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 founding 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 policymaking 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.[1]

Debate about monetary policy issues requires models.[2] 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

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.[3] 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:[4]

> 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.[5]

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?

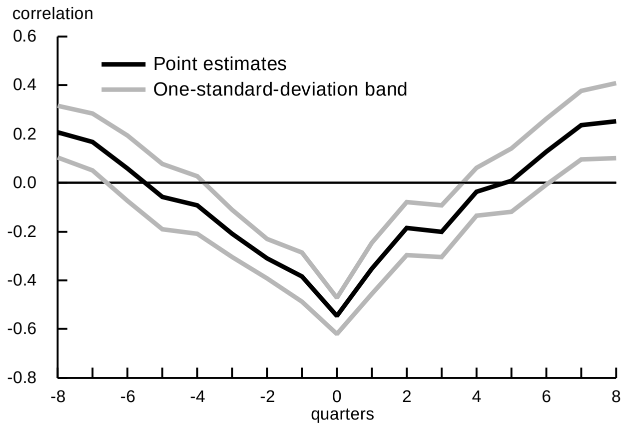
This question is interesting because the answer one selects has important implications for the construction of quantitative macroeconomic models with money. (This is discussed further in Christiano [1991] and Christiano and Eichenbaum [1995].)

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,

FIGURE 1

Correlation between the federal funds rate(*t*) and NBR(*t–k*)



Note: Data are quarterly and cover the period 1959:Q1-91:Q4. Money data have been logged, and both series were Hodrick-Prescott filtered prior to doing the computations.
Source: Christiano and Eichenbaum (1992).

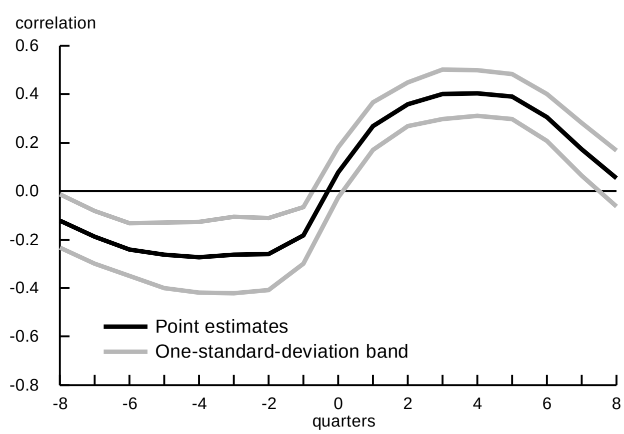
when researchers initially attempted to quantify the liquidity effect using data, they came away quite skeptical as to its plausibility. (Examples include Stephen King [1983], Melvin [1983], and Mishkin [1983].) This had an impact on the development of monetary business cycle models. For example, Barro (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.[6] 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.)[7] 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.[8] Under this view, exogenous innovations in base growth engineered by the central bank are

FIGURE 2

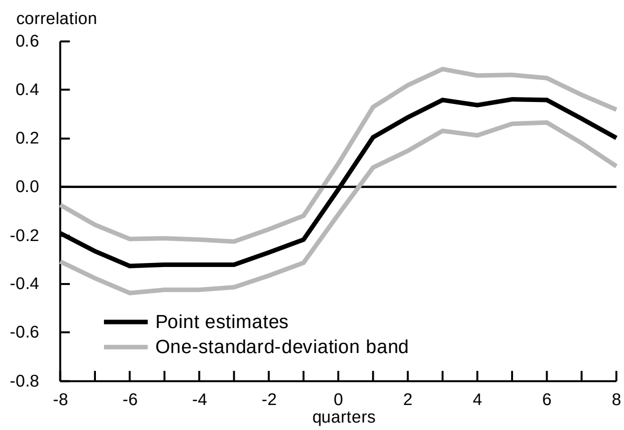
Correlation between the federal funds rate(*t*) and the monetary base(*t–k*)



Note: See figure 1.
Source: Christiano and Eichenbaum (1992).

FIGURE 3

Correlation between the federal funds rate(*t*) and M1(*t–k*)

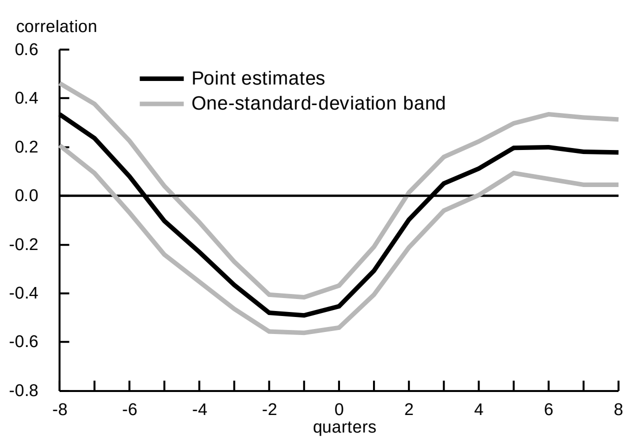


Note: See figure 1.
Source: Christiano and Eichenbaum (1992).

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.

FIGURE 4

Correlation between GDP(*t*) and NBR(*t–k*)



Note: Data are quarterly and cover the period 1959:Q1-91:Q4. Both variables were logged and Hodrick-Prescott filtered prior to doing the computations.
Source: Christiano, Eichenbaum, and Evans (1996b).

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.[9] 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 nonborrowed 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.[10] 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, ε, 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 ε. 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*, μ, 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 μ) 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.[11] I also assume that the FOMC's money supply shock, μ, and private economy shock, ε, 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:

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

The shock, υ, 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 ε. 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, μ and υ, and the private economy shock, ε, to the equilibrium interest rate, R, is assumed to be:

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

One would want to allow $a_1 \neq a_3$ since μ and υ presumably have different dynamic implications for the evolution of total reserves.[12]

The definition of *NBR* implies:

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

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 $1 - a_2\gamma < 0$.[13]

It is easily confirmed that:

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

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

A parameterization which implies the right sign pattern of covariances is $\sigma_\upsilon = 0.1$, $\sigma_\mu = \sigma_\varepsilon = \gamma = 1$, $a_1 = 0.01$, $a_2 = 1.5$, $a_3 = 1.0$, $\alpha = \gamma$. 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. . . ."[14] 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."[15] In the context of the above example, this means the identifying assumptions have to enable one to isolate the FOMC shock to money, μ, or the discount window shock to money, υ. 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, υ, are small enough to ignore. To remove the effects of ε from *NBR*, CEE make the following identification assumption: that aggregate output, *y*, and the aggregate price level, *p*, contemporaneously reflect the effects of ε, and *not* the effects of μ.[16] 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, μ.[17] First, do an ordinary least squares regression of nonborrowed reserves on *y* and *p* and treat the residual as something that contains only μ and not ε. 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, υ, 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:

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

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

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

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 σ_υ^2 be large.

This raises the possibility that CEE's measure of monetary policy shocks could be contaminated by υ. Under these circumstances, their estimate of a monetary policy shock, μ, is actually $(1 - a_1\gamma)\mu + (1 - a_3\gamma - \alpha)\upsilon$.[18] In the extreme case where μ is negligible and all monetary policy shocks correspond to υ, 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 Ω_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, μ_t is the monetary policy shock. The key identifying assumption, aside from the linearity of f and the specification of Ω_t, is:

μ_t is uncorrelated with the elements in Ω_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 Ω_t.[19] 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.

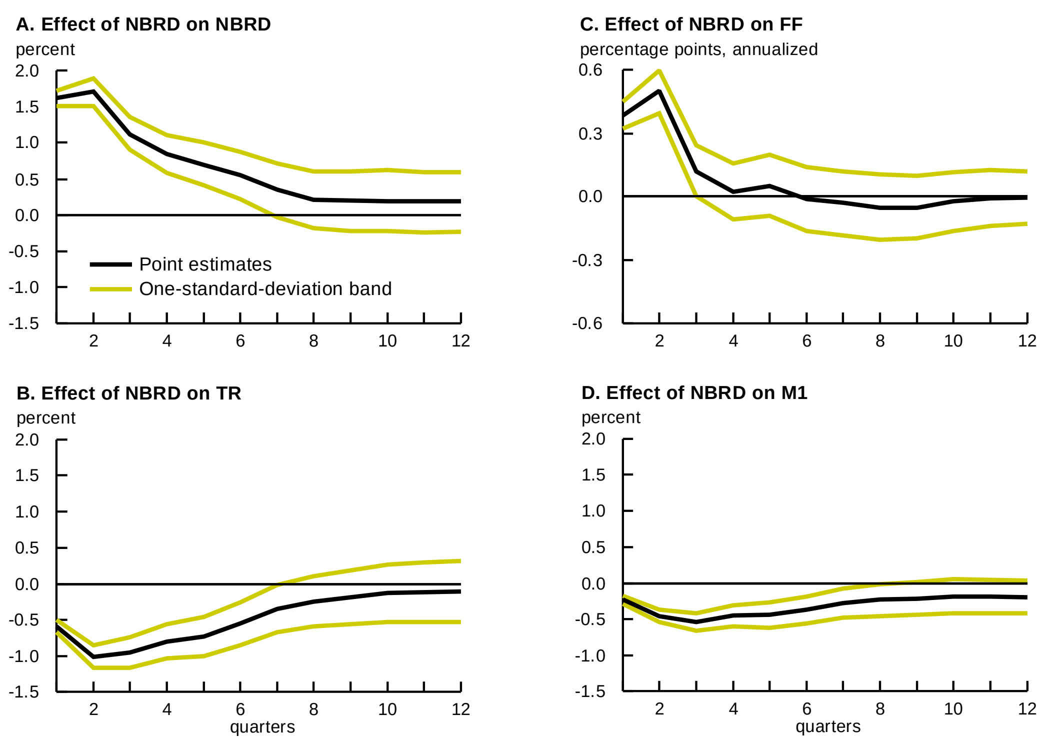
Consider figure 5, which reports the impact of a contractionary monetary policy shock on monetary and interest rate variables. Panel A of figure 5 indicates that a monetary policy shock corresponds to a persistent drop in the stock of nonborrowed reserves, beginning with a 1.5 percent drop (recall a 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.[20]

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 5

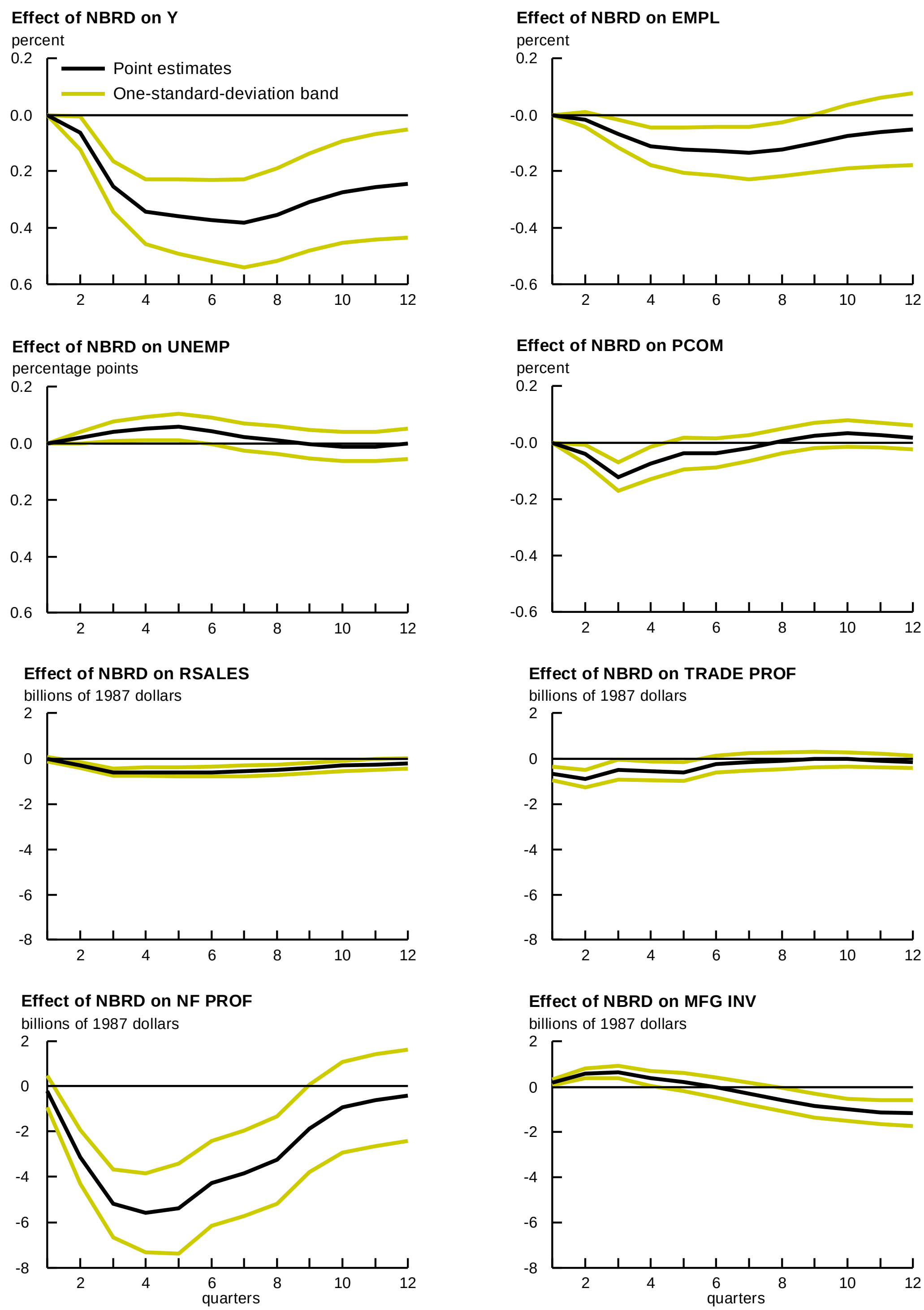
The effect of a monetary policy shock on financial variables



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

FIGURE 6

The effect of a monetary policy shock on macroeconomic variables



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.

NOTES

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

[2]The following remarks draw heavily on Christiano, Eichenbaum, and Evans (1996a).

[3]In our work, we also extract monetary policy shocks from interest rate data. I do not survey this work here.

[4]This section and the next draw heavily on the material in Christiano (1995).

[5]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.

[6]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.

[7]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.

[8]See, for example, Bernanke and Blinder (1992) and Sims (1986).

[9]The GDP data are taken from CITIBASE.

[10]Total reserves is the sum of reserves borrowed from the Fed's discount window (borrowed reserves) and the rest (nonborrowed reserves).

[11]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.

[12]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.

[13]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 ε and only weakly related to μ and υ.

[14]Christiano and Eichenbaum (1992), p. 5.

[15]Christiano and Eichenbaum (1992), p. 13.

[16]One reason why *both* p and y might be needed to pin down ε is that ε is itself a linear combination of two private economy shocks, that is, $\varepsilon = \alpha_1\varepsilon_1 + \alpha_2\varepsilon_2$. Then, to get ε, both p and y are useful, to the extent that these variables are themselves linearly related to ε_1 and ε_2.

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

[18]If p and y were functions not just of ε, but also of υ, 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 μ seems to also imply that p and y are not functions of υ.

[19]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).

[20]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.

REFERENCES

Barro, Robert J., *Macroeconomics*, 2nd ed., New York: John Wiley, 1987.

Bernanke, Ben, "Alternative explanations of the money income correlation," in *Carnegie Rochester Conference on Public Policy, Real Business Cycles, Real Exchange Rates and Actual Policies*, Vol. 25, Karl Brunner and Allan Meltzer (eds.), Autumn 1986, pp. 49–100.

Bernanke, B., and A. Blinder, "The federal funds rate and the channels of monetary transmission," *American Economic Review*, Vol. 82, September 1992, pp. 14–31.

Christiano, Lawrence J., "Modeling the liquidity effect of a monetary shock," Federal Reserve Bank of Minneapolis, *Quarterly Review*, Vol. 15, No. 1, Winter 1991, pp. 3–34.

_______________, "Commentary on 'Resolving the liquidity effect,'" Federal Reserve Bank of St. Louis, *Review*, Vol. 77, No. 3, May/June 1995, pp. 55–61.

Christiano, Lawrence J., and Martin Eichenbaum, "Identification and the liquidity effect of a monetary shock," in *Political Economy, Growth, and Business Cycles,* A. Cukierman, L.Z. Hercowitz, and L. Liederman (eds.), Cambridge, MA: MIT Press, 1992.

_______________, "Liquidity effects, monetary policy, and the business cycle," *Journal of Money, Credit, and Banking*, 1995.

Christiano, Lawrence J., Martin Eichenbaum, and Charles Evans, "Identification and the effects of monetary policy shocks," in *Financial Factors in Economic Stabilization and Growth*, Mario Blejer, Zvi Eckstein, Zvi Hercowitz, and Leo Leiderman (eds.), Cambridge, UK: Cambridge University Press, 1996a, forthcoming.

_______________, "The effects of a monetary policy shock: Some evidence from the flow of funds," *Review of Economics and Statistics*, 1996b, forthcoming.

Coleman, Wilbur John III, Christian Gilles, and Pamela Labadie, "A model of the federal funds market," *Economic Theory*, 1996, forthcoming.

Gali, Jordan, "How well does the IS-LM model fit postwar U.S. data," *Quarterly Journal of Economics,* Vol. 107, No. 2, May 1992, pp. 709–738.

Friedman, Milton, *Money Mischief*: *Episodes in Monetary History*, New York: Harcourt, Brace, Jovanovich, 1992.

Hetzel, Robert, "A better way to fight inflation," *Wall Street Journal*, April 25, 1991, p. A14.

King, Robert, "Money and business cycles," University of Rochester, manuscript, 1991.

King, Stephen, "Real interest rates and the interaction of money, output, and prices," manuscript, 1983.

King, Robert, and Mark Watson, "Comparing the fit of alternative dynamic models," Northwestern University, manuscript, 1992.

Melvin, Michael, "The vanishing liquidity effect of money on interest: Analysis and implications for policy," *Economic Inquiry*, Vol. 21, No. 2, April 1983, pp. 188–202.

Mishkin, Frederic, *A Rational Expectations Approach to Macroeconomics: Testing Policy Ineffectiveness and Efficient-Markets Models*, A National Bureau of Economic Research Monograph, Chicago: University of Chicago Press, 1983.

Pagan, Adrian R., and John C. Robertson, "Resolving the liquidity effect," Federal Reserve Bank of St. Louis, *Review*, Vol. 77, No. 3, May/June 1995, pp. 33–54.

Sims, Christopher A., "Are forecasting models usable for policy analysis?" Federal Reserve Bank of Minneapolis, *Quarterly Review*, Vol. 10, No. 1, Winter 1986, pp. 2–16.

Thornton, D. L., "The effect of monetary policy on short-term interest rates," Federal Reserve Bank of St. Louis, *Review*, Vol. 70, No. 3, May/June 1988, pp. 53–72.