

Interpreting the macroeconomic time series facts

The effects of monetary policy*

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Existing theory and evidence on the effects of monetary policy are reviewed. Substantial room for disagreement among economists remains. New evidence, based on multivariate time series studies of several countries, is presented. While certain patterns in the data consistent with effective monetary policy are strikingly similar across countries, others, particularly the tendency of interest rate increases to predict high inflation, are harder to reconcile with effective monetary policy.

1. The range of our ignorance

Though many macroeconomists would profess little uncertainty about it, the profession as a whole has no clear answer to the question of the size and nature of the effects of monetary policy on aggregate activity. Economists closely connected with policy tend to view the monetary authority as capable of controlling nominal short-term interest rates and thereby of strongly influencing the level of aggregate activity. While there is formal statistical evidence and theoretical support for such a view, many of these economists, in the United States at least, regard such support as scarcely needed, given what seems to them the clear pattern of tightened monetary policy preceding practically every postwar U.S. recession. On the other hand, many of the most active academic macroeconomic researchers are pursuing the agenda of the real business cycle (RBC) school, which has often worked with models that include only real variables. Where RBC school models have included nominal variables, it has usually been to show that some of their correlations with real variables can be reproduced in models where nominal aggregate demand management and monetary policy have no important role.

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In what follows we first discuss the existing state of support in studies of data for these conflicting views. We then present some new reduced-form evidence on the dynamic interactions of real and monetary variables, showing that certain interesting characteristics of reduced form impulse-responses are robust both across countries and across definitions and lists of included variables. In many respects these facts merely reinforce what is known from previous studies, but there are a few patterns that seem not to have been noted before. Finally we discuss the degree to which the conflicting views on the effects of monetary policy are consistent with this quantitative evidence. Our conclusion is that support in the data for both the RBC view and the view that monetary policy is clearly important is weaker than proponents of those views might think. We propose that further progress will depend on work with models that include characteristics and mechanisms not now common in the field. The models should specify endogenous monetary policy, confronting the identification problems this raises directly. They should include an investment function rather than just a demand for capital (i.e. adjustment costs or a relative price of capital). And they should include nominal variables along with real variables, so that the facts of smooth price and wage reactions to disturbances are confronted.

2. Existing theory and evidence

The theory supporting the view that monetary policy can strongly influence aggregate activity is well worked out, by the standards of the macroeconomics of the 1950s and 60s. In that period, the differences between Keynesians and monetarists seemed to many to be differences over the relative sizes of certain elasticities in a system whose formal structure was more or less agreed-upon. This framework survives in most intermediate macroeconomics textbooks, where IS and LM curves are derived and shifted about to give students a vocabulary with which to discuss macroeconomic policy. In this framework, which is essentially static, policy can increase the money stock, thereby shifting the LM curve outward under the assumed constancy of prices. Assuming the IS curve is downward-sloping and holds still under this policy action, interest rates will drop and output will increase. Of course this is only the 'demand side' of the policy effect, and in a later chapter of the typical textbook qualifications to this picture are introduced – can prices be assumed to remain constant? What mechanism induces the increased labor input required to produce the higher output? It is recognized that the answers to these questions could overturn the standard ISLM conclusions, but such issues are treated as peripheral complications, rather than part of the central framework.

By modern standards, this theory is full of gaps. Of course it is a disequilibrium theory, but it provides no explicit discussion of which

conditions for individual optimization are being relaxed. It uses an important idea of disequilibrium dynamics – that trade occurs at out-of-equilibrium prices and this has real effects – but does not have a plausible complete dynamic theory surrounding it. It does assume that labor markets don't clear, meaning that workers and/or firms are not equating marginal utilities and/or marginal products to the wage. This is a plausible postulate. But it pays no attention to optimization conditions that are more likely to be satisfied – for example the connection of nominal interest rates to real rates and expected inflation and the connection of investment to expected future marginal products. If such conditions are simply tacked on to the ISLM framework, to form a Keynesian model with rational expectations in asset markets, the conclusions about the effects of monetary policy from the usual ISLM framework are not necessarily preserved. Keynesians may object that rational expectations is an unreasonable assumption, but that expectations are volatile and sensitive to the current environment seems indisputable – even seems a Keynesian notion. That expectations may not be rational only reinforces the point that recognition of their volatility and endogeneity makes the conclusions from Keynesian ISLM reasoning suspect.

I lay out these objections to Keynesian and monetarist theory here not because I think they are fatal. The basic idea of this type of theory is the following sequence of events. Because of the sluggishness of nominal prices and/or wages, increases in nominal money stock or reductions of nominal interest rates can make the real value of government liabilities held by the public exceed their equilibrium level. In this situation output will rise as the public tries to spend their excess assets, and there will be some accompanying price rise. Building a model that behaves like this, concentrating disequilibrium in markets for labor and/or current output, assuming rational behavior for investors and bondholders, is not trivial, but it is possible. Here we simply note my conviction that there is nothing naive or self-contradictory in supposing that such a model can be constructed, despite the old-fashioned style of much of the Keynesian and monetarist theoretical literature.

And these old-fashioned theories remain influential, despite their lack of recent polishing by academic macrotheorists, because they are indeed strongly supported by historical evidence. There is a familiar set of facts. Monetary aggregates tend to move in the same direction as aggregate economic activity, as has been repeatedly documented. Simple co-movements could in principle easily be accounted for as passive response of money demand to changes in the level of activity not generated by monetary policy. Friedman and Schwartz (1963) and others therefore paid special attention to the timing of movements in monetary aggregates and aggregate activity, documenting a tendency for money in some sense to lead income. Tobin (1970) showed that both the tendency to co-movement and the timing of

movements of money and income could roughly match observations in a model where monetary policy played no role in generating aggregate fluctuations. Furthermore it was widely recognized that timing, as measured by the location of peaks in cross-correlation functions or in relative leads and lags of turning points, can shift drastically as series are differenced or differentiated. That much monetarist work related *changes* in money stock to *levels* of income, automatically inducing a phase shift in money via the difference operator, weakened the timing evidence.

Economists have therefore tried to dig deeper, trying to isolate periods when monetary policy variables moved for reasons that cannot be connected to any previous developments in the private sector. Friedman and Schwartz tried to do this in some passages of (1963), and more recently Romer and Romer (1989) have done the same thing more systematically. If we can examine the aftermath of such periods, it is thought, we will see the effects of policy unclouded by the effects of other disturbances that might also shift policy. Such studies are attempts to solve an identification problem informally, using the same intuition that leads to study of responses to reduced form innovations in multivariate models.

Responses to innovations generate timing patterns that are at least partly immune to the effects of differencing. The response of income to an innovation in money is invariant to differencing of the money data. When the responses show the extreme asymmetry of zero response of money to income innovations, this condition – Granger causal priority of money – is invariant to differencing of either income or money. It was surprising (to me at least) that money was Granger causally prior to nominal income in U.S. postwar data through the 60s [Sims (1971)], and I recently verified [Sims (1989)] that that result still holds using data through the 80s.

The historical ‘event studies’ using monetary aggregates and the study of impulse responses lead to the same conclusion: that when monetary aggregates increase unexpectedly, nominal income subsequently rises. Variation in income predicted by monetary innovations constitutes a large part of total variation in income. The variation in monetary aggregates predicted by income innovations is small. This is completely consistent with the view that random disturbances in monetary policy generate a large fraction of the observed business cycle, and it is difficult or impossible to explain with most RBC models in the literature.

In larger multivariate time series models, including a nominal interest rate, money stock innovations become smaller, as interest rate innovations predict a considerable fraction of movement in the money stock. Further, the remaining money stock innovations have less predictive power for income. These facts do not fit the most extreme monetarist view – that monetary aggregates alone are a complete measure of the stance of monetary policy – but raise no difficulty for a broader view that monetary policy disturbances

are important in generating aggregate fluctuations. Indeed this view is strengthened by the pattern of responses to interest rate innovations – there is a long, slow decline in output and a long, slightly less slow decline in money stock. The part of output predictable from interest rate innovations is substantial. Indeed this quantitative statistical evidence is a kind of summary of the more anecdotal support cited in the opening paragraph of this paper – sudden rises in interest rates have regularly been followed by recession and drops in rates by recovery.

The results summarized above have been found both by me and by others, for various time period, time units, definitions of variables, and countries. However, some researchers have criticized them as unstable, noting that they change in some respects under particular choices of time period, time unit or variable list. Recently Todd (1991) has undertaken a systematic exploration of the sensitivity of the results, for systems including interest rates, to these factors. While he does find some sensitivity, the qualitative pattern of the results as described above is quite robust. His paper includes a survey of the empirical literature in this area.

While there is intuitive appeal to these event-studies and innovation-response studies, they do rest on implicit identifying assumptions. It is assumed that an innovation in a 'monetary policy variable' – either interest rates or money stock – is generated by monetary policy autonomously. Yet it is possible that there are within-period feedbacks, so that unpredictable movements in monetary policy variables are generated in part by disturbances originating elsewhere in the economy. In an earlier paper [Sims (1986)], I found that looser identifying assumptions leave the basic interpretative picture the same, however: monetary policy disturbances are estimated to have substantial and plausible effects on real output.

This picture of strong empirical support was weakened, however, by Sims (1989). There I showed that a particular RBC-style model could mimic some of the reduced form impulse response behavior observed in the data. The model differs from other RBC-style models in the literature in that it has the monetary authority using the interest rate as its instrument, raising it in response to rapid growth in money. It also differs in having a two-good technology, so investment goods can become expensive and interest rates low even when rental rates on installed capital are high. Without this element it is difficult or impossible for a rise in demand to simultaneously increase employment, create expectations or price rises, and reduce interest rates. The model includes a small real role for transactions balances in the technology, so monetary policy does have real effects, but they are small and not of the form implied by monetarist or IS-LM theory. Nonetheless it produces a strong Granger causal ordering from money to nominal income, just as in actual data. Furthermore, when interest rate data from the model are included in the reduced form, the interest rate innovations predict declines in

money stock and output very much like those observed in reduced forms fit to actual data. The model is not a complete success. It does not divide the impulse responses of nominal income into real and price components the way impulse responses fit to actual data do. In particular, the price responses are stronger and the real responses weaker in the model data than in actual data. Nonetheless the occurrence of this strong predictive value for monetary policy variables in a model where monetary policy is unimportant must weaken the credibility of evidence based on event studies and impulse responses. Putting it briefly, this model shows that, because interest rates and money are closely linked to investment portfolio decisions, they tend to react quickly to new information, as other asset market variables do. Money and interest rates have strong predictive value for aggregate activity for the same reason that stock prices do. One can imagine, in other words, that the historical pattern of monetary tightness preceding recessions is misleading. High interest rates might 'produce' contractions in activity the way the cock's crow produces the sunrise.

It goes without saying that the theoretal underpinnings of RBC models are, at least in comparison with ISLM models, modern, complete, and fully dynamic. RBC models [with the exception of my own venture into this area [Sims (1989)]] have, however, not confronted the documented impulse-response facts about interactions of monetary and real variables. Given the profession's long experience with the Keynesian–monetarist debate, in which the limitations of evidence on correlations, timing, and (combining these) cross-correlation functions came to be widely appreciated, it is surprising that these tools are again receiving so much attention. It is not surprising that policy-oriented economists, well-taught by the earlier debates how easy it is to match a given pattern of correlations or timing with models that have widely different interpretations, do not regard this kind of exercise with RBC models as convincing. My own RBC-style model [Sims (1989)] does confront the impulse-response evidence and indeed partly succeeds in matching it. But the failure of that model to match observed price behavior is crucial. An ISLM or monetarist framework would predict strong real effects of monetary policy because of slow price adjustment. An RBC-style model where monetary policy has little real effect, but prices counterfactually respond strongly and quickly to disturbances of all kinds, is not a direct competitor with ISLM or monetarist interpretations that can rationalize behavior of all of R , M , P , and Y at once.

3. New evidence

Vector autoregressive (VAR) systems were estimated for data from France, Germany, Japan, the U.K., and the U.S. All data were taken from the IFS data base, and the series numbers and detailed descriptions are given in the

data appendix. The data are monthly and include for each country a short interest rate R , a monetary aggregate M (some variety of 'M1'), a consumer price index P , an industrial production index Y , an index of the foreign exchange value of domestic currency XR , and a commodity price index PC . The commodity price index is the same across countries, not converted to domestic currency. Production Y is seasonally adjusted in all countries, while M is adjusted in some countries but not others. A complete set of seasonal dummy variables was included in each equation for each country in any case. Each variable entered each equation with 14 lags. They began between 1957:1 and 1964:1 and ended in 1990 or 1991 in all countries but Germany. In Germany the sample was truncated at the end of 1989 to avoid distortion from the effects of unification. Exact sample periods are given in the titles of the charts. All variables but R entered as logarithms, while R entered as a percent.

Figs. 1–5 show the estimated impulse responses for the six-variable VAR estimates for the five countries.¹ Responses are shown over an expanse of 48 months. The responses are for orthogonalized innovations, with the ordering as shown in the charts – that is, contemporaneous R innovations impact all other variables, while contemporaneous Y innovations impact no other variables. However, the correlations among innovations are so low that the orthogonalization has little effect, as can be seen from table 1 and from the fact that in the charts initial heights of off-diagonal responses are seldom far from zero.² The response graphs in a given row all have the same scale, with the maximum and minimum heights shown on any graph in the row noted at the left. The filled-in areas in the graphs in a given row provide a visual measure of the relative contributions of innovations listed in the columns to explaining variance in the variable listed at the left of the row.

Note that the persistent negative response of money stock and output to positive innovations in interest rates – the fourth and sixth rows of the first column on each chart – is consistent across all five countries. The size of these responses varies, but not their general form. (The response of M to R in the U.K., which appears small, is actually larger than in the other countries except Germany, because of differences in scale of the graphs across countries.) Their form fits the monetarist/ISLM explanation: interest rate surprises represent monetary policy shocks, and monetary contraction generates declining M and Y . The innovation accounting is less robust across countries than these forms of response. That is, looking across the bottom

¹The nature of VARs, their impulse responses, and orthogonalizations of them, are described, e.g., in Sims (1980).

²However, these monthly sample periods are long enough to make quite a few of the small correlations significant according to the asymptotic distribution theory. Table 1 displays these correlations. Note that two standard errors from zero is approximately 0.10 for the correlations shown.

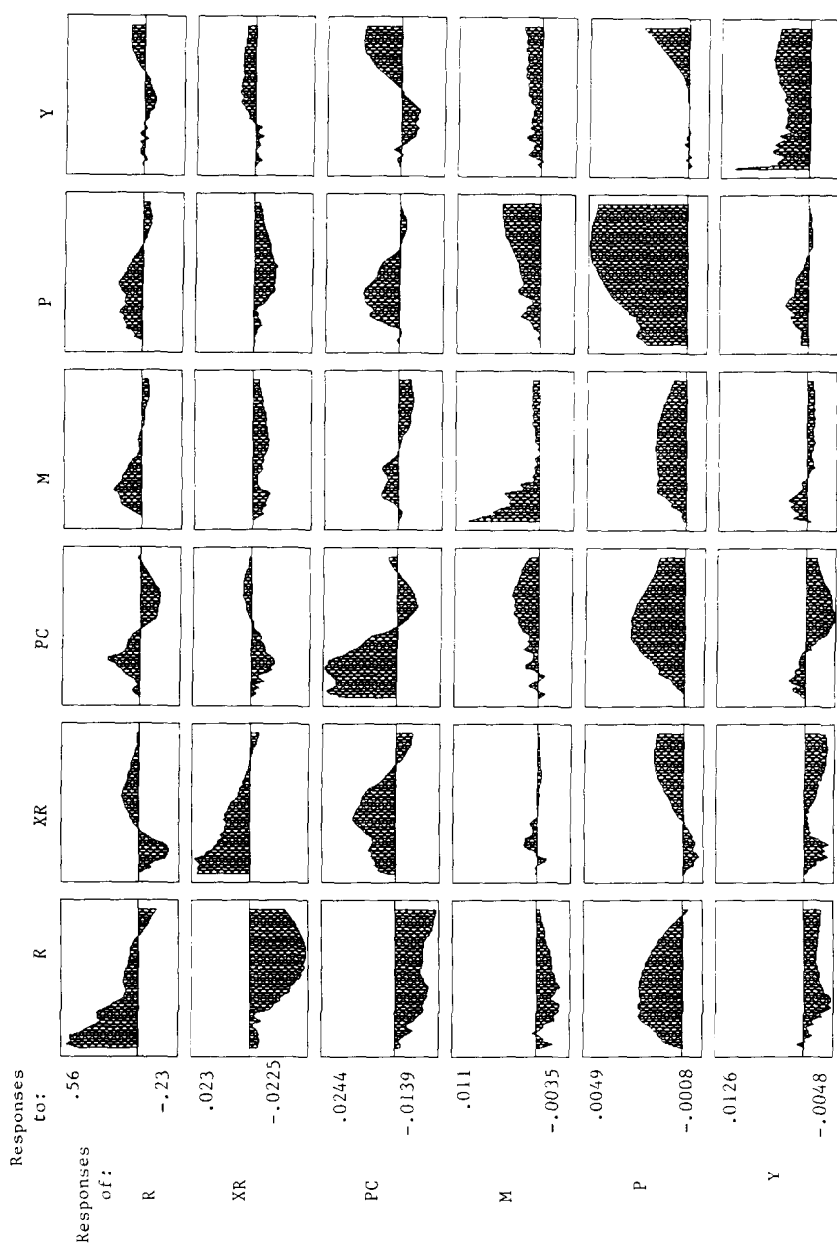


Fig. 1. France, 1965:4–1990:2.

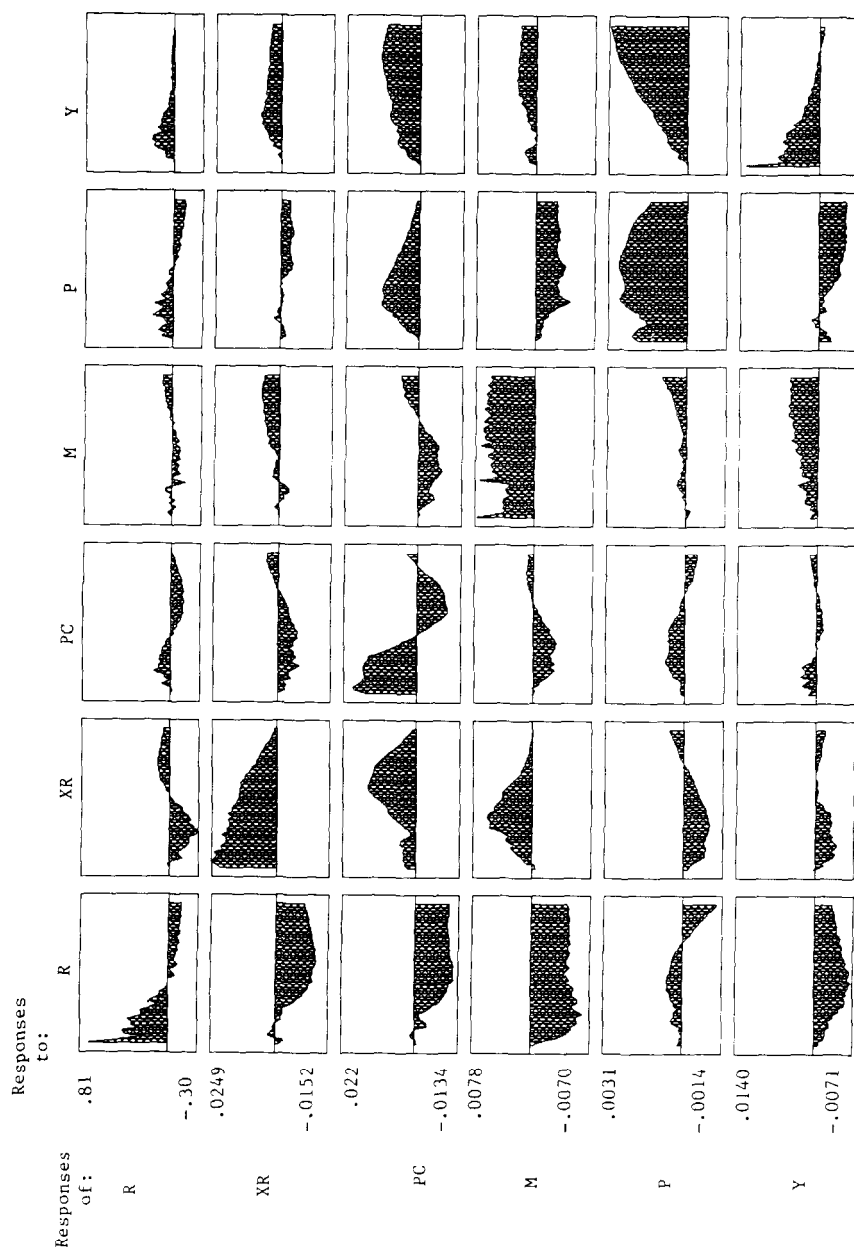


Fig. 2. Germany, 1961:4-1989:12.

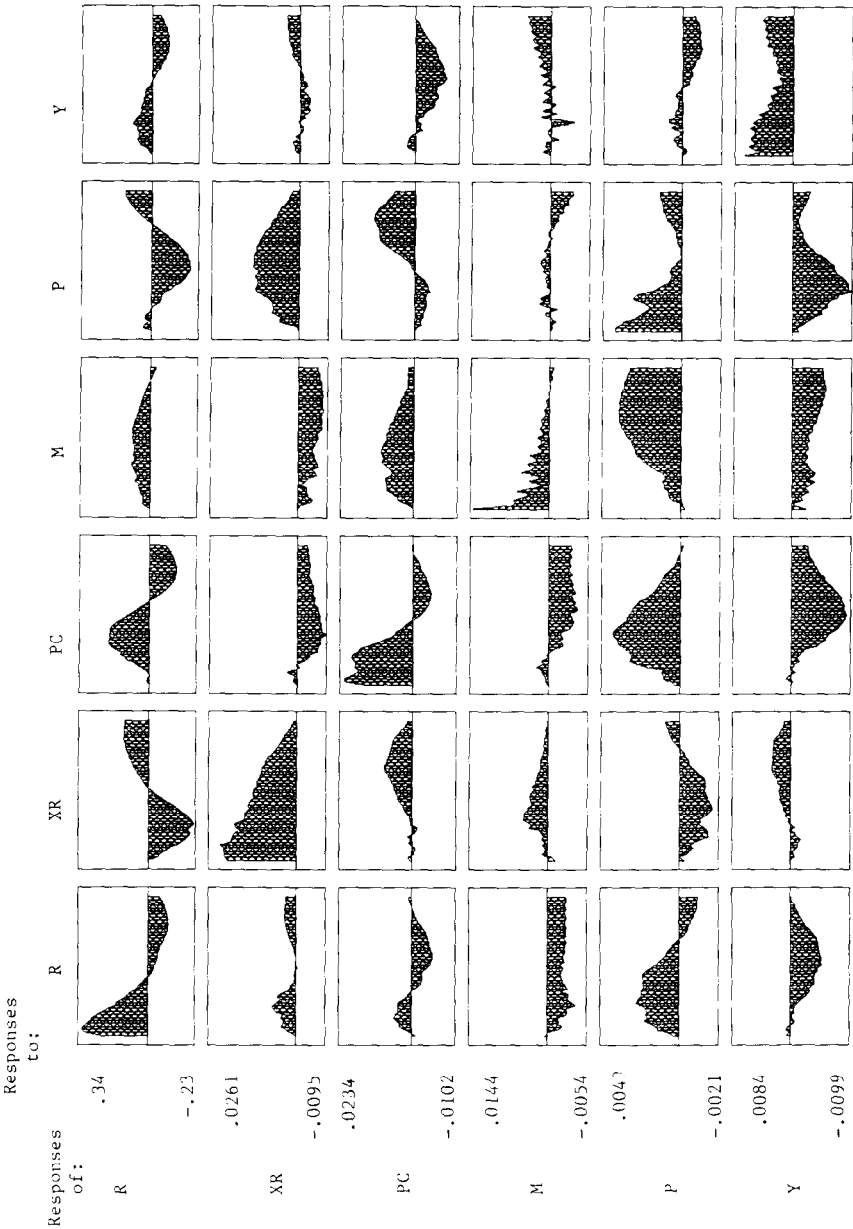


Fig. 3. Japan, 1965:4-1991:1.

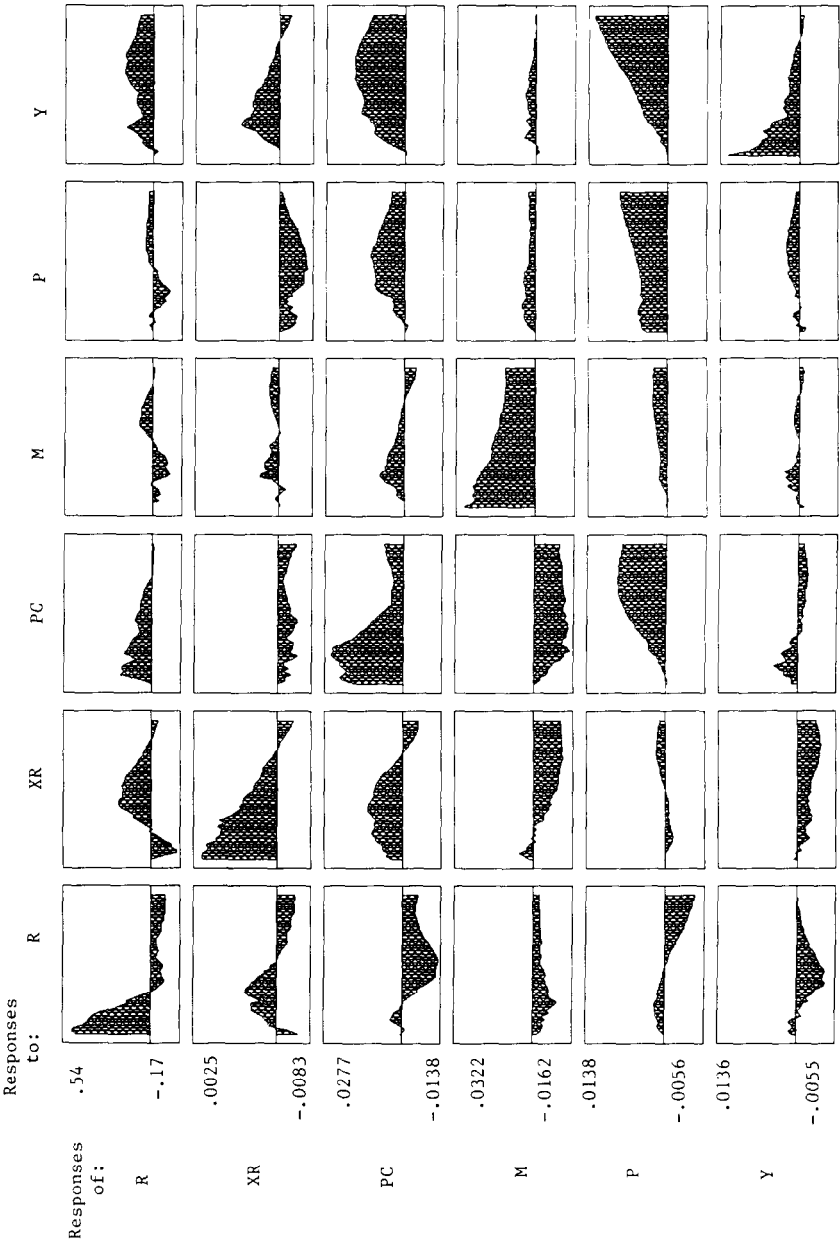


Fig. 4. United Kingdom, 1965:4–1990:12.

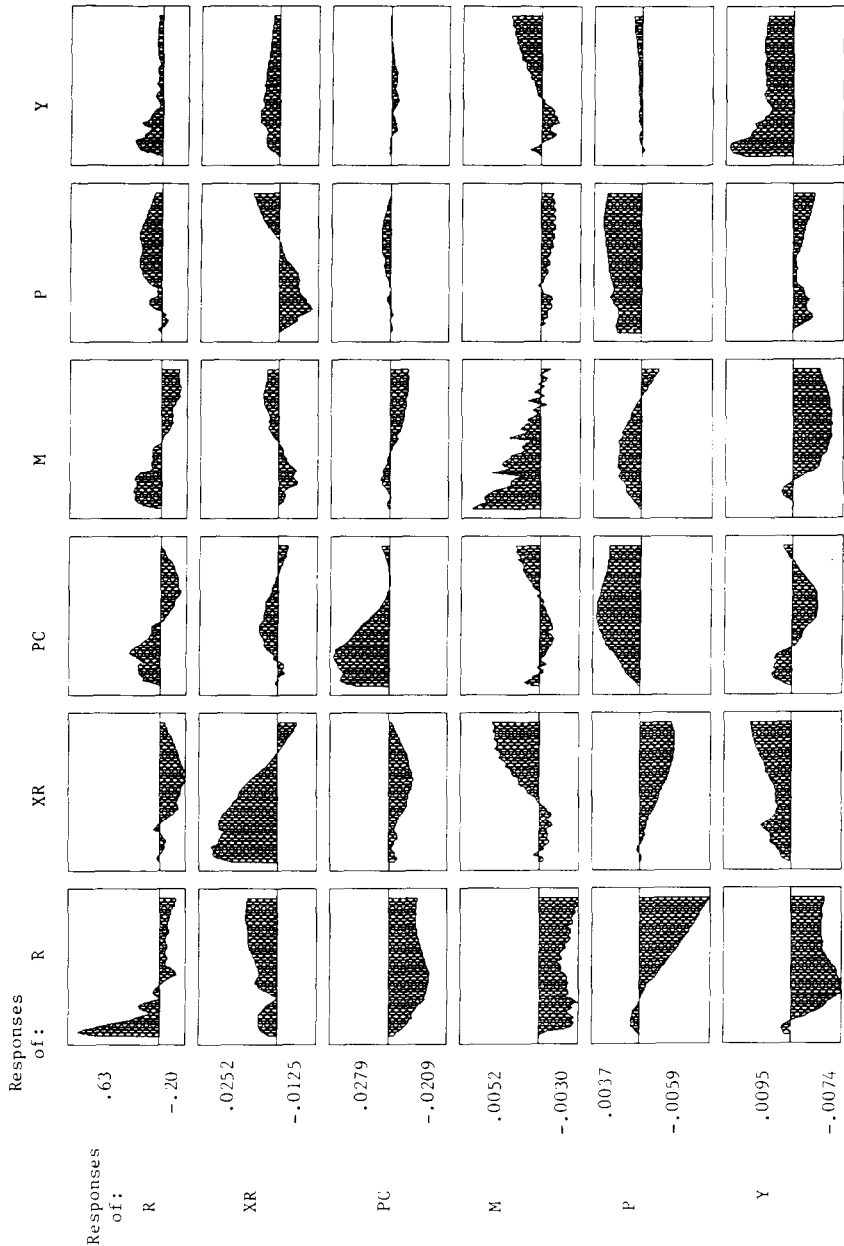


Fig. 5. United States, 1958:4–1991:2.

Table 1
Correlation matrices for innovations: six-variable systems.

<i>R</i>	<i>XR</i>	<i>PC</i>	<i>M</i>	<i>P</i>	<i>Y</i>
France					
1.000					
-0.127	1.000				
-0.089	0.172	1.000			
-0.076	0.038	-0.022	1.000		
0.078	-0.021	0.005	0.071	1.000	
-0.007	-0.021	0.033	-0.041	0.081	1.000
Germany					
1.000					
-0.062	1.000				
-0.035	0.159	1.000			
-0.067	-0.061	0.008	1.000		
0.092	-0.080	0.040	-0.030	1.000	
-0.070	0.026	0.095	0.065	-0.158	1.000
Japan					
1.000					
0.002	1.000				
-0.071	0.036	1.000			
0.037	-0.108	0.004	1.000		
0.092	-0.085	0.069	-0.056	1.000	
0.095	0.034	0.019	-0.260	-0.078	1.000
U.K.					
1.000					
-0.269	1.000				
0.022	0.183	1.000			
-0.059	0.071	0.003	1.000		
-0.014	0.048	-0.018	0.027	1.000	
0.054	0.032	0.079	-0.074	-0.073	1.000
U.S.					
1.000					
0.174	1.000				
-0.164	-0.191	1.000			
-0.010	-0.053	0.117	1.000		
-0.027	-0.029	0.080	0.053	1.000	
0.136	0.116	0.029	0.020	0.019	1.000

row of each chart, the interest rate response is not a uniquely dominant off-diagonal source of variation in output in any country, and it ranges from being the most important one in Germany and the U.S. to being fourth-ranked in Japan. Of course, if these interest rate disturbances were money supply disturbances, we would expect them to have similar effects across countries, but not necessarily to be of similar quantitative importance across countries.

The responses of prices to interest rate shocks show some consistency –

they are all initially positive – but the positive response is strong and persistent only in France and Japan. In the other countries the responses are weaker and eventually become negative. This pattern does not fit so easily into a monetarist/ISLM interpretation. If monetary contraction reduces nominal aggregate demand, lowering output through the interaction of deflationary pressure with price stickiness, how can it be associated with previously unanticipated *inflation* rather than deflation? We will come back to this point.

Money innovations show some consistency in their effects on prices – the effects are all positive. However, the effects are absolutely small and relatively unimportant in Germany and the United Kingdom – the two countries where the money innovations generate the most sustained increase in the money stock. The responses of output to money innovations are either absolutely and relatively small, or predominantly negative, in all countries except Germany. Money stock innovations therefore are not a good candidate for interpretation as a monetarist/ISLM monetary policy shock.

To complete our discussion of the responses to interest rate and money shocks we need to discuss the top three rows of the charts. The entries in the *M* column here are all fairly small. The responses of commodity prices to interest rate innovations are all sustained and negative, except in the case of Japan. This supports interpretation of interest rate innovations as monetarist/ISLM monetary policy shocks – contraction is deflationary. The only caveat is that it is perhaps surprising that four of these five countries' monetary policies could all independently have such strong influences on a single international commodity price index. It would be desirable to have a model that allowed explicitly for international interactions of monetary policies. The responses of currency value to interest rate innovations raise more difficulties. A monetary policy contraction should raise the value of domestic currency, other things being equal. This is more or less what occurs in Japan, the U.K., and the U.S. in response to interest rate innovations. But in France and Germany interest rate innovations are followed by large and persistent declines in the value of domestic currency.

4. Contemplating policy endogeneity

The strong positive responses of prices and negative responses of currency value to interest rate innovations in some countries raise serious difficulties for interpreting these innovations as monetary policy shocks. The interpretation can possibly be rescued, however, if we suppose that monetary policy authorities have information about inflationary pressures better than what can be obtained from the variables in these models. Policy authorities might know that inflationary pressure is about to arrive and contract to dampen

the effects of these pressures. Then prices would rise after the monetary contraction (though by less than they would have without the contraction) and output would fall because of the standard effects of nominal demand contraction on real output. The falling currency value in the wake of the interest rate rise is consistent with this story.

This interpretation can be given either an ISLM/monetarist or RBC twist. The RBC theorist would claim that the same foreseen disturbance that generates the inflationary pressure generates the output decline. Interest rate rises precede output declines only because the monetary authorities tend to raise interest rates when they accurately anticipate negative supply shocks. Monetary policy does not generate subsequent output decline. The monetarist/ISLM theorist would claim instead that the inflationary pressures generate lower output mainly because of the reaction to them by the monetary authorities.

The first round of statistical work for this paper was carried out with four-variable systems, excluding *XR* and *PC*. These same patterns and issues of interpretation arose in that work. The introduction of the *XR* and *PC* variables was meant to shed light on these identification questions. Figs. 6–10 show impulse responses for four-variable systems (solid lines) along with corresponding responses taken from the six-variable systems displayed in figs. 1–5. Correlation matrices for innovations in these systems are shown in table 2. Note that the large, sustained, mostly positive response of price level to interest rate innovations that in the six-variable system appears only in France and Japan, in the four-variable systems appears also in the U.K. and more weakly in the U.S. and Germany. In no case has a positive response of prices to interest rate innovations become larger rather than smaller in moving from the six- to the four-variable systems. Note also that the negative responses of output to interest rate innovations are only slightly reduced in size in the six-variable systems, more or less corresponding to the slight reductions in the size and persistence of interest rate movements themselves in the wake of an interest rate innovation.

To make this interpretation more concrete, consider the case of the U.K., where the effect of the additional variables on the price responses is probably strongest. From figs. 4 and 9 it is clear that much of the price variance that was, in the four-variable system, being attributed to interest rate innovations, is now being attributed to *PC* innovations. These innovations generate a large rise in *PC*, followed by a smoother and somewhat smaller rise in U.K. prices. Interest rates rise promptly after the *PC* increase, and money stock declines smoothly. Output does not decline. This fits the picture of a monetary contraction reacting to, without eliminating, anticipated inflationary pressure signaled by a jump in commodity prices.

Somewhat similar patterns in *PC* columns of figs. 1–5 occur in the other countries. The *XR* columns are also similar across countries, and are

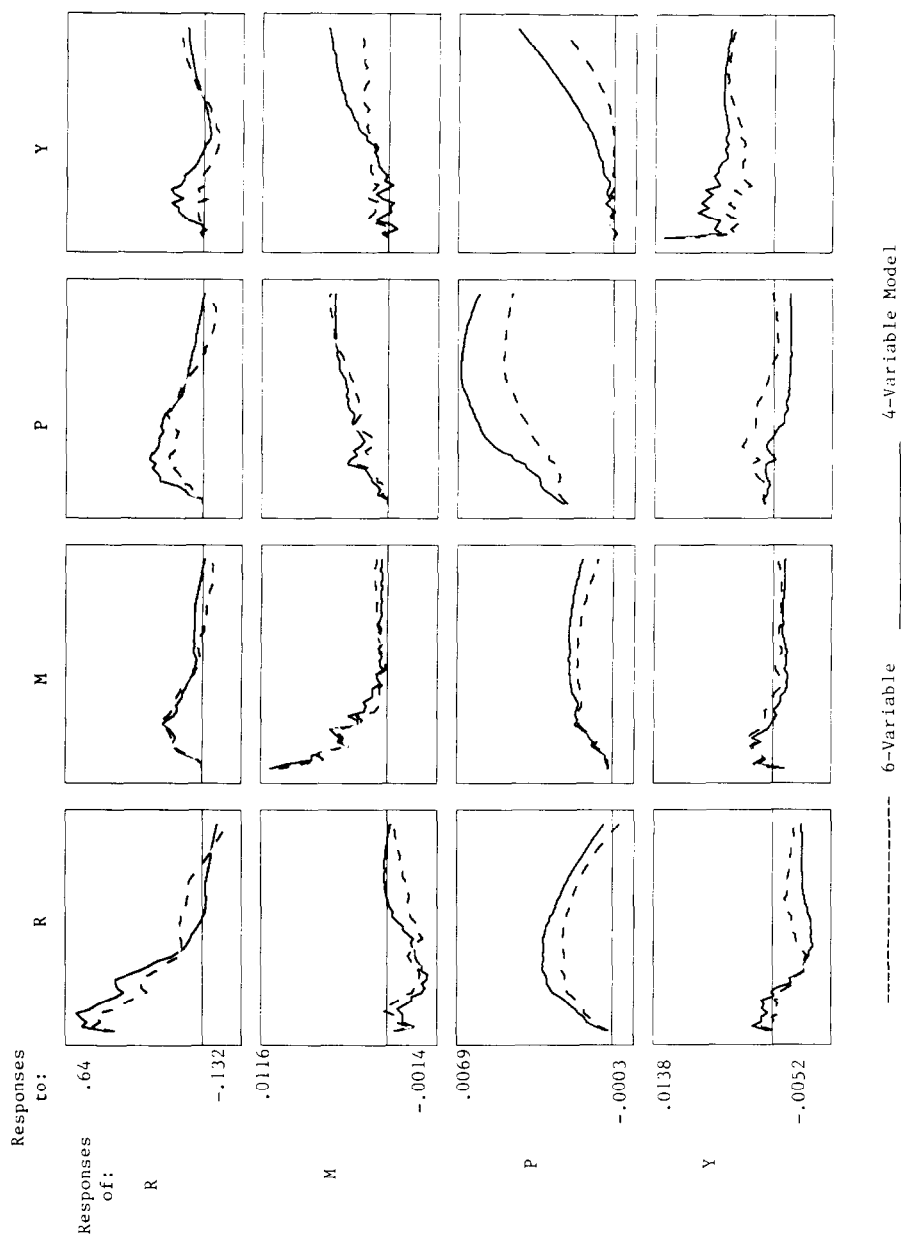


Fig. 6. France, 1965:4-1990:2.

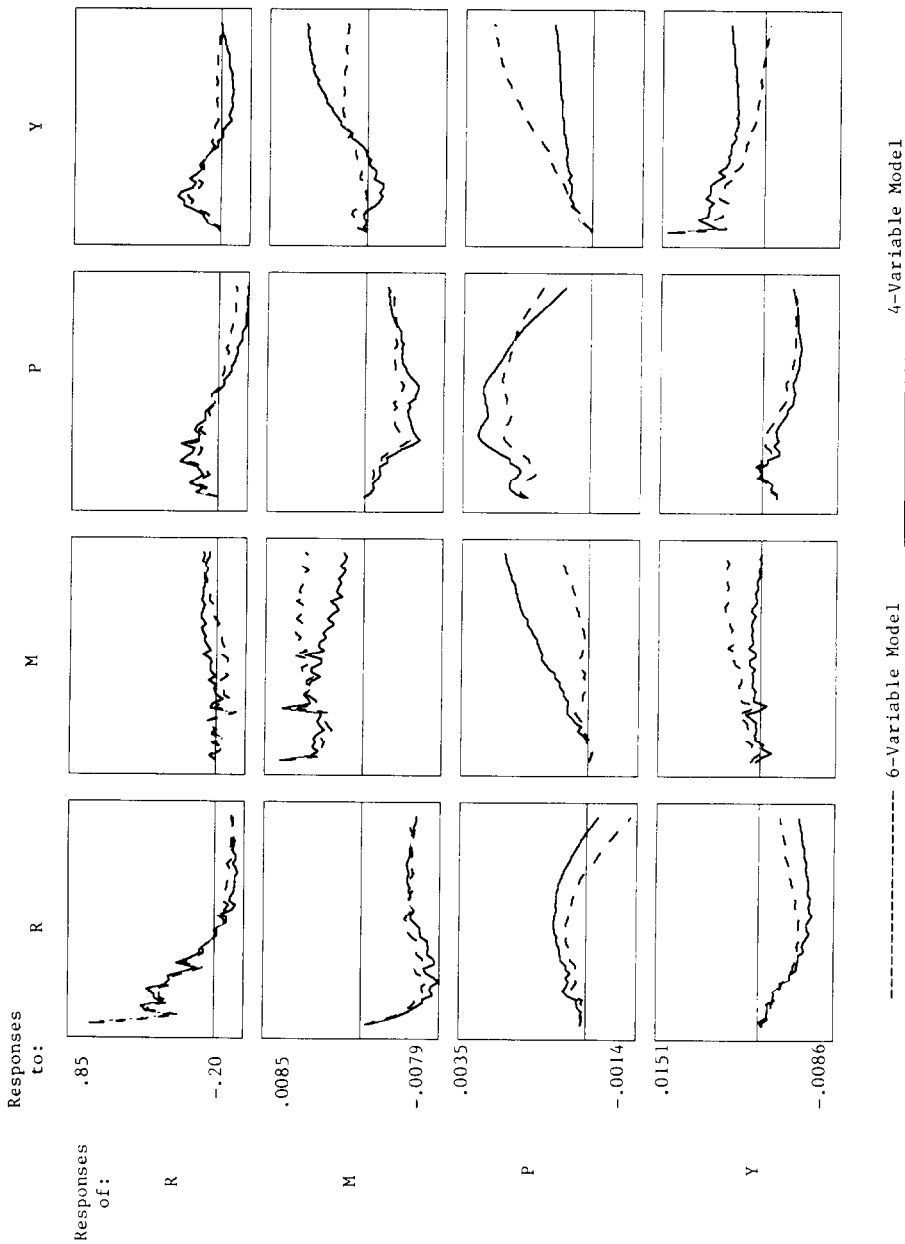


Fig. 7. Germany, 1961:4-1989:12.

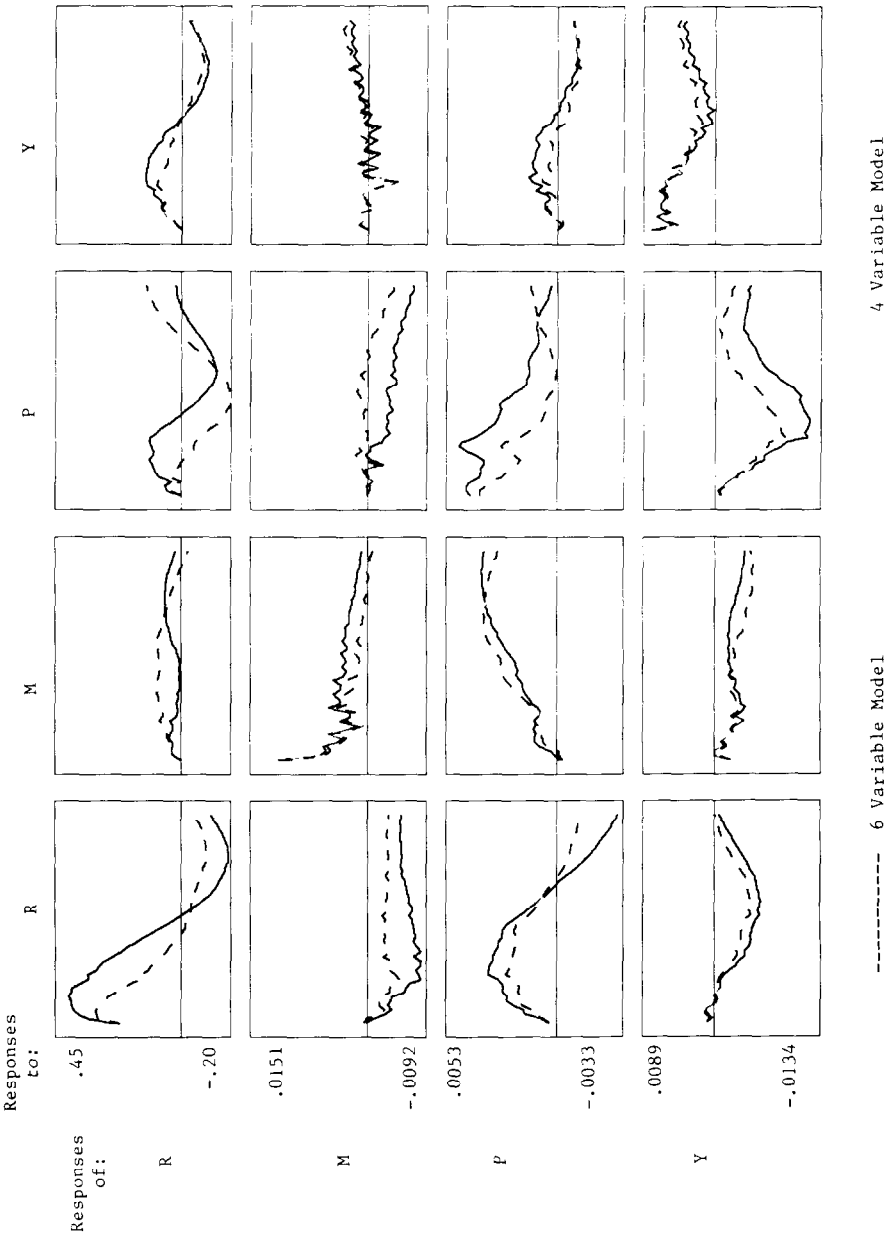


Fig. 8. Japan, 1965:4-1991:1.

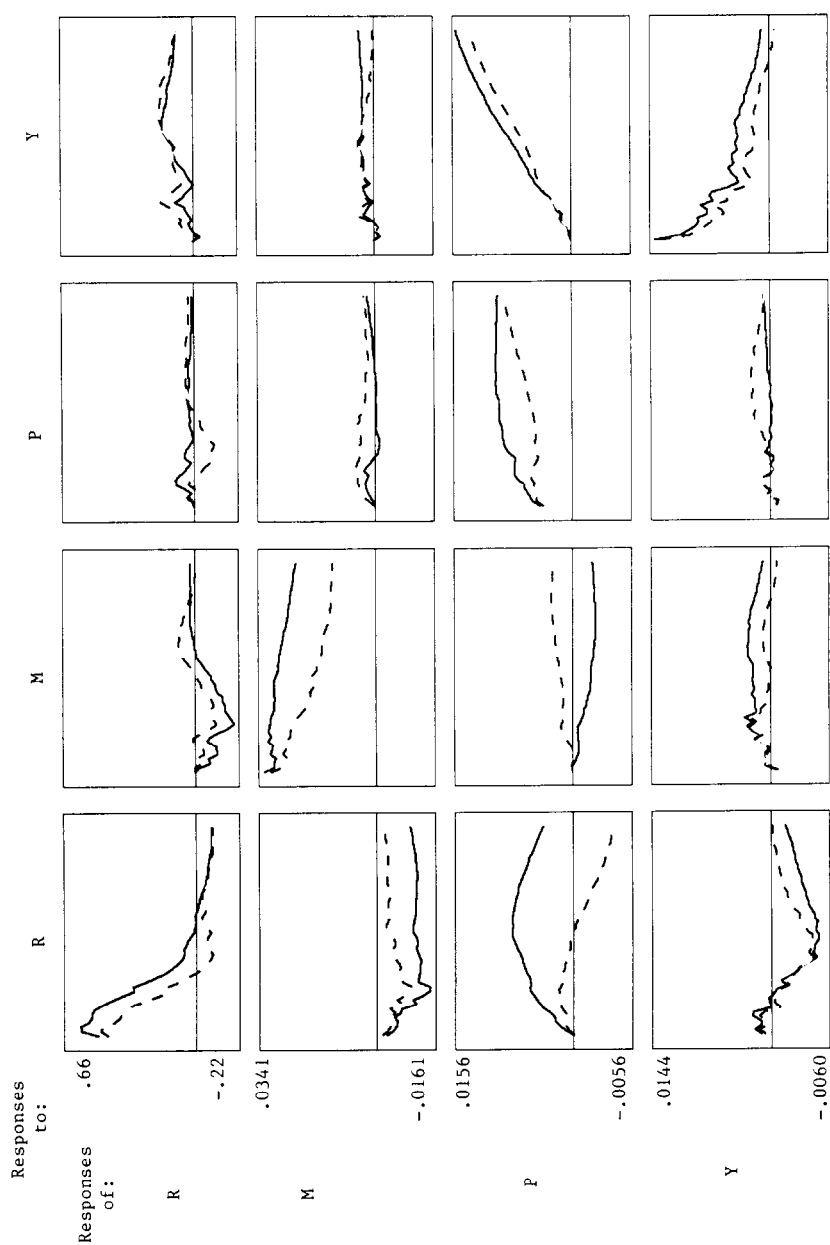


Fig. 9. United Kingdom, 1965:4–1990:12.

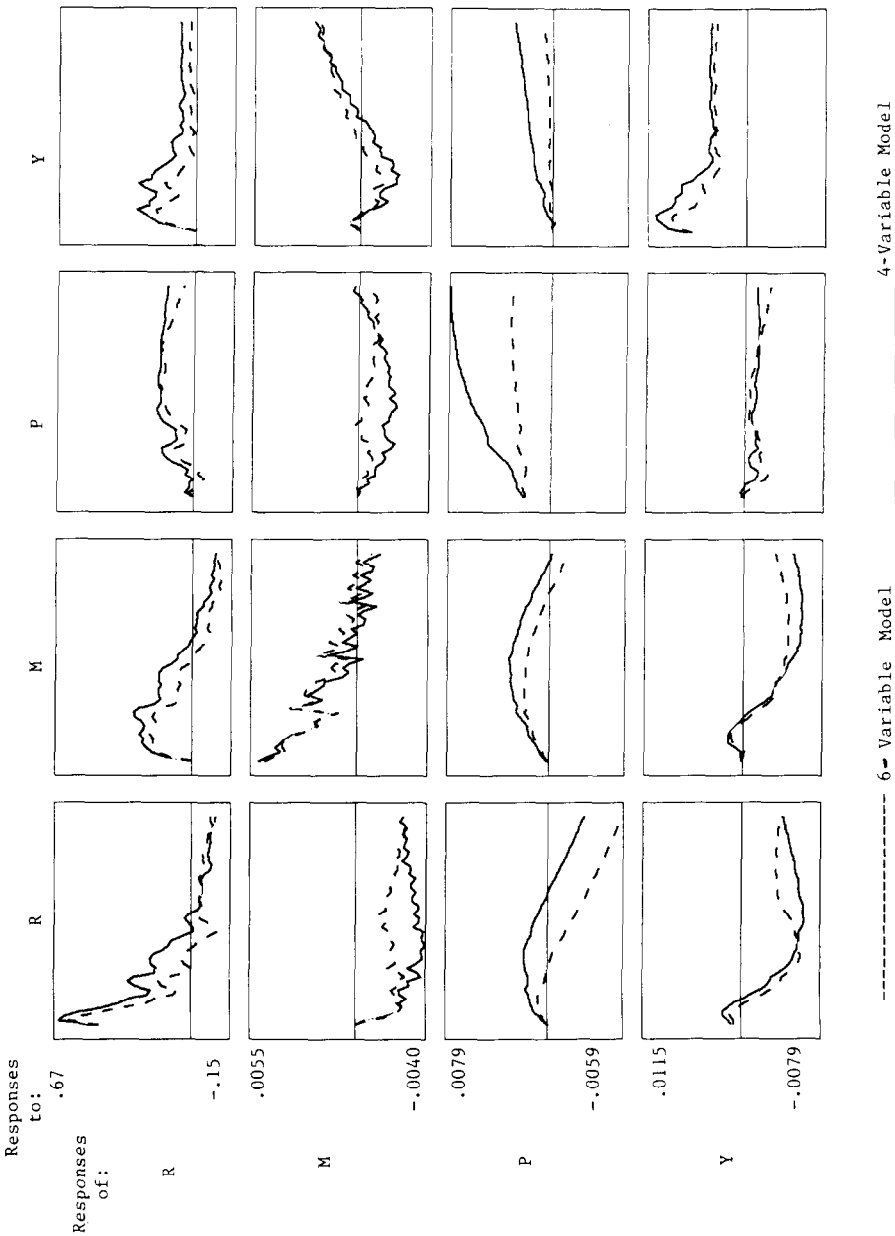


Fig. 10. United States 1958:4–1991:2.

Table 2
Correlation matrices for innovations:
four-variable systems.

<i>R</i>	<i>M</i>	<i>P</i>	<i>Y</i>
France			
1.000			
-0.081	1.000		
0.100	0.075	1.000	
0.027	-0.107	0.068	1.000
Germany			
1.000			
-0.069	1.000		
0.075	-0.039	1.000	
-0.044	0.032	-0.161	1.000
Japan			
1.000			
0.004	1.000		
0.089	-0.024	1.000	
0.099	-0.238	-0.072	1.000
U.K.			
1.000			
-0.088	1.000		
0.025	0.024	1.000	
0.082	-0.061	-0.056	1.000
U.S.			
1.000			
-0.002	1.000		
-0.007	0.057	1.000	
0.175	0.022	0.046	1.000

consistent with a story in which rises in currency value have deflationary impacts partially offset by the loosened monetary policy they induce.

On the whole, comparison of the six- and four-variable systems suggests that exchange rates and commodity prices do influence monetary policy, and that accounting for this can be important for our interpretation of the data. The fact that responses of output to interest rate innovations remain so stable as the additional variables are introduced supports the monetarist/ISLM interpretation. But it remains true even in the six-variable systems that the only country in which the price response to an interest rate innovation is primarily negative is the United States, and even there the negative response does not appear for about a year. This is an embarrassment for a monetarist/ISLM interpretation.

From a RBC perspective, the results are mixed. The repeated finding in actual data of declining output and money stock in response to interest rate

innovations has not been reproduced in any existing RBC model. My own RBC model [Sims (1989)] did at least examine the model's implied responses to innovations, but did not reproduce this observation. Most RBC-style modelers have limited their aims to matching qualitative timing patterns or bivariate cross-correlations in the data, aspects of the data we should know by now are much more easily reproduced than multivariate impulse responses. Until RBC-style modelers confront the multivariate time series data at this level of detail, they will not be making a serious contribution to reducing our ignorance in this area.

But in order to confront data at this level, some aspects of RBC-style modeling that have become conventional will need to be relaxed (though it is perhaps not clear just which ones). The bottom rows of figs. 1–5 show a relatively even scattering of predictive power for output across six mutually independent sources of disturbance. Models built around a one-dimensional source of stochastic shocks (usually neutral technology shocks in RBC models) will not match this pattern. To explain the predictive value of nominal interest rates for output from an RBC perspective seems from this paper's results to require recognition that monetary policy-makers attempt to anticipate inflationary pressures and pressures on exchange rate values – and do a better job of anticipating such pressures than can be done with a small aggregate time series model. Such behavior will not be matched by a model that treats monetary policy variables as determined by an exogenous sequence of random draws or by a model that treats it as a simple function of the main aggregates in the economy. A serious treatment of monetary policy behavior and our ignorance about it is required. That is, we will need to see RBC models that recognize and deal with the identification problem that is the source of the continuing disagreement about the effects of monetary policy.

But though this paper documents the robustness of multivariate time series facts that RBC modelers have not yet confronted, and though it shows that an informal monetarist/ISLM-style interpretation of them can go some way toward making sense of them, the paper also suggests that improved RBC-style modeling might eventually undercut some or all of the apparent support in the data for monetarist/ISLM interpretations. Much of what appears in small systems to be independent variation in monetary policy instruments is found in large systems to represent responses to disturbances that can be measured from knowledge of exchange rates and international commodity prices. Cleaning out these endogenous components of interest rate disturbances does not succeed in generating price responses to interest rate innovations that can comfortably be interpreted in the monetarist/ISLM framework. It thus remains possible that in a larger model, with a more detailed set of technology-related variables, we would find interest rate innovation effects on real variables almost entirely dwindling away.

5. A research agenda

It will be worthwhile to proceed further to study the statistical facts presented here. We have displayed no error bands about the estimated impulse responses, for which there is no excuse but time pressure. The models have been estimated independently across countries, except for the appearance of the same variable (international commodity prices) in each country's system. This is not only unsatisfying, it is logically inconsistent – we have five different equations for predicting the same variable. Though the cross-country correlations of innovations (not reported in the paper) are not large here, there can be little doubt that developments in different economies are related, and leaving *PC* as the only route for such linkage does not seem realistic. It is in principle possible that most of the apparent 'robustness' of these impulse responses across countries is simply a common component of sampling error. We cannot assess this possibility without a model that takes explicit account of international stochastic dependence.

The identification schemes used to interpret the data in this paper have relied mainly on postulating that innovations in a particular variable – short interest rates – represent monetary policy disturbances. Because our interpretations have been informal, we have been able to discuss qualitatively the possibility of contamination of this interpretation by non-policy components of interest rate innovations, but we have not used any model that takes formal account of this. Elsewhere [Sims (1986)], and in early stages of work on this paper, I have used formal 'identified VAR' frameworks that might be thought to be helpful here. It is worth noting that they turn out not to be very helpful here. The problem is that in these monthly data, correlations among innovations are so weak that the identified VAR framework gives poor results. Without going into detail, we can characterize the problem as like what would happen in a cross-section simultaneous equations model in which all exogenous and endogenous variables turned out to have approximately zero sample cross-correlations. No number of zero-restrictions on structural equations would in that case give identification. Exogenous variables would always turn out to be uncorrelated with the endogenous variables they might be used as instruments for.³

The plausibility of Wold-style identification, in which each structural equation is identified with a unique dependent variable, is increased by the

³It is perhaps worth noting that in work with quarterly U.S. data in a six-variable system, introduction of an identification scheme like that in my earlier paper [Sims (1986)] produced shifts in the responses to interest rate innovations very much like those displayed in fig. 10. With the quarterly data the correlation matrix of innovations is not so nearly diagonal, giving the identification scheme more to work with. However, the results with such schemes for other countries produced little new insight with the quarterly data. With the monthly data, there was in every case a likelihood maximum that very nearly treated each variable innovation as structural, but also other local maxima with nearly the same likelihood that were quite different.

near-diagonality of the innovation covariance matrix. If we believe that the U.S. Federal Funds Rate is for practical purposes directly controlled by the Federal Reserve from month to month, so that any change in monetary policy must impact it within the month, then the lack of correlation of interest rate innovations with contemporaneous innovations in other variables strengthens the case that they can be interpreted as policy shocks. Nonetheless this case can never be ironclad. It is always possible, e.g., that interest rate and money innovations emerge as uncorrelated because of the canceling effects of monetary policy shocks, which move interest rates and money in opposite directions, and money demand shocks, which move them in the same direction. One cannot study these possibilities without going beyond the framework of identification based on the contemporaneous impacts alone.

As already outlined in the previous section, this paper's results suggest an agenda of improvements in RBC modeling. Such modeling could combine the economic theoretical rigor of RBC models with the unblinkered confrontation of the data of identified VARs. But ideally there should be a similar movement from the monetarist/ISLM side of this discussion. It should be quite possible to formulate models with complete dynamics and explicit treatment of disequilibrium elements – workers who search rather than freely adjust their level of work effort, firms that advertise and adjust firm-specific wages rather than freely adjust their level of employment for example. If such a model could generate the monetarist/ISLM policy implications, while matching the facts of nominal as well as real aggregate fluctuations, it would provide a more direct challenge to the RBC models than existing informal appeals to time series facts.

Appendix

Below is a description of the data series. In each case the series is named and the identifying number of the series in the IMF publication *International Financial Statistics* is given.

Commodity price index

World export commodity price index. IFS 00176AXD

Exchange rates

The raw data were:

British Pounds per SDR. IFS 112...AA.

Yen per SDR. IFS 158...AA.

Deutsche Marks Per SDR. IFS 134...AA.

French Francs PER SDR. IFS 132...AA.

U.S. Dollars per SDR. IFS 111...SA.

The exchange rates actually used were, for each country except the U.S., the ratio of the SDR rate above to the U.S. SDR rate. For the U.S. the exchange rate was the ratio of the U.S. SDR rate to the average of the other four countries' SDR rates.

Industrial production

U.S. Industrial Production, SA. IFS 11166...C
 U.K. Industrial Production, SA. IFS 11266...C
 Japan Industrial Production, SA. IFS 15866...C
 Germany Industrial Production, SA. IFS 13466...C
 France Industrial Production, SA. IFS 13266...C

Price index

U.S. CPI. IFS 11164...
 U.K. CPI. IFS 11264...
 Japan CPI. IFS 15864...
 Germany CPI. IFS 13464...
 France CPI. IFS 13264...

M1

U.S. *M1*. IFS 11134...
 U.K. *M1*. IFS 11234...B
 Japan *M1*. IFS 15834...
 Germany *M1*. IFS 13434...
 France *M1*. Deterministic ssnl. adj. of (IFS 13234...) over 64:1–77:12, spliced to the official SA series (IFS 13234...C), for 77:12–90:2

Interest rate

U.S. Federal Funds Rate. IFS 11160B...
 U.K. Treasury Bill Rate. IFS 11260C...
 Japan Call Rate. IFS 15860B...
 Germany Call Rate. IFS 13460B...
 France Call Rate. IFS 13260B... 86:3–5 interpolated from (IFS 13260BS.)

References

- Friedman, Milton and Anna J. Schwartz, 1963, *A monetary history of the United States 1867–1960* (Princeton University Press, Princeton, NJ).
 Romer, Christine and Paul Romer, 1989, *Does monetary policy matter?: A new test in the spirit of Friedman and Schwartz*, NBER Macroeconomics Annual (NBER, Cambridge, MA).
 Sims, Christopher, 1971, *Money income and causality*, *American Economic Review*.
 Sims, Christopher, 1980, *Macroeconomics and reality*, *Econometrica*.

- Sims, Christopher, 1986, Are forecasting models usable for policy analysis?, Quarterly Review of the Federal Reserve Bank of Minneapolis.
- Sims, Christopher, 1989, Models and their uses, American Journal of Agricultural Economics.
- Tobin, James, 1970, Money and income: Post hoc ergo propter hoc? Quarterly Journal of Economics.
- Todd, Richard, 1991, Vector autoregression evidence on monetarism: Another look at the robustness debate, Quarterly Review of the Federal Reserve Bank of Minneapolis.