

## Comments

# 'Interpreting the macroeconomic time series facts: The effects of monetary policy'

by Christopher Sims

Martin Eichenbaum

*Northwestern University, Evanston IL, USA and the Federal Reserve Bank of Chicago, USA*

Few issues in macroeconomics have generated as much controversy as the qualitative and quantitative effects of monetary policy.<sup>1</sup> This paper describes and assesses the nature of the empirical support for the conflicting views which pervade the profession. In addition to reviewing existing empirical work, Sims brings to bear vector autoregressive methods on postwar data from France, Germany, Japan, the U.K. and the U.S., in order to characterize the dynamic effects of monetary policy disturbances. This is an important and thoughtful paper which serves as a timely reminder of the possible dangers involved in using small subsets of simple correlations or 'stylized facts' as tests of competing business cycle theories. Once we broaden the scope of our vision to encompass the multitude of information upon which vector autoregressive analyses are based, we are quickly forced to agree with Sims' main conclusion that 'support in the data for the Real Business Cycle view and the view that monetary policy is clearly important is weaker than proponents of those views might think' (page 976). Indeed my own sense is that the actual extent of our uncertainty is substantially *understated* by Sims analysis. This is because all of the inference in his analysis is based on a single measure of disturbances to monetary policy, namely innovations to short-term interest rates.<sup>2</sup> In fact, there exist equally

<sup>1</sup>I would like to thank Lawrence Christiano, Steven Strongin and Mark Watson for many helpful conversations and suggestions.

<sup>2</sup>Sims' identifying assumption stands in sharp contrast to the traditional literature on the effects of monetary policy on interest rates. A critical feature of that literature is that disturbances to monetary policy are measured as the innovation to high-order monetary aggregates. See Reichenstein (1987) for a review of this literature. Christiano and Eichenbaum (1991a) document the sensitivity of inference to this assumption.

plausible measures which generate very different inferences regarding the effects of monetary policy. The sensitivity is particularly important for questions pertaining to the interaction of monetary policy and inflation as well as the overall importance of policy disturbances for fluctuations in aggregate economic activity.

Why use innovations in short-term interest rates as a measure of shocks to monetary policy? Sims' decision to do so can be interpreted as reflecting his strong priors that any reasonable measure of shocks to monetary policy ought to have the property that expansionary shocks drive output up and lead to opposite movements in money and nominal interest rates [see for example Sims (1986)]. As it turns out, these priors, along with his decision to work with M1 as the measure of money, *compel* him to adopt interest rate innovations as the measure of shocks to monetary policy. Innovations to M1 do not qualify because they are associated with declines in output and increases in short-term nominal interest rates.<sup>3</sup>

The fact is that, at least for the U.S., we have a plethora of different measures of money at our disposal, ranging from narrow direct measures of open market operations like Non Borrowed Reserves to extremely broad aggregates like M1 or M2. There is certainly no a priori reason for working with M1 to address the kinds of issues which Sims is interested in. After all, the *only* monetary aggregate which the Federal Reserve Open Market Committee can directly control is Non Borrowed Reserves. Even the base, M0, cannot be directly controlled by that committee. This is because Borrowed and Non Borrowed Reserves are governed by different regulations and set by different decision makers within the Federal Reserve [see Goodfriend (1983) or Stigum (1990)].

One of the key points which this comment makes is that, unlike M0 or M1, innovations to Non Borrowed Reserves, satisfy both of Sims' litmus tests for measures of disturbances to monetary policy. His decision to use interest rate innovations is compelling only if we are willing to condition on his choice of monetary aggregate. I see no reason to do so. That this choice has important implications for inference is apparent from the fact that innovations in Non Borrowed Reserves generate small but positive increases in the price level. In stark contrast, Sims finds that positive innovations to short-term interest rates lead to sharp, persistent increases in the price level. Evidently, the 'price puzzle' emphasized by Sims' is not robust to working with alternative, plausible measures of the disturbances to monetary policy.

Sims' puzzle, if we accept it is as such, is an important one which poses an obvious challenge to Keynesians, Monetarists and Real Business Cycle

<sup>3</sup>For the U.S., the result that innovations in *M1* are associated with declines in output is particularly pronounced in the quarterly data when real GNP is included in the VAR rather than industrial production. In the monthly data, the decline in industrial production begins only after about twelve months.

analysts alike. Indeed I know of no business cycle theory which is consistent with the notion that monetary contractions lead to prolonged periods of inflation. A more plausible interpretation of the 'puzzle' is that it simply calls into question Sims' measure of the shocks to monetary policy. Indeed this view is implicit in Sims' own explanation of the price puzzle, which builds on the notion that the monetary authority often has information regarding inflationary pressures, not captured in the history of the variables included in the VAR. Acting on the basis of such knowledge, policy makers may raise interest rates in an effort to forestall inflation. Under these circumstances the econometrician would find that innovations to interest rates are followed by increases in the price level and interest rates as well as declines in aggregate output. What the econometrician cannot see is the price level that would have obtained had the policy maker not acted in a contractionary manner.

While this scenario certainly seems reasonable, it does mean that interest rate innovations are, at best, a polluted measure of policy disturbances. Moreover, we have no way of knowing how inference would be affected were we able to correct for the fact that some unknown fraction of innovations to interest rates represent the endogenous response of policy makers to non-policy shocks, namely those responsible for generating the inflationary pressures in the first place. To the extent that interest rate innovations are spuriously attributed entirely to exogenous shocks in monetary policy, the analyst will systematically overstate the importance of policy disturbances for aggregate output fluctuations. We know that innovations to short-term interest rates explain a high percentage of the variance of output (at least for the post-war U.S.). What we don't know, under Sims' resolution of the price puzzle, is what percentage of these innovations represent exogenous policy disturbances. Interest rate innovations provide only an upper bound for this percentage. At the same time, the lower bound provided by innovations to Non Borrowed Reserves turns out to be quite small. Analyses based solely on the interest rate innovations greatly mask the true extent of our uncertainty.

To document these claims, I now present the results of estimating the four variable vector autoregressions reported in Sims' paper using post war U.S. data. The two features of my analysis which distinguish it from Sims' are that (i) I consider three different monetary aggregates: *NBR* (Non Borrowed Reserves), *M0* and *M1*, and (ii) I report standard errors for all of the estimated response functions.<sup>4</sup> As it turns out, these standard errors have an important impact on inference. All vector autoregressions included 14 lags of a measure of money, the Federal Fund Rate (*FF*), industrial production (*Y*) and the price level (*P*) as measured by the consumer price index. All

<sup>4</sup>Standard errors were computed using the procedure described in Doan (1991, Example 10.1) with 100 draws from the posterior distribution of the VAR coefficients.

results are based on post-war monthly data for the U.S. covering the period 1965:1–1990:1.

Fig. 1 reports results obtained using  $M1$ , the measure of money used by Sims. The solid lines, labeled RESP of  $X$  to  $M1/0$  and RESP of  $X$  to  $M1/PY$ ,  $X = \{M1, P, Y \text{ and } FF\}$  in Columns 1 and 2, display the responses of  $M1$ ,  $FF$ ,  $Y$  and  $P$  to a shock in  $M1$  for the Wold ordering given by  $\{M1, P, Y, FF\}$  and  $\{P, Y, M1, FF\}$ , respectively. The solid lines in Columns 3 and 4, labeled RESP of  $X$  to  $FF/0$  and RESP of  $X$  to  $FF/PY$ ,  $X = \{M1, P, Y \text{ and } FF\}$  display the responses of  $M1$ ,  $FF$ ,  $Y$  and  $P$  to a shock in  $FF$  for the Wold orderings  $\{FF, M1, P, Y\}$  and  $\{P, Y, FF, M1\}$ , respectively. The dashed lines in these figures denote one standard deviation bands of the estimated impulse response functions. Panel A of table 1 reports the covariance matrix of the innovations in the VAR underlying the impulse response functions in fig. 1. Consistent with Sims' results, with the exception of the correlation between the innovations in  $FF$  and  $Y$ , the off diagonal elements of this matrix are close to zero, so that the Wold ordering does not affect the dynamic response functions in any significant manner, i.e. the entries of columns 1 and 2 are very similar as are those of columns 3 and 4.

Consider the response of the system to an innovation in  $M1$ . Notice that  $FF$  rises for roughly 30 months in response to such a shock. At the same time, the salient response of industrial production is a steep, pronounced *decline* beginning after about 12 months. While the interest rate effects are estimated quite accurately, those pertaining to output are not. Sampling uncertainty aside, do these results indicate that unanticipated changes in monetary policy precipitate a rise in interest rates and a decline in output? The answer is yes only if we accept the identifying assumption that the statistical innovation to  $M1$  measures unanticipated changes in monetary policy. Since the implications of this assumption are so grossly at variance with his priors, Sims' rejects this interpretation. Whatever the innovations in  $M1$  correspond to, Sims adopts the position [implicitly here and explicitly in Sims (1986)] that they do not measure unanticipated changes in monetary policy.<sup>5</sup> This seems perfectly reasonable to me.

Suppose we proceed under Sims' identifying assumption that disturbances to monetary policy are well measured by innovations to the interest rate. As can be seen from columns 3 and 4, the implications of this identifying assumption accord well with Sims' priors. In particular, innovations to the Federal Funds rate are followed by sharp, long lasting declines in  $M1$  and a large, persistent decline in real GNP. In both cases, the impulse response functions are estimated quite accurately. Columns 3 and 4 also reveal the key

<sup>5</sup>Taking sampling uncertainty into account, the output response of innovations to  $M1$  would not be inconsistent with the sign restrictions implicit in Sims' litmus test for reasonable measures of shocks to monetary policy. Nevertheless the interest rate response fails that test, even after sampling uncertainty is taken into account.

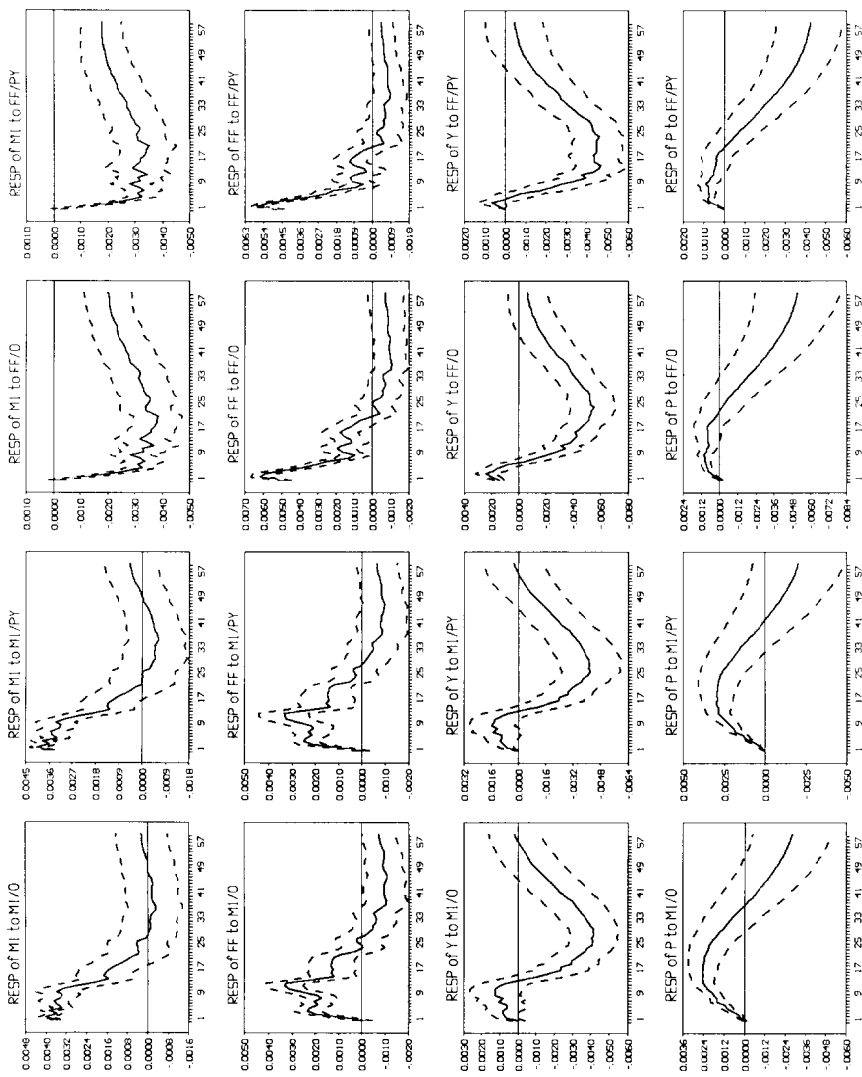


Fig. 1

Table 1

A. Correlation matrix of innovations in VAR including *M1*, *Y*, *P* and *FF*

	<i>P</i>	<i>Y</i>	<i>M1</i>	<i>FF</i>
<i>P</i>	1.0	0.06	-0.04	-0.04
<i>Y</i>		1.0	-0.01	0.23
<i>M1</i>			1.0	-0.03
<i>FF</i>				1.0

B. Correlation matrix of innovations in VAR including *M0*, *Y*, *P* and *FF*

	<i>P</i>	<i>Y</i>	<i>M0</i>	<i>FF</i>
<i>P</i>	1.0	0.08	0.04	0.04
<i>Y</i>		1.0	-0.003	0.24
<i>M0</i>			1.0	0.07
<i>FF</i>				1.0

C. Correlation matrix of innovations in VAR including *NBR*, *Y*, *P*, and *FF*

	<i>P</i>	<i>Y</i>	<i>NBR</i>	<i>FF</i>
<i>P</i>	1.0	0.11	-0.11	0.05
<i>Y</i>		1.0	-0.20	0.25
<i>NBR</i>			1.0	-0.28
<i>FF</i>				1.0

anomaly for Sims' identifying assumption. In particular, they indicate that innovations to *FF* are followed by increases in the price level for roughly one and a half years. The basic price puzzle emerges even after we take sampling uncertainty into account.

Fig. 2 reports the analog results obtained with *M0* as the monetary aggregate. The contemporaneous covariance matrix between the innovations in the underlying VAR is reported in panel B of table 1. As before, excluding the entry pertaining to (*FF*, *Y*), the off diagonal elements are close to zero. Notice that the dynamic response of the system to an innovation in *FF* is not significantly affected by switching from *M1* to *M0*. On the other hand, inference regarding the effect of an innovation to the monetary aggregate is affected. While the estimated response functions to innovations in *M0* and *M1* are quite similar, there is far greater sampling uncertainty with *M0*. This fact has important implications for Sims' litmus tests. It is true that our point estimates indicate that the interest rate rises in response to an innovation in *M0*. Indeed authors like Gordon and Leeper (1991) have used this fact to challenge the empirical motivation underlying recent business models, like those of Lucas (1990), Fuerst (1990) and Christiano and Eichenbaum (1991b) which embody strong liquidity effects. Unfortunately, the standard errors associated with the relevant impulse response function are enormous. Once

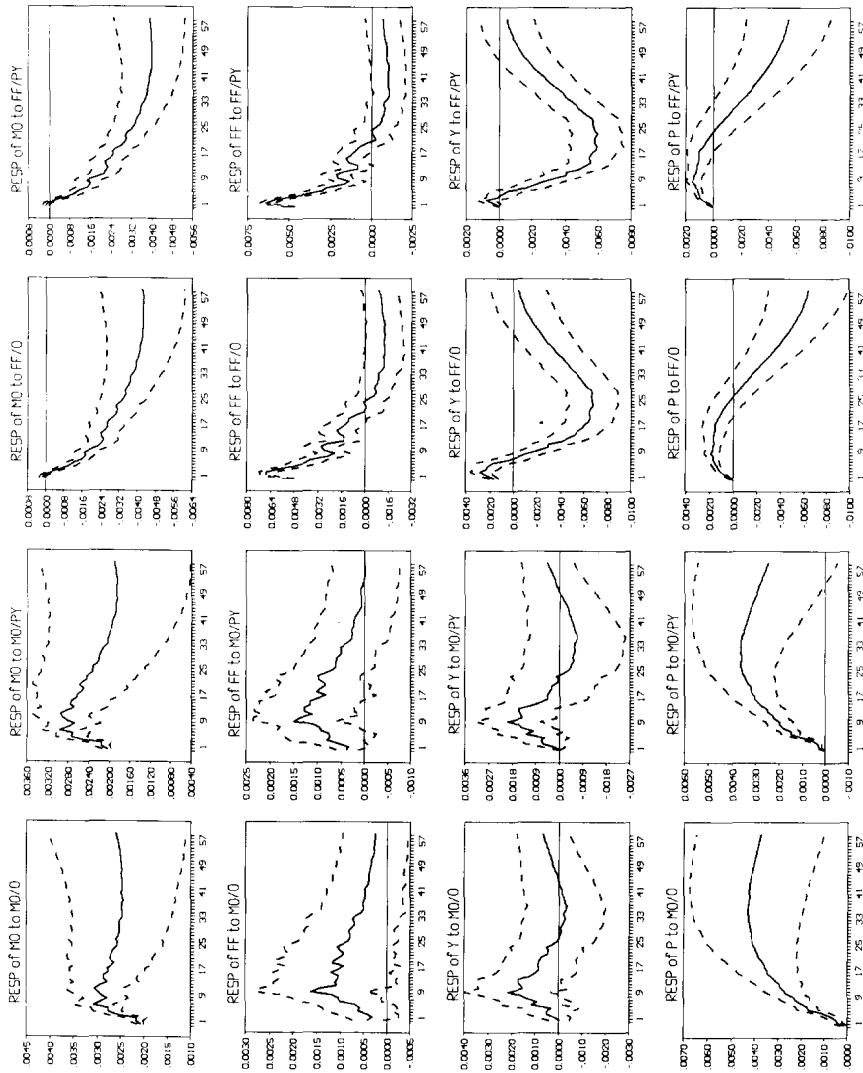


Fig. 2

sampling uncertainty is taken into account, one cannot reject the hypothesis that interest rates rise or that they fall after innovations to  $M0$ . There is not enough evidence here to claim that  $M0$  fails Sims' litmus tests. Still, it seems hard to recommend innovations to  $M0$  as a measure of policy disturbances. After all, the reason they don't fail Sims' test is that they don't contain much information about interest rates or output in the first place.

Next, consider fig. 3 which reports the analog results with  $NBR$  as the monetary aggregate. The corresponding covariance matrix of innovations in the underlying VAR is presented in panel C of table 1. Notice that, unlike  $M0$  and  $M1$ , the innovations in  $NBR$  and  $FF$  display strong negative correlations with  $FF$ ,  $Y$  and  $P$  equal to  $-0.28$ ,  $-0.20$  and  $-0.11$ , respectively. The analog correlations for  $M0$  and  $M1$  equal  $\{0.07, -0.003, 0.04\}$  and  $\{-0.03, -0.01, -0.03\}$ , respectively. The strong negative correlation between innovations to  $NBR$  and  $FF$  parallels the finding in Christiano and Eichenbaum (1991a) that the unconditional correlation between  $NBR$  and  $FF$  is sharply estimated and negative. This result is robust across a variety of different post war periods, and holds irrespective of whether one uses monthly or quarterly data or whether one induces stationarity in the data using the Hodrick and Prescott (1980) filter, growth rates or by removing exponential trends. The fact that innovations in  $NBR$  are negatively correlated with innovations in  $Y$  and  $P$  is suggestive of the hypothesis that the Federal Reserve typically has moved quickly to forestall inflationary pressures on the economy by contracting Non Borrowed Reserves, thereby inducing an increase in short-term interest rates.

The negative relationship between  $NBR$  and  $FF$  is manifested in the response of  $FF$  to an innovation in  $NBR$ . As columns 1 and 2 indicate, such a shock induces a sharp, persistent, statistically significant fall in  $FF$ . Unlike  $M0$  and  $M1$ ,  $NBR$  unambiguously passes Sims' first litmus test. From the output response function, we also see that  $NBR$  does not fail Sims' second litmus test. Using his metric then, innovations to  $NBR$  are as plausible a measure of disturbances to monetary policy as innovations in  $FF$ . But what of the price puzzle? Suppose we assume that, in setting  $NBR$ 's, the Federal Reserve responds to contemporaneous price and output information. This identifying assumption corresponds to the Wold ordering underlying column 2 of fig. 3. As can be seen, under these assumptions, innovations to  $NBR$  generate small but positive movements in the price level. Granted the standard errors associated with this response function are very large (as are those associated with the analog response function in column 1). But, unlike innovations to  $FF$ , there is no sense in which a price puzzle emerges with this measure of disturbances to monetary policy.

How does inference regarding the overall contribution of monetary policy shocks to aggregate output fluctuations depend on which of the two measures we adopt? One simple way to approach this problem is to examine



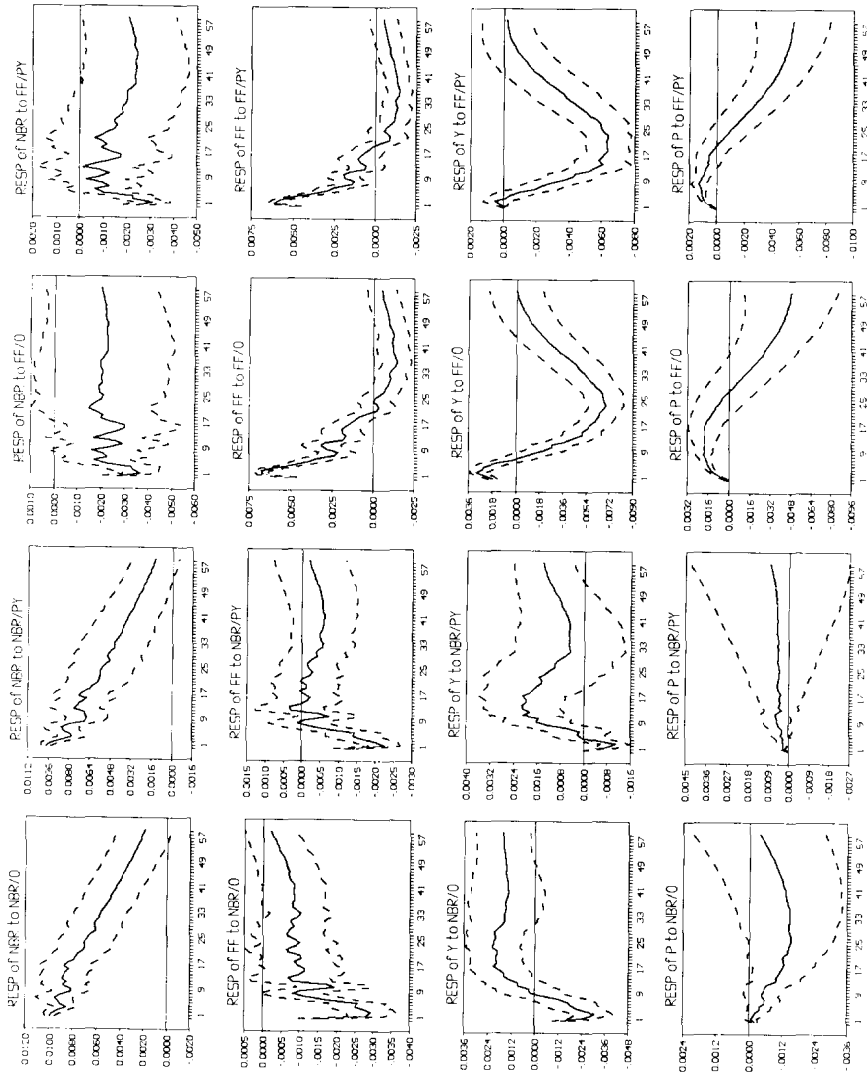


Fig. 3

the percentage of the forecast error variance in industrial output explained by the two measures. (As the horizon of the forecast error goes to infinity these statistics converge to the percentage of the unconditional variance of  $Y$  explained by the two measures of monetary policy disturbances). Using Sims' measure in a VAR with the Wold ordering  $\{FF, MI, P, Y\}$ , we find that 32% of the five-year forecast error variance in  $Y$  can be attributed to innovations in  $FF$  (the standard error of this statistic equals 10%). Simply replacing  $MI$  with  $NBR$  in this VAR causes this statistic to rise to 45%, with a corresponding standard error of 11%. Evidently, there is some sensitivity to changes in the monetary aggregate, even if we condition on Sims' basic identifying assumptions. Nevertheless, in both cases, we would conclude that shocks to monetary policy are quite important for aggregate output fluctuations. On the other hand, suppose we calculate this statistic using the measure of policy shocks underlying column 2 of fig. 3, i.e. that component of  $NBR$  which is orthogonal to contemporaneous price and output disturbances. Then we would conclude that policy shocks are quite unimportant as they explain only 5% of the five-year forecast error variance of industrial production. The corresponding standard error of this statistic equals 5%.<sup>6</sup> The basic point is that inference depends very sensitively on which of the two candidate measures we work with. Measures of sampling uncertainty regarding the percentage of the forecast error variance of  $Y$  explained by only one of the measures clearly understates the true state of our uncertainty.

In the end, my sense is that further progress on these issues can be made only by carefully studying the institutional details of how monetary policy is actually carried out in the different countries which Sims' investigates. At least for the U.S., there is a wealth of information on the targets, goals and operating procedures of the Federal Reserve. None of this information recommends the use of a single monetary aggregate for summarizing monetary policy. Consider for example the fact that Non Borrowed and Borrowed Reserves interact with short-term interest rates in fundamentally different ways. We have documented the fact that Non Borrowed Reserves and interest rates display strong negative co-movements. Christiano and Eichenbaum (1991a) document the fact that Borrowed Reserves and interest rates display strong positive co-movements.<sup>7</sup> There is no a priori reason for aggregating the two forms of reserves. If nothing else, working with high order aggregates like  $M0$ , makes it much more difficult to exploit the wealth of information we have at our disposal regarding Federal Reserve procedures and targets for the individual components of 'the money supply'. It is no

<sup>6</sup>This standard error must be treated with caution as the algorithm used to calculate it clearly breaks down as the point estimate of the statistic approaches zero.

<sup>7</sup>Despite their relatively small size, Borrowed Reserves have a major impact on the time series behavior of  $M0$ . Once we remove Borrowed Reserves from  $M0$ , the resulting aggregate behaves very much like Non Borrowed Reserves.

doubt true that incorporating this information into formal econometric analyses will be difficult. Still, I see no alternative to resolving the fundamental identification problems raised by Sims' paper.

## References

- Bernanke, B. and A. Blinder, 1990, The federal funds rate and the channels of monetary transmission, NBER working paper no. 3487 (NBER, Cambridge, MA).
- Christiano, L. and M. Eichenbaum, 1991a, Monetary policy and the liquidity effect: Some empirical evidence, Manuscript (Northwestern University, Evanston, IL).
- Christiano, L. and M. Eichenbaum, 1991b, Liquidity effects, monetary policy and the business cycle, Manuscript (Northwestern University, Evanston, IL).
- Doan, T., 1990, Users manual, rats, version 3.10 (VAR Econometrics, Evanston, IL).
- Fuerst, T., 1990, Liquidity, loanable funds and real activity, Manuscript (Northwestern University, Evanston, IL).
- Goodfriend, M., 1983, Discount window borrowing, monetary policy and the post-October 1979 federal reserve operating procedures, *Journal of Monetary Economics* 12, 345–356.
- Gordon, D.B. and E.M. Leeper, 1991, In search of the liquidity effect, Manuscript (Federal Reserve Board, Washington, DC).
- Hodrick, R.J. and E.C. Prescott, 1980, Post war business cycles: An empirical investigation, Manuscript (Carnegie Mellon University, Pittsburgh, PA).
- Lucas, R.E. Jr., 1990, Liquidity and interest rates, *Journal of Economic Theory* 50, 237–264.
- Reichenstein, W., 1987, The impact of money on short term interest rates, *Economic Inquiry* 25, no. 1, 67–82.
- Sims, C.A., 1986, Are forecasting models useful for policy analysis, *Federal Reserve Bank of Minneapolis Quarterly Review* 10, Winter, 2–16.
- Stigum, M., 1990, *The money market*, Third edition (Dow Jones-Irwin, Homewood, IL).