a consensus that interest rates do not *rise* significantly after a money injection. There is less agreement on the magnitude of an interest rate *drop* after a monetary injection.

<sup>7</sup>The nonborrowed reserves data were obtained from Steve Strongin, then at the Federal Reserve Bank of Chicago. The other data were taken from CITIBASE. The federal funds rate, monetary base, and M1 have mnemonics FFYF, FMBASE, and FM1, respectively. The results reported in figures 1–3 are robust to alternative detrending procedures and sample periods. See Christiano and Eichenbaum (1992) for details.

<sup>8</sup>See, for example, Bernanke and Blinder (1992) and Sims (1986).

<sup>9</sup>The GDP data are taken from CITIBASE.

<sup>10</sup>Total reserves is the sum of reserves borrowed from the Fed's discount window (borrowed reserves) and the rest (nonborrowed reserves).

<sup>11</sup>One interpretation of this assumption is that I am thinking about the (non-orthogonalized) vector autoregressive innovations in  $R$ ,  $NBR$ ,  $BR$ , and  $TR$ . In empirical work these variables are typically specified in logs, whereas in the example they are specified in levels. Presumably, this distinction is inessential.

<sup>12</sup>As long as  $a_1 \neq a_3$ , the decomposition, between borrowed and nonborrowed components, of disturbances to total reserves matters for the interest rate. There are several reasons to think that this might be true. One of these is based on the notion that banks regard the privilege of going to the window as an option, in which case they may be reluctant to exercise that option. In this case, the Fed could raise interest rates by holding total reserves fixed, but reducing the nonborrowed component. To see that this could drive up the interest rate (and, hence affect real economic decisions), consider a draining action by the New York Fed's trading desk. Initially, banks would scramble on the fed funds market to make up the shortfall. They would do this before going to the discount window, since going to the window deprives them of the opportunity to do so again in the near future. But, the reserves shortfall cannot be made up in the fed funds market, and so money market rates will be bid up. Eventually, they would have to rise enough to overcome banks' reluctance to go to the window. With a low enough short-run demand elasticity for reserves (due, say, to an inability to quickly alter the liability structure of their balance sheets), banks would go to the window and borrow the full amount of the desk's draining action, leaving total reserves—but not the interest rates—unchanged.

<sup>13</sup>This hypothesis has some empirical appeal, because  $NBR$  and output are negatively contemporaneously correlated (see figure 4). This is an implication of the example, assuming output is positively correlated with  $\epsilon$  and only weakly related to  $\mu$  and  $\nu$ .

<sup>14</sup>Christiano and Eichenbaum (1992), p. 5.

<sup>15</sup>Christiano and Eichenbaum (1992), p. 13.

<sup>16</sup>One reason why *both*  $p$  and  $y$  might be needed to pin down  $\varepsilon$  is that  $\varepsilon$  is itself a linear combination of two private economy shocks, that is,  $\varepsilon = \alpha_1\varepsilon_1 + \alpha_2\varepsilon_2$ . Then, to get  $\varepsilon$ , both  $p$  and  $y$  are useful, to the extent that these variables are themselves linearly related to  $\varepsilon_1$  and  $\varepsilon_2$ .

<sup>17</sup>CEE actually used an asymptotically equivalent procedure which is based on vector autoregressions. For more details, see Christiano, Eichenbaum, and Evans (1996a,b).

<sup>18</sup>If  $p$  and  $y$  were functions not just of  $\varepsilon$ , but also of  $v$ , then there would be no problem: the residual in the first-stage regression would be  $(1 - a_1, \gamma)\mu$ , as before. I do not consider this case because the reasoning underlying the notion that  $p$  and  $y$  are not functions of  $\mu$  seems to also imply that  $p$  and  $y$  are not functions of  $v$ .

<sup>19</sup>Alternative classes of identifying assumptions include those that involve restrictions on the long-run impact of

shocks to monetary policy. See, for example, Gali (1991) and King and Watson (1992). A class of identifying assumptions that does not employ the recursiveness assumption in the text is analyzed in Bernanke (1986) and Sims (1986), among others. A class of assumptions that does use the recursiveness assumption, but extracts money shocks from interest rate data is reported in Bernanke and Blinder (1992), Christiano and Eichenbaum (1992, 1995), and Christiano, Eichenbaum, and Evans (1996a,b).

<sup>20</sup>Although the *sign* of the interest rate response appears reasonably robust to subsamples, the use of monthly data and other defensible strategies for identifying shocks, the magnitude is not. Monetary shocks based on the use of nonborrowed reserves suggest a smaller interest rate effect more recently. See Christiano and Eichenbaum (1992), Pagan and Robertson (1995), and Christiano (1995). However, other methods for calculating monetary shocks do not have this implication.

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## Soft landings on a bumpy runway

Francesca Eugeni and  
Charles L. Evans



In February 1994, the Federal Open Market Committee (FOMC) began a slow process of increasing the federal funds rate by 300 basis points. The

intention was to “head off an incipient increase in inflationary pressures and to forestall the emergence of imbalances that so often in the past have undermined economic expansions.”<sup>1</sup> Real gross domestic product (GDP) growth for 1994 was 4.1 percent on the fixed-weight 1987 dollar basis reported at the time, and CPI inflation was under 3 percent for the third year in a row. The final 50 basis point increase in the federal funds rate came on February 1, 1995. By spring 1995, however, initial signs of an economic slowing were beginning to appear. For example, payroll employment was virtually unchanged in April and fell in May; building permits and new home sales fell below 1994 levels; and the purchasing managers’ index (PMI) fell below 50 percent in May (a reading below 50 percent indicates that the manufacturing economy is declining).

Chairman Greenspan stated in a speech to the Economic Club of New York in June 1995 that “incoming information on the forces involved does suggest some increased risk of a modest near-term recession.” As table 1 shows, the apparent slowing of the economy was reflected in the FOMC’s mid-year Humphrey-Hawkins and Blue Chip forecasts for 1995. The central tendency of the FOMC’s real GDP growth forecasts had shifted downwards from an initial range of 2 percent to

3 percent to a lower range of 1.5 percent to 2 percent. Similarly, the Blue Chip consensus forecast for 1995 moved down from 2.5 percent in January to 2.2 percent in June. The anticipated soft landing had become a bit bumpy.

We now estimate that 1995 GDP growth came in at 2.4 percent (1987 dollars), making it a year of roughly average growth. However, the individual indicators appeared to weaken uniformly in the spring and early summer of 1995. Should this weakening have been expected, or was it prompted by some unexpected event that occurred in the first half of 1995? These questions take on an added importance when the most recent real GDP growth rate is under 1 percent (as the 1995:Q4 data indicate). This article uses simple statistical forecasting models to investigate the bumpy ride of 1995. Our findings are that the second quarter 1995 slowdown (1) should have been partly expected, but (2) some additional bumpiness suggests that a supply shock hit the economy in the first quarter of 1995. The vector autoregressions (VAR) tools employed in this case study are readily applicable to other historical periods, such as that leading up to the 1990 recession, as well as to a real-time evaluation of several exogenous shocks which tend to affect the U.S. economy.

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Francesca Eugeni is an economist and Charles L. Evans is a senior economist and assistant vice president at the Federal Reserve Bank of Chicago. The authors thank Anil Kashyap and David Marshall for helpful comments.

### Competing explanations for the 1995 slowdown

Table 1 displays real GDP growth, the unemployment rate and inflation for 1994, two sets of forecasts for 1995, and the actual data for 1995. The GDP data are reported according to the fixed-weight 1987 dollar national income and product account (NIPA) measures, since the Humphrey-Hawkins forecasts were reported that way. The July forecasts show a clear reassessment of the outlook. An important reason for this was the uniform slowing in the April and May economic releases. Figure 1 displays actual data for eight economic indicators from January 1993 through September 1995. Sharp declines are evident in the housing sector, with building permits falling below 1994 levels. A slowdown is also apparent in the employment indicators: Average hours worked in manufacturing and the Conference Board's help-wanted index suffered sharp declines in the second quarter of 1995. In addition, two leading economic indicators, the Conference Board's index of leading indicators and Stock and Watson's experimental nonfinancial leading index (XLI2), declined during this period. Declines in the rate of capacity utilization and the purchasing managers' index in the second quarter of 1995 also reflect a softening in the manufacturing sector.

What events caused this slowdown? We consider four potential explanations. The first hypothesis is that monetary policy was unusually restrictive during the 12 months in which the federal funds rate rose from 3 percent to 6 percent, and the final two policy moves in November 1994 (75 basis points) and February 1995 (50 basis points) put a significant damper on the economy (monetary policy [MP] shocks). Second, the 300 basis point increase was simply a normal, passive response of monetary policy to underlying fundamentals. In this setting, normal response implies that the policy actions were largely predictable on the basis of historical data (normal response of MP). Third, from the February 1995 forecasts to the July 1995 forecasts, some other fundamental

changed which is unrelated to monetary policy. For example, an adverse supply shock or money demand shock could have intervened in the first or second quarter of 1995 (other shocks). Fourth, the spring data could have been uniformly "noisy"—just a fluke—perhaps due to a shifting seasonal pattern which will be corrected in future data revisions (noise).

Although these hypotheses are not mutually exclusive, each has testable implications. First, the *normal response hypothesis* suggests that the spring 1995 slowdown should have been predictable using data through 1994. Specifically, the uniform slowing of the economic indicators by June 1995 should have been implied at the time of the February Humphrey-Hawkins forecasts. A *prima facie* case against this explanation is that the July Humphrey-Hawkins forecasts were lower than the February forecasts: If the slowdown was expected, why did the forecasts change? A possible counter to this argument is that the outlook for the first half was as expected, but something fundamentally changed to alter the outlook for the second half of 1995. We can address this question by comparing forecasts of the economic indicators against the actual data: If the slowdown is uniformly forecast, this is consistent with the normal response hypothesis.

	GDP (87\$)	CPI	Unemployment rate <sup>1</sup>
	(percent change, Q4/Q4)		(percent)
<b>1994 actual</b>	4.1	2.6	5.6
<b>1995 actual</b>	2.4 <sup>e</sup>	2.6	5.6
<b>Humphrey-Hawkins 1995 forecasts</b>			
February 22, 1995	2.0-3.0	3.0-3.5	5.5
July 19, 1995	1.5-2.0	3.1-3.4	5.8-6.1
<b>Blue Chip 1995 forecasts<sup>2</sup></b>			
January 10, 1995	2.5	3.5	5.6
June 10, 1995	2.2	3.5	5.7

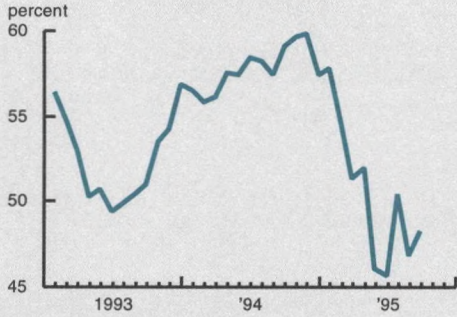
<sup>1</sup>Fourth-quarter average.  
<sup>2</sup>Consensus forecast.  
<sup>e</sup>Estimate.  
Sources: U.S. Department of Labor; U.S. Department of Commerce; Federal Reserve Board of Governors; and Blue Chip Economic Indicators.



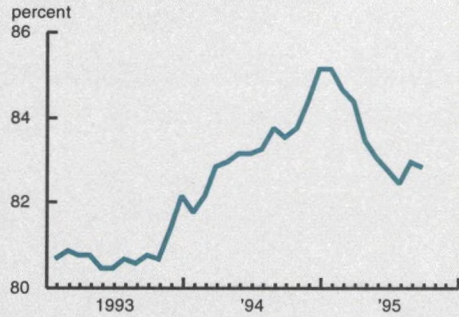
**FIGURE 1**

**Economic indicators: Actual data, January 1993–September 1995**

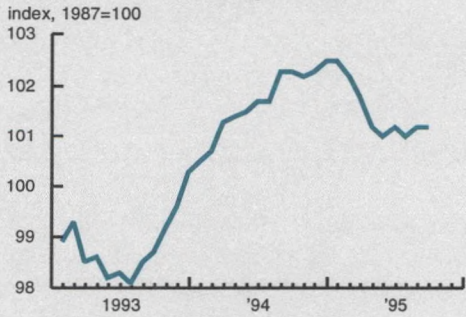
**Purchasing managers' index (PMI)**



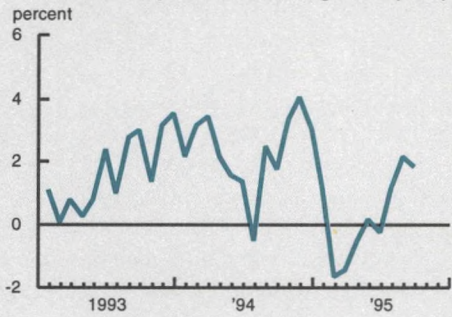
**Capacity utilization, manufacturing**



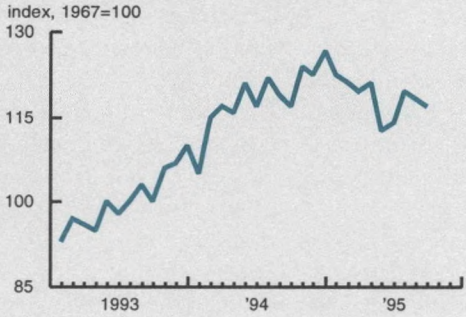
**Composite index of leading indicators**



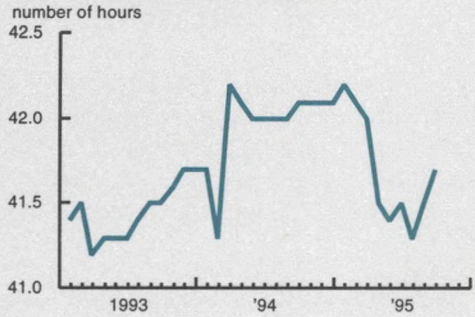
**Nonfinancial experimental leading index (XLI2)**



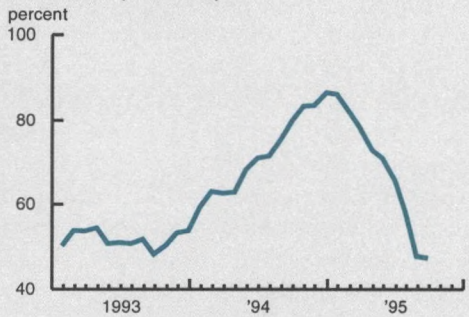
**Help-wanted index**



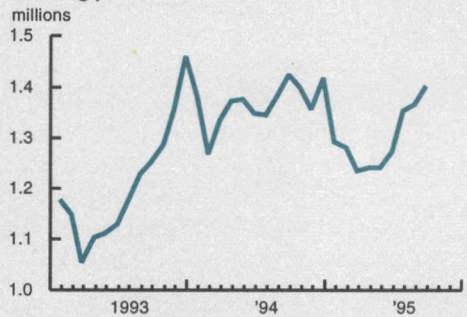
**Average weekly hours, manufacturing**



**Price index (PMPRICE)**



**Building permits**



Sources: The National Association of Purchasing Management; the Conference Board; the Federal Reserve; James Stock and Mark Watson nonfinancial experimental index; the U.S. Department of Labor; and the U.S. Department of Commerce.

Second, the *monetary policy shock hypothesis* may also be consistent with the predictability of the second-quarter slowdown. Given the 75 basis point increase in the federal funds rate in November 1994, it may have been possible to forecast the spring slowdown. One way to distinguish between the normal response hypothesis and the MP shock hypothesis is to measure the size of monetary policy shocks in 1994 and 1995. If the shocks are small and infrequent, the 300 basis point increase in the federal funds rate is consistent with a normal response. If the shocks are large and contractionary, however, that favors the MP shock hypothesis.

Third, if the spring slowdown was unpredictable and not due to monetary policy shocks, then *other shocks* may have been responsible. We attempt to quantify three other shocks which macroeconomists think affect the aggregate economy: permanent supply shocks (like energy and technology shocks), money demand shocks, and temporary expenditure shocks (such as consumer demand or government shifts). Our analysis uses a structural VAR method which is closely related to work by Gali (1992). Finally, if no other shocks are responsible, then the slowdown could conceivably have been *noise*. Table 2 summarizes the four hypotheses and testable restrictions.

### Forecasting the economic indicator slowdown

The February 1995 Humphrey-Hawkins forecasts were prepared by the FOMC members' staff in mid-January. This means that the forecasts were initially prepared with data through the third quarter of 1994 and some monthly data from the fourth quarter. In asking whether or not an economic event was evident at the time, it is critical that only the data which was available *at that time* be used.<sup>2</sup> The forecasts presented below use the initial data releases.

We consider separately eight indicators of economic activity to forecast the changes in employment, CPI inflation, and the federal funds rate, as well as the indicator itself. For each indicator we estimate a seven-variable VAR, which includes the indicator, the change

Hypothesis	Implication		
	Predictable	Large MP shocks	Large other shocks
MP shocks	Yes	Yes	No
Normal response of MP	Yes	No	No
Other shocks	No	No	Yes
Noise	No	No	No

in payroll employment, the change in inflation, the smooth change in sensitive materials prices, the change in the federal funds rate, the growth rate of nonborrowed reserves, and the growth rate of total reserves. The equation which determines the indicator includes a constant and six lagged values of all seven variables. The other six equations do not include lagged values of the indicator. This block-recursive structure guarantees that the employment, inflation, and federal funds rate forecasts are the same across each seven-variable VAR system.

Of the eight indicators, six are in level form: the purchasing managers' index of the National Association of Purchasing Management (NAPM), the NAPM's price index (PMPRICE), the Stock and Watson nonfinancial experimental leading index (XLI2), manufacturing capacity utilization, the Conference Board help-wanted index, and manufacturing average weekly hours. Two of the indicators are in annualized log levels: the Conference Board index of leading indicators and the Department of Commerce building permits.

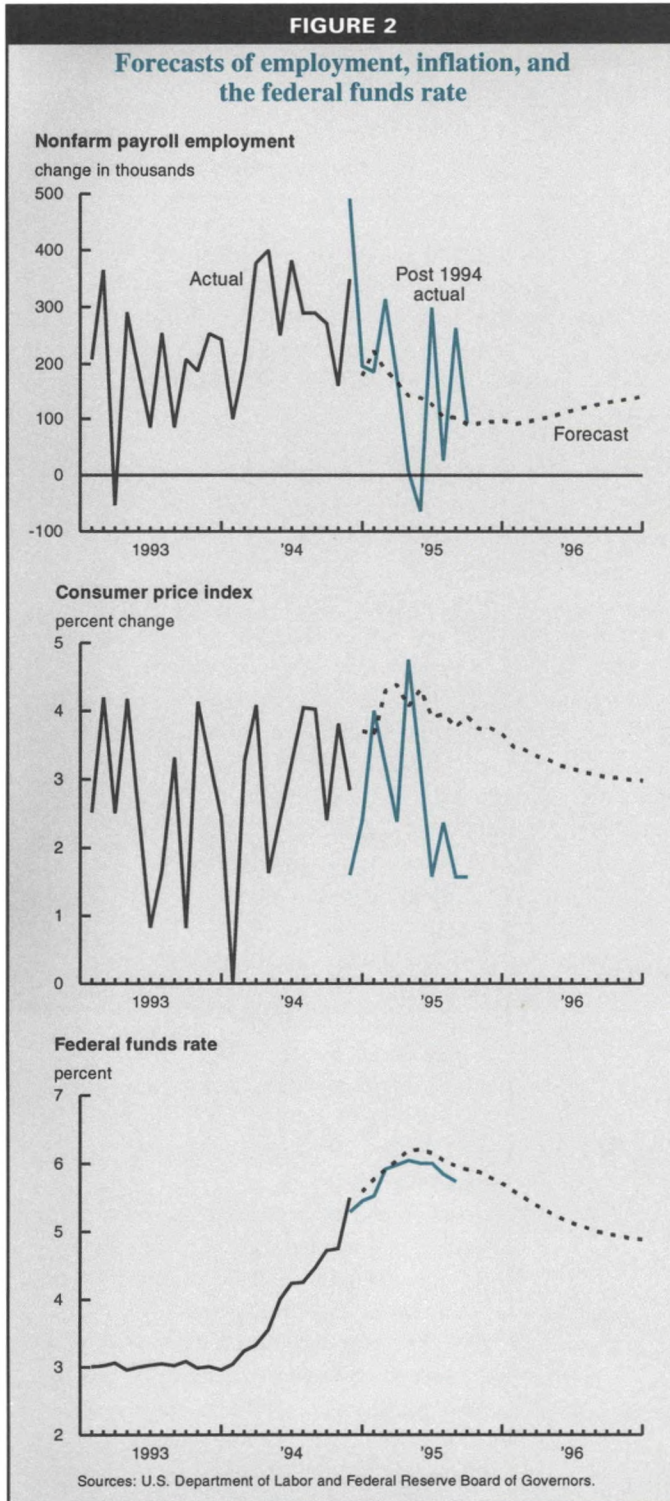
The data are monthly and the sample period for the estimation runs from January 1970 to November 1994. We estimated the system of equations using ordinary least squares (OLS).<sup>3</sup>

We forecast the change in employment, inflation, and the federal funds rate from December 1994 through December 1996 on a monthly basis, assuming no shocks to the system over our forecast horizon. Since our errors are assumed to be mean zero and serially uncorrelated, this is a conditional expectation. Each graph in figure 2 plots three objects: (1) the initial unrevised data from January

1993 through November 1994, (2) forecasts from December 1994 through December 1996, and (3) revised actual data from December 1994 through September 1995, which we did

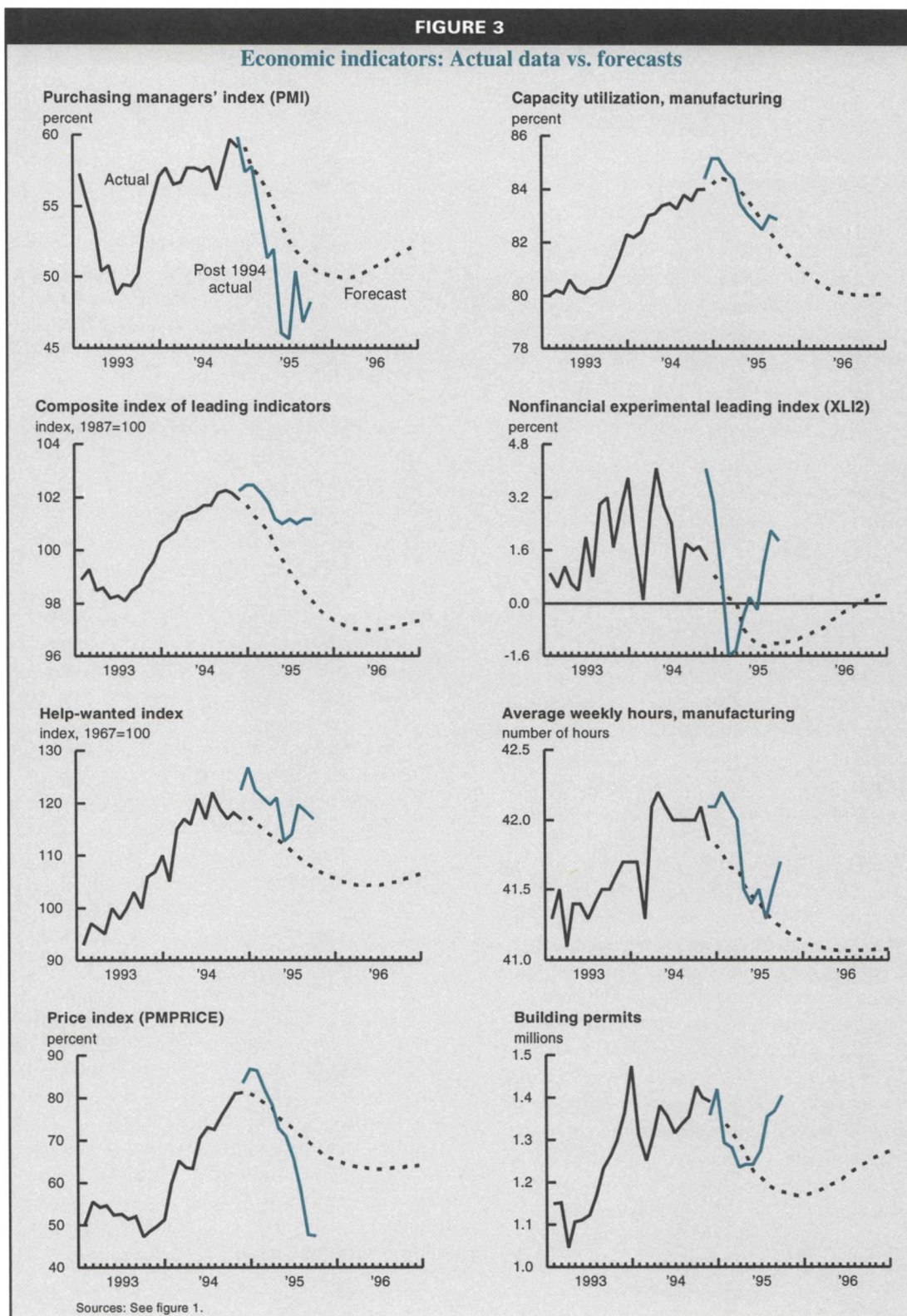
not use in the estimation. Focusing on the forecast paths and the actual data, payroll employment was expected to slow gently from a pace of 200,000 per month to 100,000 by the end of 1995. Instead, the actual data came in quite bumpy—falling abruptly from a gain of over 300,000 in February to a loss of 62,000 in May. Inflation had been forecast to average above 4.1 percent in the first half of 1995, but instead was a much milder 3.2 percent. The statistical forecast called for the federal funds rate to rise until the middle of the year before beginning a slow decline; the actual funds rate held steady from February until midyear when it was lowered slightly. The data in figure 2 indicate a soft landing scenario which encountered a bumpy runway.

The forecasts of economic indicators (figure 3) begin to shed light on the monetary policy shock and normal response hypotheses: Could the slowdown have been forecast? Overall, the indicators consistently predicted a slowdown over the forecast horizon. For example, the PMI was projected to fall from a level of over 59 percent to under 50 percent by the end of 1995. The XLI2 index was forecast to turn negative by the second half of 1995, indicating below-average growth. However, in most cases, the decline in the actual data for 1995 was sharper than forecast; this is the case for PMI, PMPRICE, XLI2, capacity utilization, and building permits. Two exceptions are the help-wanted index and the index of leading indicators, for which the forecasts were more pessimistic than the actual data. Some portion of the slowdown in early 1995 should have been anticipated according to this analysis; this is consistent with both the monetary policy shock hypothesis (late 1994 monetary



policy shocks) and the normal response of monetary policy to underlying economic fundamentals in 1994. However, since the spring

slowdown was somewhat sharper than anticipated, some other shocks may also have played a role in the mid-year forecast revisions.



## Structural identification of monetary policy and other shocks

The discussion above suggests that some new information on economic fundamentals became available between the February and July Humphrey-Hawkins forecasts. What was this new information? Below, we examine four types of shocks which may play a significant role in the evolution of the U.S. economy—a supply shock, a money demand shock, a monetary policy shock, and an expenditure shock.

### Identifying exogenous events

The U.S. economy has experienced nine recessions since 1945. One interpretation of these economic ups and downs is that the economy tends toward its average growth rate, but periodically exogenous events intervene—both positive and negative shocks—which lead to persistent deviations of real GDP from its trend. A large negative event, such as the quadrupling of world oil prices in 1973, could account for a recession on its own. Alternatively, a series of smaller, less visible negative shocks could account for a downturn. Many events are observable, but their effects on the economy, in terms of timing and magnitude, are difficult to detect: for example, the 1993 Revenue Reconciliation Act which introduced individual income tax rate brackets of 36 percent and 39.6 percent; the economic transitions due to the NAFTA and GATT free-trade agreements; industrial reshaping due to legislative restrictions or relaxations such as interstate branch banking; and the shift toward managed health care and its accompanying effects on labor costs. Other events are virtually impossible to observe contemporaneously. For example, technological improvements related to computer miniaturization have been taking place over the last 20 years or more, but it is difficult to quantify the timing and extent of the accompanying effects on productivity.

Since casual observers of the economy's ups and downs—both economists and the public—cannot agree on the causes of any particular economic downturn, business cycle researchers have turned to statistical methods to identify exogenous events which lead to economic fluctuations. Structural vector autoregressions (SVARs) are a statistical attempt to identify these shocks by their immediate effects,

or perhaps their implied long-run effects, on the economy. For example, Milton Friedman's proposition that inflation is everywhere and always a monetary phenomenon may lead us to identify monetary policy actions with shifts in inflation (perhaps at certain forecast horizons); this is an example of a long-run identifying restriction. A belief that the monetary authority always eases in the face of rising unemployment—a normal response of policy to the state of the economy—might lead us to identify *unusual easing* of monetary policy (a shock) with a decrease in short-term interest rates which was not accompanied by a prior increase in the unemployment rate. This is an example of a contemporaneous identifying restriction.<sup>4</sup>

We consider four aggregate, quarterly data series: the growth rate of real GDP, the change in the federal funds rate, the change in real money balances, and a short-term *ex post* real interest rate. Our data selection is similar to Gali's (1992) empirical implementation. The GDP data are the 1987 dollar fixed-weight data which were available to policymakers in spring 1995. Real money balances are measured as M1 deflated by the consumer price index for urban consumers. We use M1 to capture better the influence of financial innovations on the economy, not based on its usefulness as an indicator of monetary policy. *Ex post* real interest rates are measured as the fed funds rate minus the inflation rate.

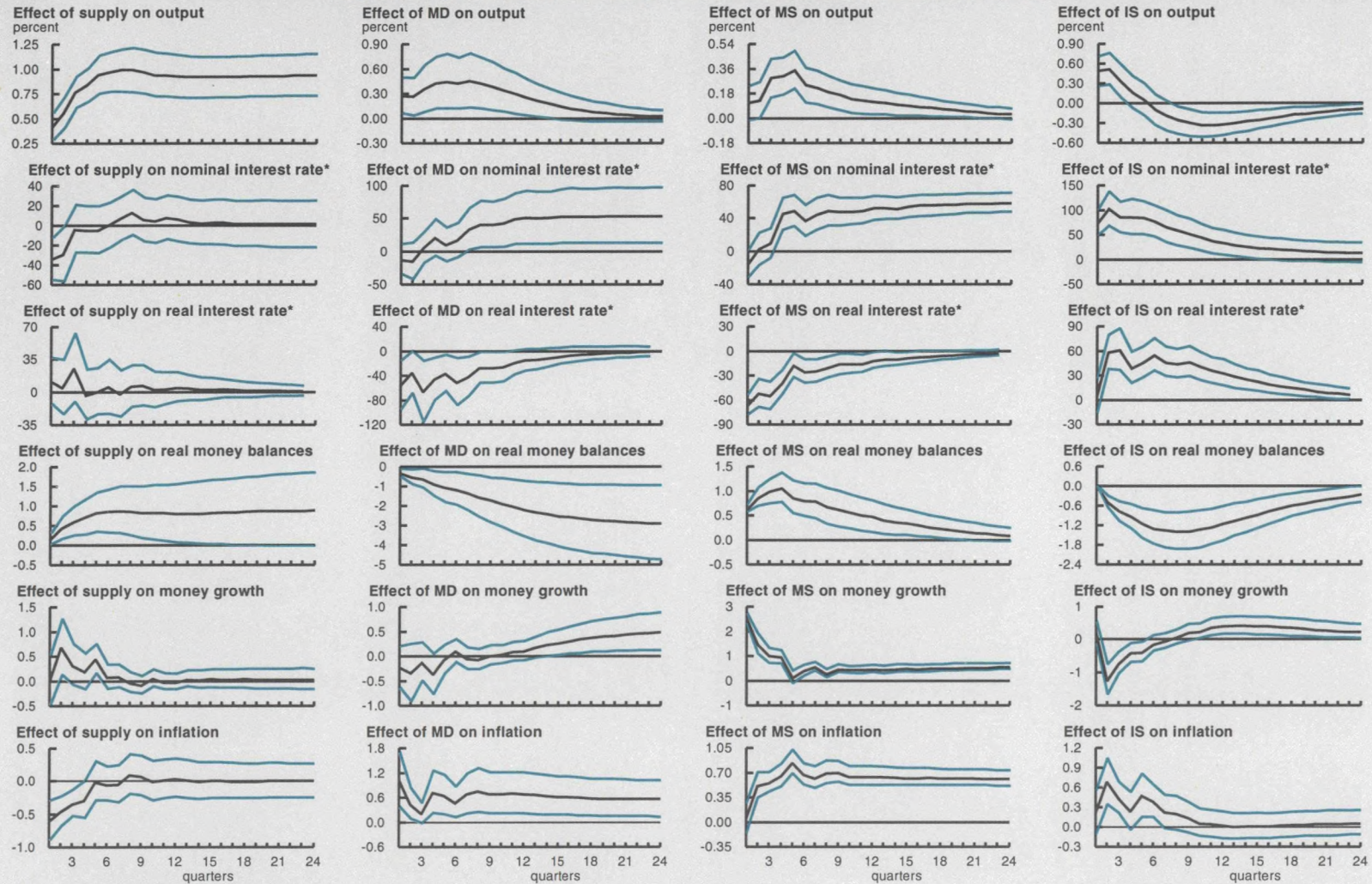
We impose a sufficient set of identifying assumptions on the vector autoregression to just identify four exogenous shocks that influenced the postwar U.S. economy; four loose labels for these shocks are (1) a supply shock, (2) a money demand shock, (3) a monetary policy shock, and (4) an expenditure shock.<sup>5</sup>

The *supply shock* captures exogenous events which permanently affected the level of real GDP. Intuitively, the SVAR statistical analysis investigates fluctuations in real GDP, which did not quickly revert to its unconditional growth path, and labels these events supply shocks. Some candidate observable events are energy shocks, technological improvements or regress, and regulatory restrictions or easings.

The *money demand shock* (MD) captures exogenous events which permanently affected the level of real balances; but did not permanently affect real GDP. Some candidate

FIGURE 4

Impulse response functions: Responses to one-standard-deviation shocks



\*In basis points (all others in percent).

Notes: The black lines represent point estimates. The colored lines represent standard error bands. Real output is measured in 1987 dollars; nominal interest rate is the federal funds rate in basis points; real money balances is M1 deflated by the consumer price index; the real interest rate is ex-ante and is measured as the federal funds rate minus the expected change in the consumer price index.

Source: U.S. Department of Commerce; Federal Reserve Board of Governors; and U.S. Department of Labor.

observable events are: a change in the public's desire to use cash or demand deposit instruments; the effects of regulations on depository institutions and financial intermediaries; and improvements in the financial intermediation process. The insistence that these shocks have not affected real GDP permanently is not a generic economic implication. The practical significance of this restriction is to identify separately the money demand and supply shocks by imposing a long-run Wold causal ordering.

The *monetary policy shock* (MS) captures exogenous shifts in short-term interest rates which have no permanent effect on output; the precise identifying restriction is related to the expenditure shock identification discussed below. The monetary policy shock can be interpreted in the following way. Typically, the Fed's influence on short-term interest rates can be related systematically to the state of the economy. Occasionally, the Fed looks at the current state of the economy and decides to deviate from this systematic rule in an *ex ante* unpredictable way: The deviation is the monetary policy shock. Christiano, Eichenbaum, and Evans (1996) use a related set of assumptions to identify an analogous monetary policy shock. An advantage of the approach taken here, however, is that the monetary policy shock may be correlated with the current state of the economy.<sup>6</sup>

The *expenditure shock* (IS) is intended to capture temporary shifts in aggregate demand expenditures. (Gali [1992] refers to a shock like this as an IS shock, a label that relates to the textbook macroeconomic IS-LM models.) This shock's identifying restrictions are that it has no permanent effects on real GDP or real money balances and no contemporaneous effect on real money balances.<sup>7</sup> Candidate examples of this shock include temporary shifts in investment demand, government purchases or net exports, as well as shifts in consumer confidence. Since temporary supply shifts can also affect aggregate demand, these are also candidate shocks so long as their contemporaneous effect on real balances is nil.

#### *Estimates of the impulse response functions*

The system of equations is estimated over the period from January 1970 to November 1995. Although the central objects of interest

in the investigation are the shocks themselves, we must inspect the implications of the shocks first in order to assess the plausibility of the estimates. Figure 4 displays the responses of output, nominal and real interest rates, real balances, money growth, and inflation to one-standard-deviation shocks.<sup>8</sup> The identifying restrictions are evident from the impulse responses. Notice that only the supply shock affects the level of output at horizons longer than 24 quarters, and only the money demand and supply shocks affect real balances in the long-run. The final identifying restriction is that the expenditure shock does not affect real balances contemporaneously, as is evident from figure 4.

Although the identifying restrictions here differ from Gali's (1992) slightly and our sample period extends to 1995 instead of 1987 as in Gali's paper, the estimated impulse response functions are quite similar to his estimates.

*Supply shock*—A positive one-standard-deviation supply shock stimulates output growth before leveling off after six quarters. Inflation falls immediately but temporarily. This finding of a conditionally countercyclical inflation rate accords well with the predictions of business cycle models in which technology and supply shocks lead to economic fluctuations. (See, for example, King and Watson [1994].) The rise in real balances is a plausible response to individuals' desire to facilitate a greater number of transactions.

*Money demand shock*—A negative one-standard-deviation money demand shock stimulates output growth temporarily, but the standard error bands are large enough that the entire pattern of responses may be insignificantly different from zero. According to the point estimates, however, real balances fall permanently: The long-run response of money growth and inflation is to increase. This leads to a permanent increase in nominal interest rates and a permanent decline in the quantity of money demanded.

*Monetary policy shock*—A positive one-standard-deviation money supply shock stimulates output and leads to an increase in inflation. Many small-scale VAR models, similar to ours, find that an expansionary monetary policy shock leads to an anomalous decrease in the price level, and Gali's estimates also dis-

play a hint of this “price puzzle” (see Christiano, Eichenbaum, and Evans [1996] for a discussion of the price puzzle phenomenon). However, our estimates do not display a price puzzle, which may be due to the structural identification. Although the contemporaneous fall in nominal interest rates is insignificant, real interest rates fall significantly.

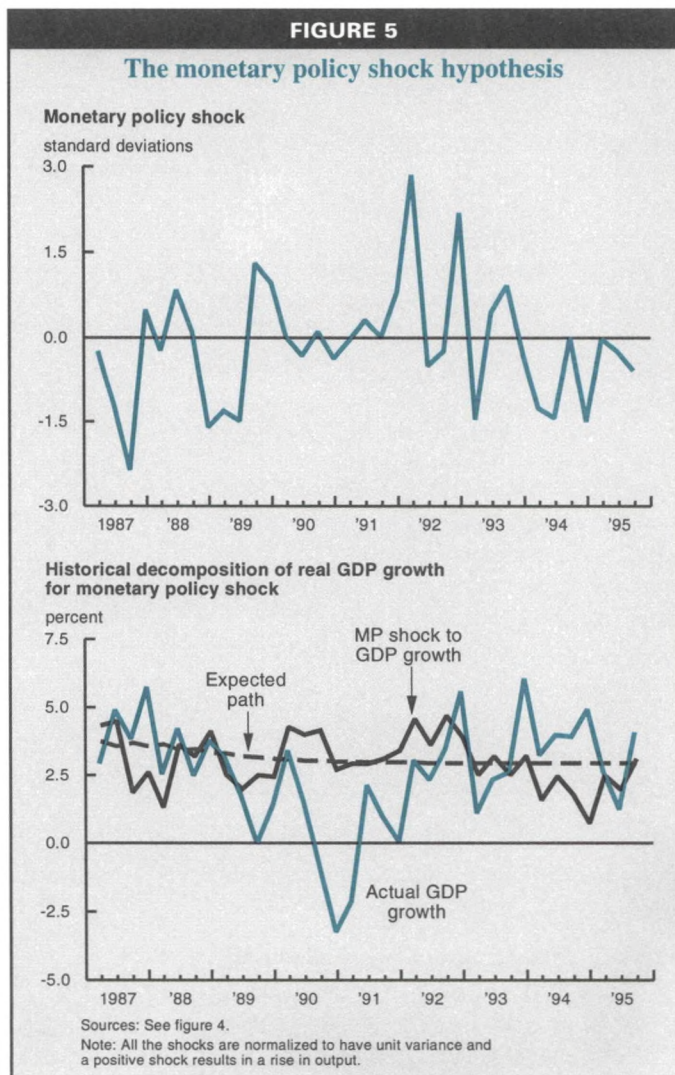
*Expenditure shock*—A positive one-standard-deviation expenditure shock leads to a temporary increase in output and a rise in real interest rates. This response pattern seems consistent with a shift outward in an aggregate-demand relationship when aggregate supply is roughly fixed: Scarce resources today suggest that future consumption is cheaper than today’s consumption (that is, real interest rates are currently high).<sup>9</sup> The fall in real balances seems to be consistent with a fall in money demand, as is evident from the sharp increase in nominal interest rates and falling output level after the second quarter.

Below, we examine the results within the context of the monetary policy shock and other shocks hypotheses.

### The monetary policy shock hypothesis

The top panel of figure 5 displays the estimated monetary policy shocks from the structural VAR estimation discussed above. The shocks have been normalized to have a variance of one. The bottom panel displays a historical decomposition of real GDP growth based upon the monetary policy shocks only: Specifically, this decomposition records how output growth would have evolved since 1987 if there had only been the estimated monetary policy shocks. According to figure 5, monetary policy was unexpectedly tight at the end of 1988 and in early 1989—the decomposition reveals that real GDP growth was reduced by about 1.25 percent in 1989. These estimated shocks

accord well with the Fed’s stated intention of fighting inflation during that period. The historical decomposition of inflation (not reported here) reveals that inflation was about 1.25 percent lower as a result of these shocks. According to these estimates, a series of expenditure shocks in 1987-88 would have caused inflation to rise above 6 percent during the mid-1988 to mid-1990 period if the monetary shocks had not intervened. After the 1990-91 recession, monetary policy was unexpectedly easy at year-end 1991 and year-end 1992. This accords well with the Fed’s 100 basis point cut in the discount rate in December 1991 and the lack of a monetary policy tightening in the second half of 1992 when real GDP grew by 4.5 percent. The decomposition of output growth reveals that



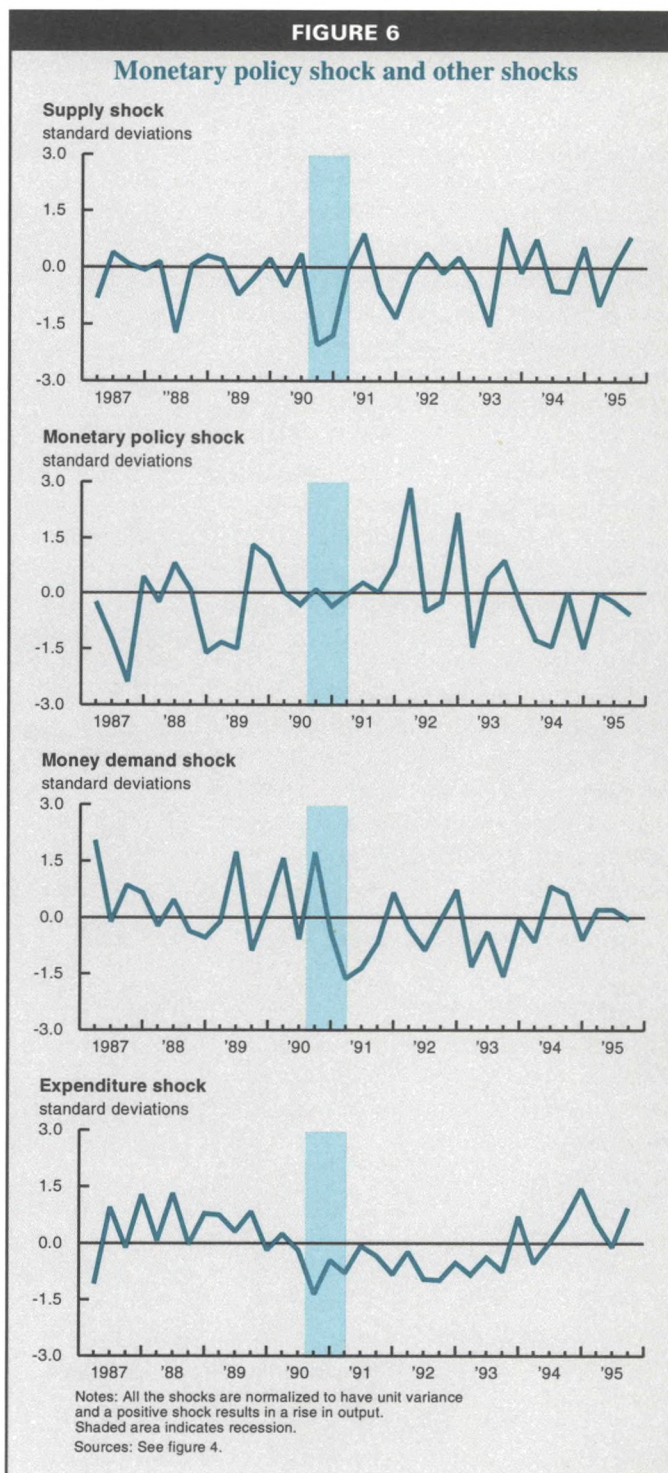


1992 output growth was about 1.5 percent higher due to these shocks. Consequently, these measures of unanticipated monetary policy actions seem to capture the flavor of this period.

According to the *monetary policy shock hypothesis*, the 1995 second-quarter slowdown was due to an unanticipated policy tightening at the end of 1994 or in the first quarter of 1995. There is some validity to this hypothesis. The 75 basis point increase in the federal funds rate in November 1994 seems to be consistent with a large unexpected monetary policy shock in the fourth quarter of 1994; indeed three of the four quarters of 1994 point to tight monetary policy. Furthermore, the impulse response functions displayed in figure 4 indicate that a 1.5-standard-deviation shock in the fourth quarter of 1994 would lead to about a 0.5 percent reduction in real GDP by the second quarter of 1995. So this hypothesis may account for a portion of the slowdown.<sup>10</sup> The decomposition of output growth indicates that monetary policy shocks reduced second-quarter 1995 real GDP growth by 1 percent, but this estimate includes the lagged effects of policy shocks earlier in 1994. Nevertheless, the Fed's action in the fourth quarter of 1994 should have been taken into account in the February 1995 Humphrey-Hawkins forecasts. Consequently, while the statistical analysis indicates that monetary policy actions may have slowed the economy in the first half of 1995, it can't explain the midyear projection of slower economic growth in 1995.

### The other shocks hypothesis

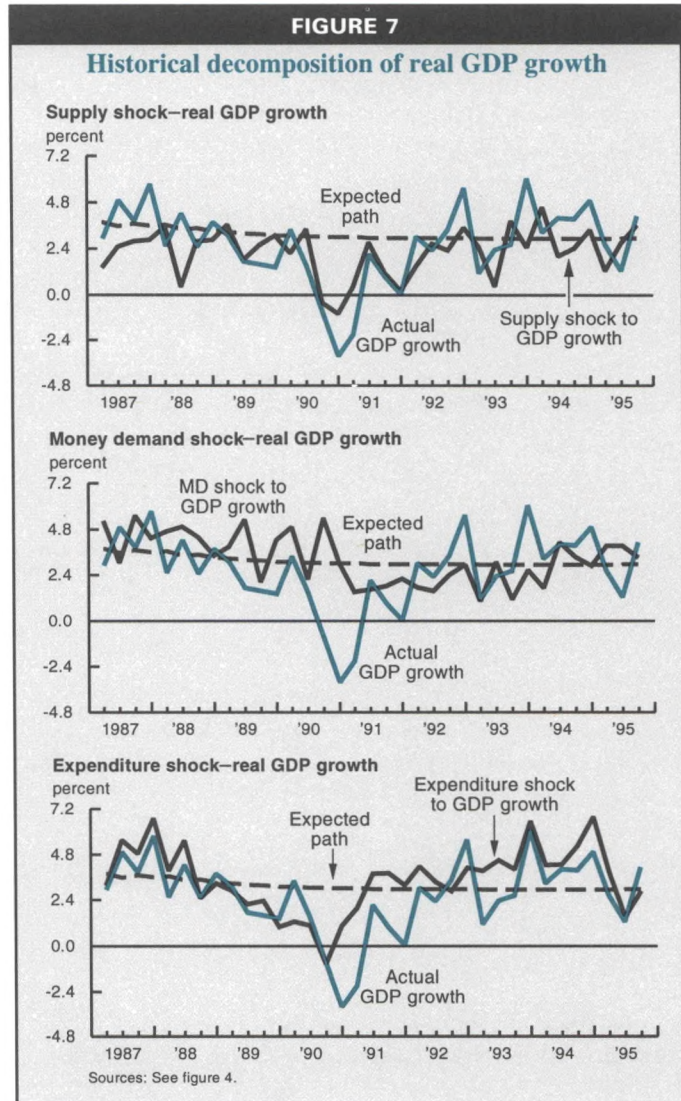
Figure 6 displays each of the four estimated shocks over the period 1987 to 1995, while figure 7 displays the historical decompositions



of real GDP growth for the supply, money demand, and expenditure shocks. As mentioned above, between mid-1988 and mid-1989 the Fed raised the federal funds rate by about 300 basis points; according to our estimates,

this was a period of unexpectedly tight monetary policy aimed at fighting inflationary expenditure shocks in 1988, which were growing 1987 real GDP phenomenally (and above capacity rates). Typical accounts of this period refer to attempts to engineer a soft landing for the economy, but by fall 1990, the U.S. was slipping into a recession.<sup>11</sup> According to our estimates, two large negative supply shocks hit the economy in the second half of 1990. The decompositions in figure 7 reveal that these shocks were large enough to induce two quarters of negative growth by themselves. This seems like a plausible account given the Iraqi invasion of Kuwait in August 1990 and the accompanying military buildup in the Persian Gulf during the remainder of 1990. Compounding these problems were slightly negative expenditure shocks in 1990 and two large negative money demand shocks in the first half of 1991. The latter shocks correspond to a period of turbulent financial intermediation, as evidenced by the closure of insolvent thrift institutions and bank capital replenishment. Monetary policy during this period was extraordinarily neutral according to these measures. Consequently, this statistical analysis suggests that events other than monetary policy played a significant role in the 1990-91 recession.

Turning to the 1995 period, notice first that the money demand and monetary policy shocks are relatively small and neutral. For example, although the fourth-quarter expenditure shock (a relatively high 1.5 standard deviations) leads to an immediate increase in fourth-quarter output (according to the impulse response functions in figure 4), the effects begin to reverse within two quarters. Thus, the fourth-quarter expenditure shock does imply a slight slowing for 1995, although it should have been known at the time of the February Humphrey-Hawkins forecasts. The second



culprit is an estimated first-quarter negative supply shock. According to figure 4, this shock alone, if not reversed, would have led to an almost 0.75 percent reduction in output before the end of the year. For economic forecasters, this shock represents news that became available in late April 1995. The decomposition in figure 7 indicates that the supply shock cumulatively (beyond just the first-quarter shock) reduced output growth by almost 2 percent, but these effects were neutralized by mid-1995. The latter fact couldn't have been deduced until late July, given the data release dates for the second quarter. Therefore, a first-quarter supply shock appears to be the most likely culprit for the slower growth forecasts by midyear 1995.

## Conclusion

Our case study of the 1995 economic slowdown reveals that part of the widespread deterioration in economic indicators was predictable in light of 1994 monetary policy actions—in terms of the statistically unusual actions that the Fed took, as well as its typical response to the state of the economy in 1994. This was not clearly evident *ex ante* from the February 1995 Humphrey-Hawkins forecast

range of 2 percent to 3 percent growth; but it is consistent with the lower end of this range. Second, the midyear slowdown appears to have been partially unpredictable. This is evident from the July 1995 Humphrey-Hawkins forecast revision of 1.5 percent to 2 percent growth, and our statistical analysis identifies that an adverse supply shock of modest proportions hit the economy in the first quarter of 1995.

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## NOTES

<sup>1</sup>Greenspan (1996).

<sup>2</sup>For an example of how important this distinction can be in another context, see Diebold and Rudebusch (1991).

<sup>3</sup>Since six of the equations do not contain the seventh variable (the economic indicator), estimation using the method of seemingly unrelated regression (SUR) is more efficient than OLS. However, we found that the results were relatively insensitive to the estimation method, so we report below the results from the OLS estimation.

<sup>4</sup>Alternatively, a large decrease in short-term interest rates which was not commensurate with the (small) increase in unemployment could signal an *unusual easing*.

<sup>5</sup>For technical details related to analyses like this one, see Gali (1992) or Watson (1993).

<sup>6</sup>Both approaches to measuring monetary policy shocks require the assumption that the Fed has implemented a single, stable reaction function for monetary policy over the estimation period under study. In the current study, this is 1970 to the present. An additional requirement is that the four variables in the present VAR must span the space of exogenous events affecting the U.S. economy.

<sup>7</sup>One interpretation of this latter restriction is to take the IS-LM apparatus at face value: A positive expenditure

shock increases output and interest rates contemporaneously without real money balances changing initially. Note that if money demand is stable, then the increase in output leads to a higher quantity of money demanded, but the increase in interest rates has an opposing effect. Our identifying restriction assumes that these two effects cancel. A test of this restriction is the plausibility of its implications for other variables.

<sup>8</sup>The colored lines refer to one-standard-error “bootstrap” standard errors. The bootstrap standard errors were generated using 500 Monte Carlo draws. The original VAR estimates were taken to be the data-generating process, Monte Carlo errors were selected by sampling from the original VAR innovations with replacement, and the identifying restrictions were imposed and re-estimated for each draw.

<sup>9</sup>See Barro’s macroeconomic textbook (1987) for an analytical framework like the one described above.

<sup>10</sup>Our discussion refers to our estimates of the shocks. Economists can disagree over whether a 1.5-standard-deviation shock should be labeled “statistically different from zero.”

<sup>11</sup>For a reference to a “soft landing,” see the Transcript of the Federal Open Market Committee meeting, March 28, 1989.

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