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DO MEASURES OF MONETARY POLICY IN A VAR MAKE SENSE?*

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No. In many vector autoregressions (VARs), monetary policy shocks are identified with the least squares residuals from a regression of the federal funds rate on an assortment of variables. Such regressions appear to be structurally fragile and are at odds with other evidence on the nature of the U.S. Federal Reserve's reaction function; furthermore, the residuals from these regressions show little correlation across various VARs or with funds rate shocks that are derived from forward-looking financial markets. My results provide a sharp critique of current monetary VARs.

1. INTRODUCTION

It is easy to quantify the effects of a monetary policy action with a complete structural model of the economy (e.g., Taylor 1993a). The lack of general agreement about the nature of these effects reflects the fact that there is no such consensus structural model. In response to this lack of consensus, much research has examined the effects of monetary policy using vector autoregressions (VARs), including Bernanke and Blinder (1992), Leeper and Gordon (1994), Christiano et al. (1996a, 1996b), and Bernanke and Mihov (1995). The great appeal of using VARs for studying monetary policy transmission is that they appear to be able to identify the effects of policy without a complete structural model of the economy.

Indeed, only a bare minimum of structural identifying assumptions are maintained for the recent monetary VAR analyses. Of these assumptions, the most important are those that allow endogenous monetary policy actions to be distinguished from exogenous ones. Endogenous (or reactive) policy responds to developments in the economy; exogenous (or autonomous) policy consists of all other actions. As stressed by Christiano et al. (1996a), without a complete structural model of the economy it is the response of variables to *exogenous* policy actions that must be examined in order to gauge the effects of monetary policy. This is because movements of the economy following an endogenous policy action may be due to the policy action itself or to the variable that spurred that action. Therefore, the separation of monetary policy

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actions into those that are endogenous and those that are exogenous is a crucial element in VAR analyses of the effects of monetary policy.

Since Bernanke and Blinder (1992), VARs have typically assumed that the federal funds rate is the instrument of monetary policy. Therefore, in recent VARs, the dissection of exogenous from endogenous monetary policy is determined essentially by an equation that regresses the funds rate on an information set that includes lags of the funds rate as well as lags and possibly contemporaneous values of the other variables in the VAR. The fitted values from this regression are the endogenous monetary policy actions; the residuals are the exogenous policy actions.

The literature has provided only cursory examinations of the VAR funds rate equations and their associated residuals; instead, the focus has been on impulse response functions. This is perhaps not surprising because most VAR equations do not have a clear structural interpretation. However, because the funds rate is under the direct control of the Federal Reserve as its operating instrument, there is a clear structural interpretation of a VAR funds rate equation as the Federal Reserve's reaction function and of its residuals as policy shocks. Such an interpretation is neither new nor in dispute—it is, for example, explicitly maintained in many of the VAR studies cited above. This interpretation has, however, been overlooked, and in this paper I will explore it in detail in order to assess the validity of standard VAR representations of monetary policy.

Two questions are at the heart of my investigation: "Does a standard VAR funds rate equation correctly model reactive Federal Reserve policy?" and "Do the residuals from this equation plausibly represent monetary policy shocks?" After describing a typical VAR model in the next section, I consider each of these questions in turn.

In Section 3, I examine whether the fitted values of VAR funds rate equations correctly model endogenous policy—that is, whether VAR funds rate equations make sense as representations of the Federal Reserve's reaction function in terms of functional form and information set. One benchmark for this evaluation is a large literature of non-VAR structural estimates of the Federal Reserve's reaction function. This literature, which has been completely ignored by VAR modelers, provides some insights into modeling Federal Reserve behavior. In addition, I consider the structural stability of VAR reaction functions, and I contrast their information set with the Federal Reserve's own descriptive record of its policy actions. Based on these and other analyses, the Federal Reserve reaction functions estimated in standard monetary VARs appear implausible and misspecified in many respects.

In Section 4, I consider whether the residuals from a monetary VAR's funds rate equation make sense. I focus on the interpretation of these residuals as unanticipated monetary policy shocks and examine them from the perspective of forward-looking financial markets. The futures market for federal funds rates provides very clear readings on expected future movements in the funds rate; thus, a measure of unanticipated policy shocks can be easily constructed. I find that the funds rate shocks from VARs have little in common with the funds rate shocks in financial markets. This low correlation provides a straightforward, intuitive measure of the importance of the misspecification problems in Section 3.

Indeed, the two investigations in Sections 3 and 4 examine two sides of the same coin. It seems unlikely that a VAR Federal Reserve reaction function can make sense unless its monetary policy shocks make sense and vice versa. However, the dual nature of my critique, which considers descriptive evidence and structural models of systematic Federal Reserve policy as well as information from financial markets on policy surprises, provides a forceful cross-*in*validation of recent monetary VAR models.

2. THE CHARACTERIZATION OF MONETARY POLICY IN A VAR

The VAR is a system of linear equations, one for each variable. In the reduced form, each equation specifies one of the variables as a linear function of its own lagged values as well as lagged values of the other variables in the system. Of interest here is the federal funds rate equation from recent VARs that study monetary policy,

$$FFR_t = \sum_{s=1}^{L} \hat{A}_s X_{t-s} + \hat{u}_t^{VAR}, \tag{1}$$

where FFR_t is the funds rate, X_t is an n-vector of variables (including the funds rate), and $\hat{A}_s$ is an n-vector of estimated coefficients. The linear function $\sum_{s=1}^{L} \hat{A}_s X_{t-s}$ can be considered a reduced-form reaction function for the Federal Reserve. It specifies predictable movements in the funds rate that are based on lagged information in X_t. The residuals $\hat{u}_t^{VAR}$ are the *unanticipated* monetary policy shocks or 'innovations' (or one-step-ahead forecast errors) of the VAR.

Of course, the residuals $\hat{u}_t^{VAR}$ may be correlated with the residuals (that is, the unanticipated shocks) of the other equations in the VAR. If this is the case, then assumptions must be made about the causal direction of this correlation in order to completely identify the monetary policy reaction function. For example, if it is assumed that the Federal Reserve sets the funds rate at time t based on commodity prices at time t, then contemporaneous commodity prices must be added to the regression to obtain the structural reaction function of the Federal Reserve.

With assumptions about Federal Reserve reactions to contemporaneous variables, the funds rate equation is:

$$FFR_t = \sum_{s=0}^{L} \hat{B}_s X_{1,t-s} + \sum_{s=1}^{L} \hat{C}_s X_{2,t-s} + \hat{e}_t^{VAR}, \tag{2}$$

where the vector of variables in X is split so that X_1 and X_2 are a p-vector and m-vector of variables (with $0 \leq p < n$, $0 < m \leq n$, and $p + m = n$).[2] X_1 contains those

[2] This discussion is based on a common type of identification scheme used in the monetary VARs, namely a Choleski decomposition. I view the protracted debate on VAR identification as tangential to my critique because recent 'structural VARs,' using alternative identification schemes, are also typically subject to all of the criticisms below.

variables that are ordered causally prior to the funds rate, so their contemporaneous values enter equation (2) as well as their lags. X_2 contains those variables ordered after the funds rate (and, of course, the funds rate itself), so it contains only lagged values. The residuals $\hat{e}_t^{VAR}$ are the estimated exogenous monetary policy shocks (the 'orthogonalized innovations') in the VAR. The linear function in (2) is a structural Federal Reserve reaction function that specifies the predictable movements in the funds rate that are based on contemporaneous and lagged information in X_t.

Examples of equations (1) and (2) are given in Table 1 at a monthly frequency, from a VAR in Christiano et al. (1996b), and in Table 2 at a quarterly frequency, from a VAR in Christiano et al. (1996a).[3] These reaction functions are typical of those estimated in the VAR literature. The first column of Table 1 gives the monthly, reduced form reaction function, which regresses the monthly average of the daily federal funds rate (*FFR*) on twelve lags of itself as well as on twelve lags each of the log of nonfarm payroll employment (*EMP*), the log of the implicit price deflator for consumption expenditures (*PCE*), the smoothed change in an index of commodity prices (*PCOM*), minus the log of nonborrowed reserves (*NBRD*), the log of total reserves (*TR*), and the log of M1 (*M1*). The second column gives the structural form assuming that the Federal Reserve reacts to employment (*EMP*) and prices (*PCE* and *PCOM*) in month t in setting the funds rate during that month; thus, column 2 adds the contemporaneous values of those three regressors to the reaction function.

Similarly, the first column of Table 2 gives a reduced form reaction function at a quarterly frequency that regresses the quarterly average of the federal funds rate (*FFR*) on four lags of itself as well as on four lags each of the log of real GDP (Y), the log of the GDP deflator (P), the quarterly average of smoothed monthly changes in an index of commodity prices (*PCOM*), minus the log of nonborrowed reserves (*NBRD*), and the log of total reserves (*TR*). For the quarterly structural form, the benchmark identification scheme assumes that the Federal Reserve reacts contemporaneously to output (Y) and prices (P and *PCOM*) in setting the funds rate, as in column 2.

Figures 1 and 2 plot the residuals from the equations in Tables 1 and 2, respectively. Note that for these VARs there is little difference between the unanticipated shocks (innovations) and the exogenous shocks (orthogonalized innovations)—the correlation between $\hat{u}_t^{VAR}$ and $\hat{e}_t^{VAR}$ is 0.98 at a monthly frequency and 0.92 at a quarterly frequency.

3. DO VAR INTEREST RATE EQUATIONS MAKE SENSE?

Very little attention is usually paid to the individual equations of any VAR; indeed, estimated VAR coefficients are never reported as in Tables 1 and 2. This lack of attention reflects the fact that typically VAR equations do not have a clear structural interpretation even in their 'structural' form. In contrast, *the interest rate*

[3] I have updated their data sample but otherwise have used their computer programs (kindly supplied by Charlie Evans) to produce the results below. Note that my definition of *PCOM*, although it differs from their textual description, is the one that they (and I) actually used.

TABLE 1
ESTIMATED COEFFICIENTS FROM VAR INTEREST RATE EQUATIONS
MONTHLY DATA (1960:1 TO 1995:3)

Variable	Reduced Form	Structural Form	Variable	Reduced Form	Structural Form
EMP{0}	...	0.357*	FFR{5}	0.082	0.081
PCE{0}	...	−0.175	FFR{6}	0.117	0.102
PCOM{0}	...	0.663*	FFR{7}	−0.225*	−0.227
			FFR{8}	0.202*	0.210
EMP{1}	0.303*	−0.100	FFR{9}	0.080	0.084*
EMP{2}	−0.211	−0.222	FFR{10}	−0.034	−0.057*
EMP{3}	−0.035	0.006	FFR{11}	−0.143	−0.123
EMP{4}	0.135	0.105	FFR{12}	0.127*	0.129
EMP{5}	−0.091	−0.004	NBRD{1}	0.053*	0.051
EMP{6}	−0.215	−0.229	NBRD{2}	−0.096*	−0.092*
EMP{7}	0.170	0.130	NBRD{3}	0.020	0.028*
EMP{8}	0.106	0.142	NBRD{4}	0.010	−0.001*
EMP{9}	0.008	−0.028	NBRD{5}	0.037	0.040
EMP{10}	−0.056	−0.010	NBRD{6}	−0.060*	−0.056
EMP{11}	−0.245	−0.276	NBRD{7}	0.001	0.005
EMP{12}	0.108	0.123	NBRD{8}	0.032	0.024*
PCE{1}	0.028	0.204	NBRD{9}	−0.014	−0.003
PCE{2}	0.190	0.197	NBRD{10}	0.002	−0.010
PCE{3}	−0.080	−0.128	NBRD{11}	−0.027	−0.016
PCE{4}	0.013	0.068	NBRD{12}	0.024	0.022
PCE{5}	−0.075	−0.042	TR{1}	−0.042	−0.024
PCE{6}	−0.013	−0.078	TR{2}	0.006	0.010
PCE{7}	0.006	0.016	TR{3}	−0.020	−0.009
PCE{8}	−0.190	−0.205	TR{4}	0.085	0.055
PCE{9}	−0.031	−0.016	TR{5}	−0.019	−0.008
PCE{10}	0.340*	0.384*	TR{6}	−0.003	0.020
PCE{11}	−0.247	−0.286	TR{7}	−0.051	−0.054
PCE{12}	0.056	0.076	TR{8}	0.051	0.045
PCOM{1}	0.537*	−0.741	TR{9}	−0.023	−0.021
PCOM{2}	−0.546	0.250	TR{10}	−0.053	−0.060
PCOM{3}	−0.148	−0.181	TR{11}	0.046	0.069
PCOM{4}	0.299	0.138	TR{12}	0.015	0.005
PCOM{5}	0.434	0.494	M1{1}	0.403*	0.379
PCOM{6}	−1.213*	−1.193*	M1{2}	−0.301*	−0.334
PCOM{7}	0.680	0.636	M1{3}	−0.109	−0.068*
PCOM{8}	0.608	0.599	M1{4}	−0.113	−0.130*
PCOM{9}	−0.738	−0.684	M1{5}	0.125	0.157
PCOM{10}	0.475	0.475	M1{6}	0.072	0.020
PCOM{11}	−0.605	−0.545	M1{7}	−0.303*	−0.283
PCOM{12}	0.398	0.336	M1{8}	0.337*	0.329
FFR{1}	1.243*	1.259*	M1{9}	−0.015	0.000*
FFR{2}	−0.313*	−0.334*	M1{10}	−0.025	−0.037*
FFR{3}	0.087	0.075	M1{11}	−0.193	−0.187
FFR{4}	−0.190*	−0.160*	M1{12}	0.124	0.117

Note: The numbers in brackets indicate the number of months that the variable is lagged. Starred coefficients are significant at the 10 per cent level.

TABLE 2
ESTIMATED COEFFICIENTS FROM VAR INTEREST RATE EQUATIONS
QUARTERLY DATA (1960:Q1 TO 1995:Q1)

Variable	Reduced Form	Structural Form
Y{0}	...	0.250*
P{0}	...	0.044
PCOM{0}	...	0.817*
Y{1}	0.262*	−0.074
Y{2}	−0.205	−0.142
Y{3}	0.051	0.115
Y{4}	−0.111	−0.157
P{1}	0.289	0.101
P{2}	0.173	0.393
P{3}	−0.781*	−0.979*
P{4}	0.321	0.438*
PCOM{1}	0.355	−0.772*
PCOM{2}	0.035	0.698*
PCOM{3}	0.009	−0.302
PCOM{4}	0.146	0.361
FFR{1}	0.991*	1.075*
FFR{2}	−0.339*	−0.330*
FFR{3}	0.389*	0.363*
FFR{4}	−0.094	−0.081
NBRD{1}	−0.013	−0.022
NBRD{2}	−0.039	−0.025
NBRD{3}	−0.003	−0.020
NBRD{4}	0.019	0.033
TR{1}	0.054	0.032
TR{2}	−0.143	−0.093
TR{3}	0.045	−0.004
TR{4}	0.008	0.037

Note: The numbers in brackets indicate the number of quarters that the variable is lagged. Starred coefficients are significant at the 10 per cent level.

equation in a monetary VAR does have a clear structural interpretation. Because the Federal Reserve directly controls the level of the funds rate, the VAR funds rate equation is a structural representation of the Fed's reaction function.[4,5] This interpretation of the funds rate equation is explicit, for example, in Christiano et al. (1996a), who call their estimated funds rate equation the "monetary authority's rule

[4] There are two qualifications to note. First, the Federal Reserve does allow transitory reserve market pressures to affect the daily market funds rate somewhat; that is, there is not a complete peg of rates, but close to it. Second, during the postwar period, the Federal Reserve has varied the importance it has placed on the funds rate as an operating instrument. See Rudebusch (1995) for details.

[5] This interpretation is not valid for the previous vintage of monetary VARs, which used broad measures of money to model monetary policy rather than the funds rate. Movements in broad monetary aggregates, even on a quarterly basis, were not completely determined by the Federal Reserve. The existence of these antecedent money VARs is likely part of the reason why the structural nature of the funds rate equation in current VARs has not been fully appreciated.

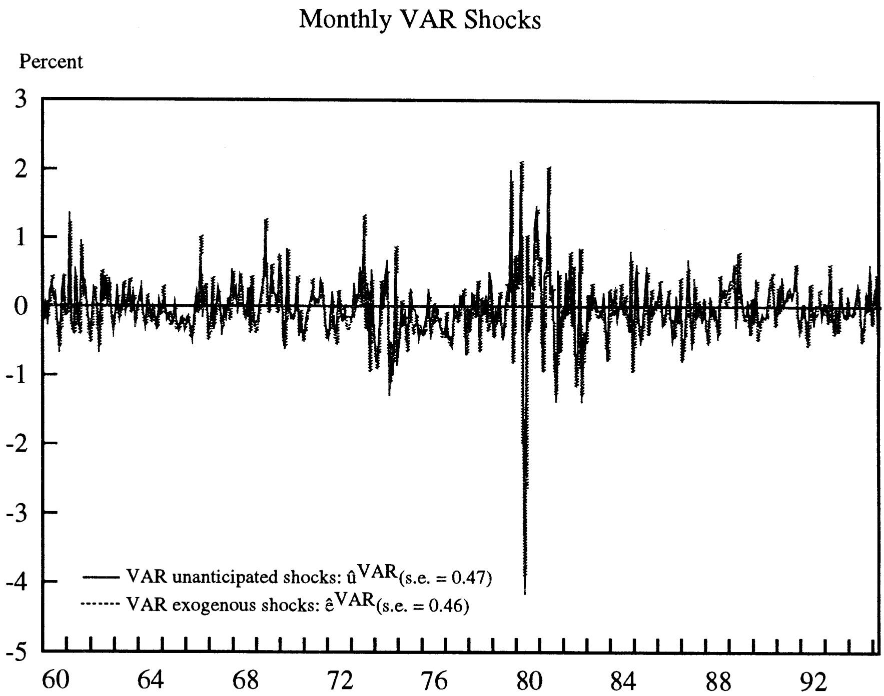

FIGURE 1

for setting [the policy instrument]," and in Bernanke and Blinder (1992, p. 991), who call it an estimated "policy reaction function."

As a structural reaction function, the VAR's funds rate equation can be directly examined econometrically for structural stability and misspecification, and it can be compared to the large number of non-VAR structural Federal Reserve reaction functions that have been estimated and to other descriptions of Federal Reserve behavior. Such an analysis highlights several shortcomings of the standard VAR reaction function: (1) a time-invariant, linear structure, (2) a restricted information set, (3) the use of final, revised data, and (4) long distributed lags. These problems are each described below in turn.

3.1. *A Time-Invariant, Linear Structure.* The typical VAR reaction function, as illustrated in Tables 1 and 2, imposes a simple constant linear structure on several decades of Federal Reserve behavior. In contrast, the temporal instability of such empirical Federal Reserve reaction functions is now taken for granted in the non-VAR literature on reaction functions. Recent estimated non-VAR reaction functions are limited to very short samples to explicitly account for different structural regions (as in McNees 1992, Hakkio and Sellon 1994, Judd and Rudebusch 1998, and Clarida et al. 1997). To even a casual observer of the Federal Reserve, such instability is not surprising. Over time, the members of the Federal

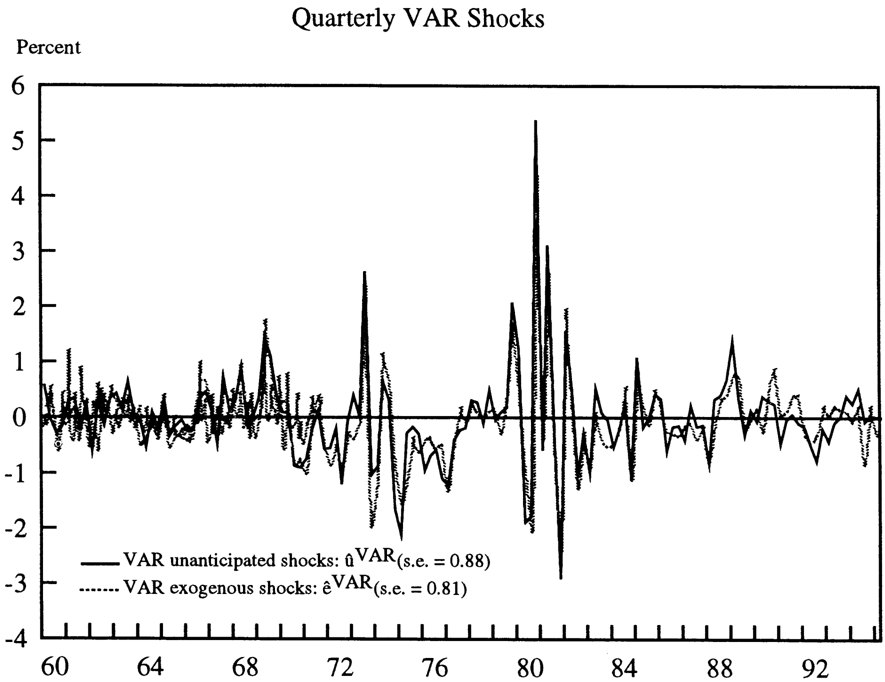

FIGURE 2

Open Market Committee (FOMC) change, and because of the new attitudes and abilities, there are changes in the Federal Reserve's response to a given economic environment. There are also changes in the structure of the economy that necessitate changes in the reaction function; thus, for example, a given movement in M1 today may have a different implication for the economy, and hence for the Federal Reserve, than it did in the 1980s.

These structural changes suggest that simple time-invariant linear monetary VARs are misspecified.[6] Indeed, the monthly and quarterly structural reaction functions in Tables 1 and 2 do exhibit fragile coefficients across various sub-periods. For example, a Chow test rejects the null of structural stability at the sample midpoint for all of the reaction functions at a significance level well below the 1 per cent critical value. A similar result is obtained, without the a priori selection of a breakpoint, using the maximum F-Statistic test of Andrews (1993). Such a test conducted over the middle 40 per cent of the sample rejects the null of structural

[6] This is consistent with the conclusions of Brunner (1994), McCarthy (1995), and Stock and Watson (1996). Of course, not all preference shocks invalidate (VAR or non-VAR) estimates of reaction functions. As in Bernanke and Mihov (1996), mean-zero i.i.d. period-by-period taste shocks may simply translate into estimated residuals.

stability at the 5 per cent level (using a small-sample distribution obtained via monte carlo simulation).[7]

It also appears that these statistical rejections are significant in economic terms. To demonstrate the importance of such instability, it is illuminating to compare the full-sample VAR reaction function to a reaction function estimated over a shorter sample.[8] An obvious candidate reaction function at a quarterly frequency is one of the type proposed by Taylor (1993b), which is widely acknowledged to be a good approximate description of how the Federal Reserve has actually set policy under Chairman Alan Greenspan. (See Judd and Rudebusch 1998, and Taylor 1997.)

The Taylor rule simply relates the funds rate to the real output gap (in essence, the level of detrended output) and to the four-quarter inflation rate. Estimates of this reaction function are shown in the second column of Table 3, while estimates of the quarterly VAR reaction function are shown in the first column for comparison. (In this table, the variable Y refers to detrended output rather than output, a change that appears to be negligible in terms of the VAR estimates.) As the distribution of significant coefficients in Table 3 suggests, the estimated Taylor reaction function and the VAR reaction function are completely different representations of the endogenous part of monetary policy. According to the estimated Taylor reaction function, the Federal Reserve responds exclusively to contemporaneous output (with a coefficient of 0.7) and to the four-quarter difference in the log aggregate price level (with a coefficient of 1.8). (For comparison, the original coefficients in Taylor (1993b) were 0.5 for output and 1.5 for inflation.) The VAR reaction function has a significant response to many other variables as well as a very weak inflation response. The estimated Taylor Rule and VAR descriptions of Federal Reserve policy over the past decade ostensibly appear unreconcilable.

One way to demonstrate the differences between the two reaction functions is to examine their implied dynamics given the full VAR system. The full quarterly VAR is a system of six equations—one for each of the variables in Table 3. There are six separate exogenous shocks in the system and hence 36 separate impulse responses that summarize the dynamics of the system: one for each combination pair of variables. Figure 3 displays just one of these impulse responses: the response of the funds rate to a price shock, which as noted in Bernanke and Blinder (1992), provides information on the Federal Reserve reaction function. The dashed line in Figure 3 provides the impulse response from the full VAR with the VAR reaction function and the dotted lines give the 95 per cent confidence interval. The solid line is the impulse response from a system that replaces the VAR reaction function in the full VAR system with the estimated Taylor rule. The substitution of this one equation in the system induces large changes in the dynamics of the system. Not surprising given Table 3, the Federal Reserve responds more strongly (and more plausibly for the Greenspan era) to an aggregate price shock in the estimated Taylor rule system than

[7] The heteroskedasticity of the residuals, which is evident in Figures 1 and 2, is another type of misspecification that can seriously affect the estimated VAR coefficients.

[8] Balke and Emery (1994a, 1994b) also calculate very different impulse responses for the same VAR estimated over different sub-samples.

TABLE 3
COMPARISON OF VAR AND TAYLOR FED REACTION FUNCTIONS
QUARTERLY DATA

Variable	Structural VAR Form with Output Gap	Taylor Rule
Constant	4.481	0.412
Y{0}	0.441*	0.677*
P{0}	−0.005	1.784*
PCOM{0}	0.782*	...
Y{1}	−0.087	...
Y{2}	0.059	...
Y{3}	−0.074	...
Y{4}	−0.019	...
P{1}	0.115	...
P{2}	0.714*	...
P{3}	−0.841*	...
P{4}	0.032	−1.784*
PCOM{1}	−0.545	...
PCOM{2}	0.700*	...
PCOM{3}	−0.293	...
PCOM{4}	0.279	...
FFR{1}	0.571*	...
FFR{2}	0.095	...
FFR{3}	0.089	...
FFR{4}	0.278*	...
NBRD{1}	−0.215*	...
NBRD{2}	0.247*	...
NBRD{3}	−0.055	...
NBRD{4}	0.012	...
TR{1}	0.272*	...
TR{2}	−0.329*	...
TR{3}	0.124	...
TR{4}	−0.061	...
s.e. of residuals (65:3−95:1)	0.714	...
s.e. of residuals (87:4−95:1)	0.487	0.477
Estimation Period	65:3−95:1	87:4−95:1

Note: The numbers in brackets indicate the number of quarters that the variable is lagged. Starred coefficients are significant at the 10 per cent level.

in the VAR system. Thus, conclusions about VAR impulse responses are not robust to plausible structural shifts in the assumed reaction function.[9]

3.2. *The Scope of the Information Set.* There has been much debate in the literature about which variables should be included in a monetary VAR. For example, Christiano et al. (1996a, 1996b) argue that commodity prices were a crucial input for monetary policy and must be included in a properly specified VAR, while others have disagreed. Most surprisingly, this debate has not considered the statistical significance of the variables; indeed, most of the regressors in Tables 1 and 2 are

[9] Very similar results are also obtained using the estimated Taylor rule in Judd and Rudebusch (1998) for the Greenspan period that accounts for more lagged interest rate dynamics. Also, see Rudebusch and Svensson (1998).

Response of Funds Rate to Price Shock

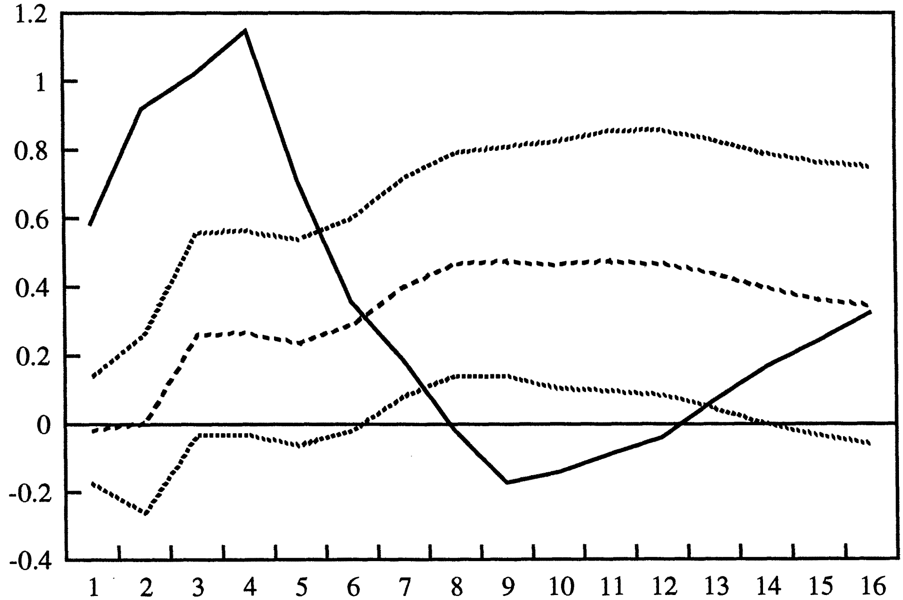

FIGURE 3

THE IMPULSE RESPONSE FOR THE FULL VAR IS SHOWN AS THE SHORT-DASHED LINE AND ITS 95 PERCENT CONFIDENCE INTERVAL IS DELINEATED BY DOTTED LINES. THE IMPULSE RESPONSE OF THE VAR WITH THE ESTIMATED TAYLOR RULE USED IN PLACE OF THE VAR REACTION FUNCTION IS SHOWN AS THE SOLID LINE.

insignificant even at the 10 per cent level.[10] Beyond statistical significance, there are two sources that can illuminate the range of variables important for Federal Reserve decisions.

First, there is the long list of regressors that have been used in various non-VAR empirical structural reaction functions. For example, some of the reaction functions in Khoury's (1990) survey include as significant determinants of policy such non-VAR variables as the foreign trade deficit, the stance of fiscal policy, and measures of political pressure.[11]

[10] Of course, multicollinearity among various lags of the same variable will reduce these individual significance levels. Still, it is noteworthy that exclusion tests can eliminate all of the lags of about half the variables in these tables.

[11] It is quite surprising that the VAR analyses have completely ignored the non-VAR empirical reaction functions when the two literatures are *estimating the same object*: the endogenous response of policy. For example, if a well-specified, stable non-VAR Federal Reserve reaction function equation had an R^2 of 0.8 and the VAR reaction function had an R^2 of 0.6, then clearly part of what the VAR treated as exogenous policy was really endogenous and, by the arguments given in the introduction, the VAR analysis would be unreliable.

Second, there is much untapped evidence from official records and verbatim transcripts of the FOMC meetings (cf. The 'narrative' approach) about which variables the Federal Reserve itself considered to be important factors in the determination of monetary policy. For example, in 1987, according to its official policy operating directives, the FOMC focused quite closely on the value of the dollar, at first, and then, later in the year, on the value of the stock market and general financial liquidity (see Heller 1988). These endogenous policy reactions to financial markets, though obvious at the time, are generally excluded from VARs.[12]

3.3. *Use of Final, Revised Data.* With all the attention given to the number and ordering of the variables in VARs, it is surprising that there has been so little consideration of the fact that the monetary VARs actually use far too much information on the variables they do include. The VARs are estimated using final, revised data unavailable to the FOMC at the time of its decisions. In real time, policymakers had to rely on initial releases and preliminary data and could not use final estimates.[13]

To see the potential importance of this issue, assume that the final estimate of output in quarter t, Y_t^F, is only available with a one-quarter lag (that is, in period $t+1$). A preliminary estimate is available in quarter t as Y_t^P. The revision from the preliminary to final estimate, w_t, is defined by

$$Y_t^F = Y_t^P + w_t. \tag{3}$$

Now, consider a simple quarterly reaction function in which the Federal Reserve responds to the preliminary estimate of the current quarter's output, Y_t^P, the final estimate of last quarter's output, Y_{t-1}^F, and last quarter's funds rate (which is measured without error):

$$FFR_t = \alpha Y_t^P + \beta Y_{t-1}^F + \delta FFR_{t-1} + e_t. \tag{4}$$

A bivariate output-funds rate VAR with one lag and with output ordered first will correctly model the form of this reaction function. However, if the econometrician uses the final estimates of the data, the estimated VAR structural funds rate equation is

$$FFR_t = \hat{\alpha} Y_t^F + \hat{\beta} Y_{t-1}^F + \hat{\delta} FFR_{t-1} + \hat{e}_t^{VAR} \tag{5}$$

or

$$FFR_t = \hat{\alpha} Y_t^F + \hat{\beta} Y_{t-1}^F + \hat{\delta} FFR_{t-1} + (e_t - \hat{\alpha} w_t). \tag{6}$$

In this simple example, much depends on the properties of the revision. If one assumes that the statistical agency producing the initial estimate processes all

[12] See Braun and Mittnik (1993) for a general analysis of such misspecification.

[13] As an example of how important this distinction can be in another context, see Diebold and Rudebusch (1991). For non-VAR structural reaction function studies that confront this issue, see McNees (1986, 1992). For a careful formal analysis, see Maravall and Pierce (1986).

available information efficiently, then w_t will be uncorrelated with Y_t^P but correlated with Y_t^F. In this case, the VAR's regression disturbance is now correlated with one of its regressors. Thus, the classic results from the errors-in-variables model suggest that all of the estimated coefficients in (5) will be biased and inconsistent. Bernanke and Mihov (1996) independently describe a problem similar to the above; however, they assume that the statistical agency's revision process is inefficient and, in effect, simply adds 'noise' to the *final* estimate to obtain the *preliminary* estimate. In this case, w_t is correlated with Y_t^P but uncorrelated with Y_t^F, and the coefficients will be estimated consistently (although potentially with great variance).

Thus, the efficient 'news' or added 'noise' nature of the revision process is crucial for the consistency of VAR estimates. The available evidence (e.g., Mankiw and Shapiro 1986 or Diebold and Rudebusch 1987) suggests that the relevant data revisions do contain a substantial amount of efficient forecast error ('news'), which suggests that the coefficient estimates of the VAR are inconsistent. This is especially true given that the data 'revisions' implicit in VARs are substantially more than mere statistical updating. Equation (5), as is typical of most VARs, assumes that contemporaneous output is available for setting the interest rate. In fact, the *initial* estimate of a given quarter's GDP is released one month after that quarter has ended. Thus, the Y_t^P in equation (4) must be a forecast, and the 'revision' w_t, which is the difference between the *forecasted* value and the final estimate, is especially likely to behave like an efficient forecast error.

Not only are statistical revisions and forecast errors in w_t but definitional revisions are contained there as well. The Federal Reserve reaction functions in VARs are often estimated using variables that have been redefined ex post or did not even exist during the historical period being modeled. For example, Bernanke and Blinder (1992) use an experimental version of the consumer price index that was not available until after the end of their estimation sample, while Bernanke and Mihov (1995) reconstruct their own monthly output and price variables ex post using the entire sample of data. Diebold and Rudebusch (1991) provide an example of how definitional revisions can be crucial; namely, they find no predictive information in the index of leading indicators in 'real-time' but significant information in the final, revised figures (after the index components had been reselected).

3.4. *Long Distributed Lags*. There is one last feature of interest rate equations in typical VARs that suggests that they misrepresent endogenous policy. About half of the significant coefficients in the *reduced form* VAR reaction functions in Tables 1 and 2 are for variables that are lagged four months or more. Taken literally, these *reduced form* VAR equations indicate that the Federal Reserve reacts systematically to old information. Such a reaction function would imply predictable variation in the funds rate at horizons of more than three months. This contradicts a large literature, surveyed in Rudebusch (1995), that has found essentially no information in the term structure for predicting short-term interest rates beyond a horizon of about three months. This suggests that many of the significant *reduced form* coefficients in Tables 1 and 2 may be the spurious result of in-sample data fitting (or of serially correlated omitted variables). For example, the coefficient on the sixth lag of *PCOM* in the reduced form regression in Table 1 is most certainly spurious.

For the *structural form* coefficients in Tables 1 and 2, *which include contemporaneous variables as well as lagged ones,* the situation is less clear-cut. As an example, assume z_t is a random walk that responds to contemporaneous *news* about other variables. While the regression of the change in z_t on *only lags* of other variables (as in the reduced form regressions above) must in population result in insignificant coefficients, that is not the case when lagged *and* contemporaneous values of other variables are included. If, for example, z_t responds to news about an autocorrelated production series, Y_t, then a regression of z_t on its own lag and the contemporaneous and lagged values of Y_t will result in significant contemporaneous and lagged coefficients on Y_t. Essentially, the difference between the current value of production and the distributed lags of production provides a measure of the current news about production. While this scenario is a theoretical possibility, the type of autoregressive processes needed to support the estimated structural form coefficients in Tables 1 and 2 suggests that this is a highly unlikely explanation. For example, the significant coefficient on the tenth lag of the consumption price in Table 1, even though the contemporaneous value of this variable is insignificant, again suggests a spurious regression.

4. DO VAR INTEREST RATE SHOCKS MAKE SENSE?

The flip side of the question as to whether VAR funds rate fitted values make sense is whether VAR funds rate shocks make sense. One obvious consideration is the mutual consistency of shocks among VARs. However, this section also judges VAR shocks from the independent perspective of forward-looking financial markets. Unanticipated movements in the funds rate can be easily identified using financial market expectations for future rates. Financial markets, in forming these expectations (assuming rationality), will account for a time-varying or nonlinear structure for the Federal Reserve reaction function, will incorporate all the relevant informational variables, and will use only the contemporaneous, real-time data available to the Federal Reserve. That is, the criticisms of VAR reaction functions leveled in the previous section cannot be readily applied to market-derived definitions of reactive and unanticipated Federal Reserve policy actions. Accordingly, if the above criticisms are important, there should be a large divergence between VAR shocks (which would be based on a faulty structure) and market-based shocks.

The focus of this section is primarily on judging the $\hat{u}_t^{VAR}$ rather than the $\hat{e}_t^{VAR}$. Although they are not as prominent in the VAR literature, the $\hat{u}_t^{VAR}$ are arguably as important as the $\hat{e}_t^{VAR}$. Indeed, it is hard to imagine that one could get the unanticipated shocks wrong (the $\hat{u}_t^{VAR}$), but still get the exogenous unanticipated shocks right (the $\hat{e}_t^{VAR}$). (Also, for the VAR in Figures 1 and 2, it appears that the latter are simply a modestly orthogonalized version of the former.) As the discussion in Section 2 makes clear, the measurement of the $\hat{u}_t^{VAR}$, unlike the $\hat{e}_t^{VAR}$, does not depend on the particular VAR identification scheme used. Thus, any criticisms of the $\hat{u}_t^{VAR}$ are robust to whether the funds rate is ordered first or last or whether a structural VAR identification scheme is used instead.

4.1. *Construction of Shocks from Financial Market Data.* Unanticipated shocks to the funds rate could be constructed from various forward-looking financial market series, including Treasury bill rates or quotes on Eurodollar futures. I use rates from federal funds futures (FFF) contracts because they provide expectations about the funds rate that are relatively unclouded by time-varying term premia or non-federal-funds-market idiosyncratic movements. Most importantly, unlike any other series, these futures contracts are bets about the monthly average of the daily funds rate, which is precisely the interest rate series that enters most VARs.[14] The disadvantage of using FFF rates is that the underlying contracts were first traded in late 1988, but based on Figures 1 and 2, the sample period following this date does not appear to be atypical.

The hypothesis that short-term interest rate futures are efficiently priced has much support in the literature.[15] As evidence of the unbiased nature of the FFF rates, it is instructive to run the usual forecast evaluation regression of actual on expected. Let $FFF1_{t-1}$ be the FFF market's one-month-ahead expected funds rate as of the end of period $t-1$.[16] The regression of the actual funds rate on this expected rate (with standard errors in parentheses) yields:

$$FFR_t = \underset{(0.0463)}{-0.04641} + \underset{(0.0074)}{1.0003}\ FFF1_{t-1}; \quad R^2 = 0.996; \quad 1988{:}10\text{–}1995{:}3.$$

There is no significant bias, the slope coefficient is insignificantly different from one, and the residuals are serially uncorrelated (for example, the Durbin–Watson statistic equals 1.83).[17] Based on this regression and the support for efficiency in the literature, I construct the FFF market one-month-ahead unanticipated policy shocks simply as $\hat{u}_t^{FFF} \equiv FFR_t - FFF1_{t-1}$.

Likewise, $FFF2_{t-2}$ and $FFF3_{t-3}$, the two-month- and three-month-ahead forecasts of FFR_t (also measured at the end of the month), appear unbiased:

$$FFR_t = \underset{(0.0789)}{-0.1198} + \underset{(0.0126)}{1.0051}\ FFF2_{t-2}; \quad R^2 = 0.988; \quad 1988{:}11\text{–}1995{:}3,$$

$$FFR_t = \underset{(0.1187)}{-0.1720} + \underset{(0.0190)}{1.0045}\ FFF3_{t-3}; \quad R^2 = 0.974; \quad 1988{:}12\text{–}1995{:}3.$$

Thus, the one-*quarter*-ahead *anticipated* rate can be constructed as the average of the one-month-, two-month-, and three-month-ahead expected rates all measured as

[14] Quarterly VARs typically use the quarterly average of the daily funds rate. See Carlson et al. (1995) for a discussion of the FFF market.

[15] For example, Krueger and Kuttner (1996, p. 878) conclude that the FFF market "...efficiently incorporates virtually all publicly available quantitative information that can help forecast changes in the Funds rate."

[16] Results essentially identical to those below were obtained using FFF rates measured at the middle of the month. As stressed in Section 3.3, the actual timing (especially within the month) of the information set of a typical VAR is completely indeterminate.

[17] If *FFR* and *FFF1* are integrated, this regression tests whether their cointegrating factor is one, a necessary but not sufficient condition for efficient forecasts. For this case, the evidence of no residual serial correlation is crucial, a fact also supported in Figure 3, where the forecast error, $\hat{u}_t^{FFF} \equiv FFR_t - FFF1_{t-1}$, is shown and appears to be white noise. In addition, similar results to this regression and the following two, are obtained by regressing the *change* in the funds rate on the anticipated *change* in the funds rate. I prefer the levels regression for the reasons outlined in Giorgianni (1996).

of the end of the previous quarter. Accordingly, I construct one-quarter-ahead *unanticipated* policy shocks at a quarterly frequency from the monthly data as

$$\hat{u}_q^{FFF} \equiv (FFR_t + FFR_{t+1} + FFR_{t+2} - FFF1_{t-1} - FFF2_{t-1} - FFF3_{t-1})/3$$

where quarter q contains months t, $t+1$, and $t+2$.

Finally, I also made an attempt to construct *exogenous* policy shocks, $\hat{e}_t^{FFF}$, from the monthly $\hat{u}_t^{FFF}$. Recall that the $\hat{u}_t^{FFF}$ are surprises relative to information through the end of month $t-1$ but may reflect endogenous policy responses to news about the economy that arrives during month t. In construct $\hat{e}_t^{FFF}$ by regressing the $\hat{u}_t^{FFF}$ on the month-t news about nonfarm payroll employment, which is probably the most important single monthly indicator of economic activity. This news, $EMPNEWS_t$, is defined as the difference between the initial estimate of the change in nonfarm payroll employment from month $t-2$ to $t-1$, which is released close to the start of month t, and the median expectation of that change, which is from a Money Market Services survey taken near the end of period $t-1$.[18]

There is some evidence that the payroll employment numbers were, at times, a key factor in determining the Federal Reserve's policy actions (Cook and Korn 1991). Indeed, eight of the 43 changes in the Federal Reserve's funds target rate during my sample occurred on release dates for the employment data.[19] However, the linear regression of the policy innovation on employment news yields fairly modest results (with a p-value of 0.07 on the significance of $EMPNEWS_t$):

$$\hat{u}_t^{FFF} = \underset{(0.017)}{-0.040} + \underset{(0.00015)}{0.00028}{}^{*} EMPNEWS_t + \hat{e}_t^{FFF}; \qquad R^2 = 0.043; \;\; 1988{:}10\text{–}1995{:}3.$$

The size of the coefficient is also small in economic terms: The maximum observation (in absolute value) of *EMPNEWS* is 320 (in thousands of workers), which translates into a change in the funds rate of just under 10 basis points. Still, the $\hat{e}_t^{FFF}$ go part of the way to orthogonalizing the $\hat{u}_t^{FFF}$. Attempts at further orthogonalizing the $\hat{u}_t^{FFF}$ with news on other variables were not fruitful.[20] Also, I did not model $\hat{e}_t^{FFF}$ at a quarterly frequency because I lacked the requisite two-month- and three-month-ahead forecasts of economic variables.

4.2. *Comparison of Financial Market and VAR Shocks.* How well do the VAR shocks and the futures market shocks match? At a monthly frequency, Figure 4 displays the innovations $\hat{u}_t^{FFF}$ and $\hat{u}_t^{VAR}$, and Figure 5 displays the exogenous shocks $\hat{e}_t^{FFF}$ and $\hat{e}_t^{VAR}$. There is little apparent fit. Most notably, in early 1989 and again during 1991, the VAR shocks indicate large unanticipated and large exogenous policy tightenings that were not present in the futures markets. There is also an obvious difference in the sizes of the shocks. Standard errors for the shocks

[18] I thank Athanasious Orphanides for supplying these data.

[19] These dates (based in part on Rudebusch 1995) are July 7, 1989, December 7, 1990, February 1, 1991, March 8, 1991, December 6, 1991, July 2, 1992, September 4, 1992, and February 4, 1994.

[20] This may reflect two inadequacies in the measure of news. First, surprises to the market may not be surprises to the Federal Reserve. Second, my data set contains only initial release surprises, so informative revisions to earlier months are not accounted for.

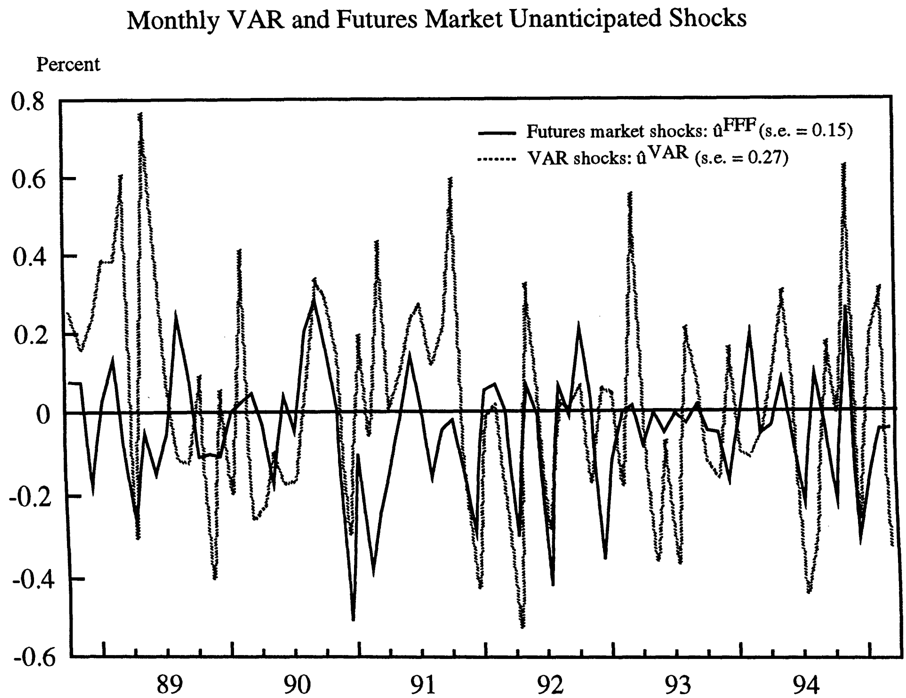

FIGURE 4

(calculated from 1988:10 to 1995:3) are given in parentheses in the figures. The VAR shocks, which are almost twice as volatile as the FFF shocks, give a much greater role to unanticipated movements in monetary policy than do futures markets. As shown in Figure 6, at a quarterly frequency, the story is much the same with wide divergences between the VAR and FFF shocks, particularly at the beginning of 1989 and 1991.

To provide some formal measures of fit, I regressed the VAR shocks on the associated FFF shocks. At a monthly frequency, these regressions yielded

$$\hat{u}_t^{VAR} = \underset{(0.03)}{0.07} + \underset{(0.20)}{0.57}\, \hat{u}_t^{FFF}; \quad R^2 = 0.10; \quad 1988{:}10\text{–}1995{:}3,$$

$$\hat{e}_t^{VAR} = \underset{(0.03)}{0.05} + \underset{(0.21)}{0.56}\, \hat{e}_t^{FFF}; \quad R^2 = 0.08; \quad 1988{:}10\text{–}1995{:}3.$$

At a quarterly frequency, this regression is

$$\hat{u}_t^{VAR} = \underset{(0.08)}{0.16} + \underset{(0.34)}{0.92}\, \hat{u}_t^{FFF}; \quad R^2 = 0.23; \quad 1988{:}Q4\text{–}1995{:}Q1.$$

The statistic of note is the very low R^2 of these regressions. Assuming the FFF markets accurately measure policy shocks, then movements in these 'true' shocks

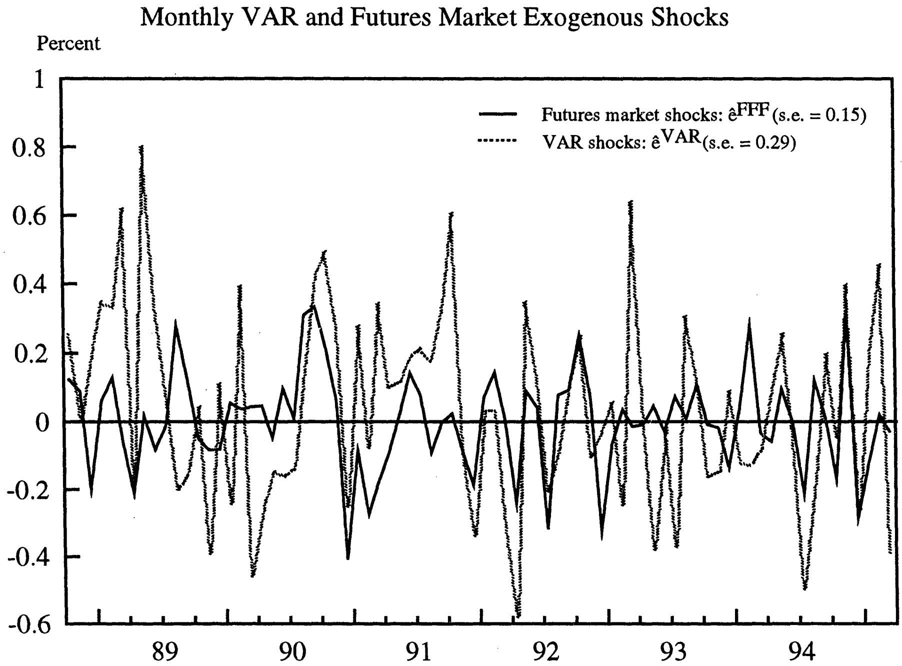

FIGURE 5

account for only about 10 to 20 per cent of the variation in the VAR shocks. That is, most of the variation in VAR funds rate residuals appears unrelated to financial market perceptions of monetary policy shocks.

4.3. *Comparing Shocks Among VARs*. In order to ensure that my results are not specific to the particular VAR that I have estimated, I examined the monetary policy innovations and exogenous shocks from several other VARs in the literature as well. These can be compared to the benchmark financial market series as well as contrasted with each other.

First, at a monthly frequency, I examined the exogenous funds rate shocks from a VAR (their model B) in Bernanke and Mihov (1995).[21] Their VAR shocks, denoted $\hat{e}_t^{BM}$, displayed a low correlation with the financial market shocks

$$\hat{e}_t^{BM} = \underset{(0.01)}{0.00} + \underset{(0.08)}{0.19}\ \hat{e}_t^{FFF}; \quad R^2 = 0.08; \quad 1988{:}11\text{–}1994{:}3,$$

as well as surprisingly little correlation with the original VAR shocks

$$\hat{e}_t^{BM} = \underset{(0.01)}{-0.01} + \underset{(0.04)}{0.12}\ \hat{e}_t^{VAR}; \quad R^2 = 0.12; \quad 1988{:}11\text{–}1994{:}3.$$

[21] I am grateful to Illian Mihov for supplying these shocks.

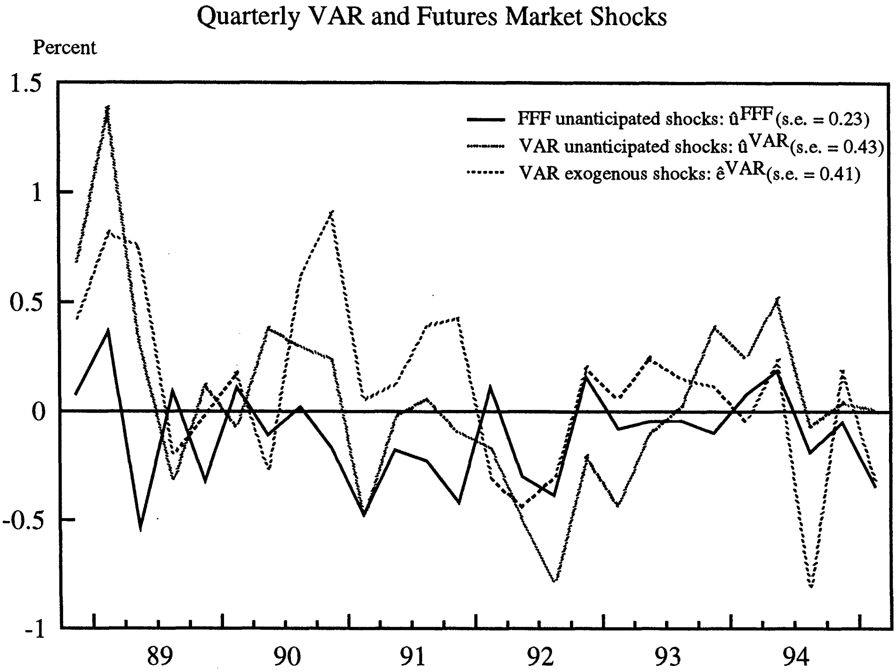

FIGURE 6

Similar results are obtained at a quarterly frequency with two other VAR innovations in the literature. Figure 7 displays the unanticipated shocks from VARs in Christiano et al. (1997), denoted $\hat{u}_t^{CEE}$, and Sims and Zha (1995), denoted $\hat{u}_t^{SZ}$.[22] The lack of correlation between these innovations and unanticipated shocks in the futures market as well as their modest mutual correlation is documented by the regressions:

$$\hat{u}_t^{CEE} = \underset{(0.10)}{0.10} + \underset{(0.40)}{0.71}\ \hat{u}_t^{FFF}; \quad R^2 = 0.12; \quad 1988{:}Q4\text{–}1995{:}Q1,$$

$$\hat{u}_t^{SZ} = \underset{(0.10)}{0.08} + \underset{(0.39)}{0.76}\ \hat{u}_t^{FFF}; \quad R^2 = 0.14; \quad 1988{:}Q4\text{–}1995{:}Q1,$$

$$\hat{u}_t^{SZ} = \underset{(0.08)}{-0.01} + \underset{(0.17)}{0.55}\ \hat{u}_t^{CEE}; \quad R^2 = 0.31; \quad 1988{:}Q4\text{–}1995{:}Q1.$$

Obviously, these three series give very different interpretations of the history of monetary policy surprises, and in several periods, the VAR series describe a stance for monetary policy that is greatly at variance with historical accounts. For example, consider the 1993:Q4 observation in Figure 7 (marked by an asterisk). At the beginning of this quarter, the real funds rate was close to zero (as it had been for

[22] I am grateful to Charlie Evans for supplying the shocks from these VARs.

Sims-Zha and Christiano-Eichenbaum-Evans
Quarterly VAR and Futures Market Unanticipated Shocks

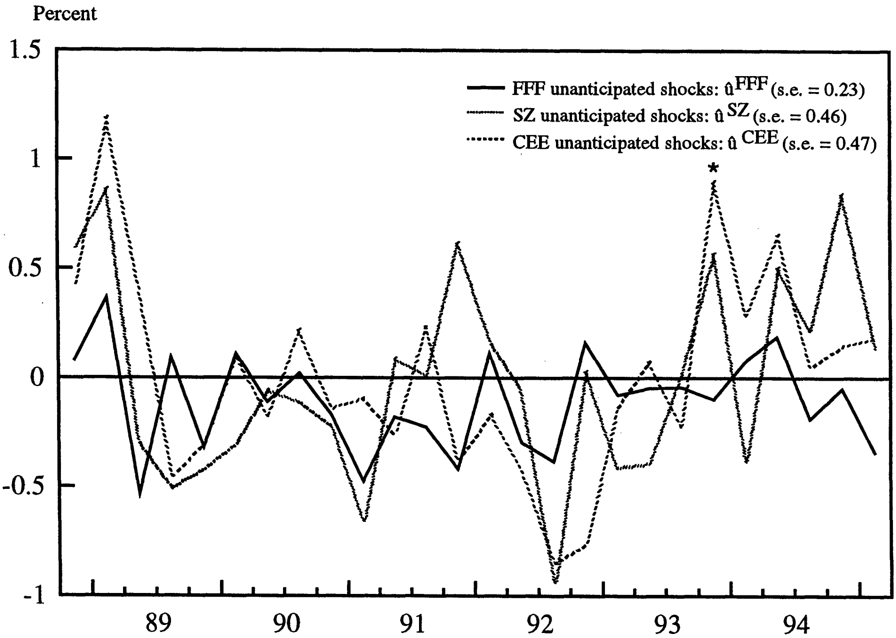

FIGURE 7

about a year), and there was general agreement that the nominal and real funds rate would have to be increased at some point (see Pakko 1995). As it turned out, in fact, the Federal Reserve's nominal funds rate target did not change in 1993:Q4. Instead, it remained at 3 per cent, where it had been since the fall of 1992. This scenario is consistent with the observed FFF surprise, which indicates a small unanticipated shock as to the how *loose* policy was in the fourth quarter—on the order of about 9 basis points. The VARs, however, record policy in 1993:Q4 as unexpectedly extremely *tight*. For example, the Christiano et al. VAR has an 80 basis point positive innovation to the funds rate in that quarter. Such an interpretation of history seems completely implausible.

Finally, it is interesting to compare the quarterly exogenous shocks of the CEE and SZ VARs. These are denoted $\hat{e}_t^{CEE}$ and $\hat{e}_t^{SZ}$ and are shown in Figure 8. The regression of one on the other gives

$$\hat{e}_t^{CEE} = \underset{(0.10)}{0.06} + \underset{(0.11)}{0.01}\, \hat{e}_t^{SZ}; \quad R^2 = 0.00; \quad 1988{:}Q4\text{–}1995{:}Q1.$$

That is, there is no correlation between these two measures of monetary policy shocks.

4.4. *Consequences of Mismeasured Shocks.* The fact that VARs cannot even agree among themselves—much less with financial markets—about the history of

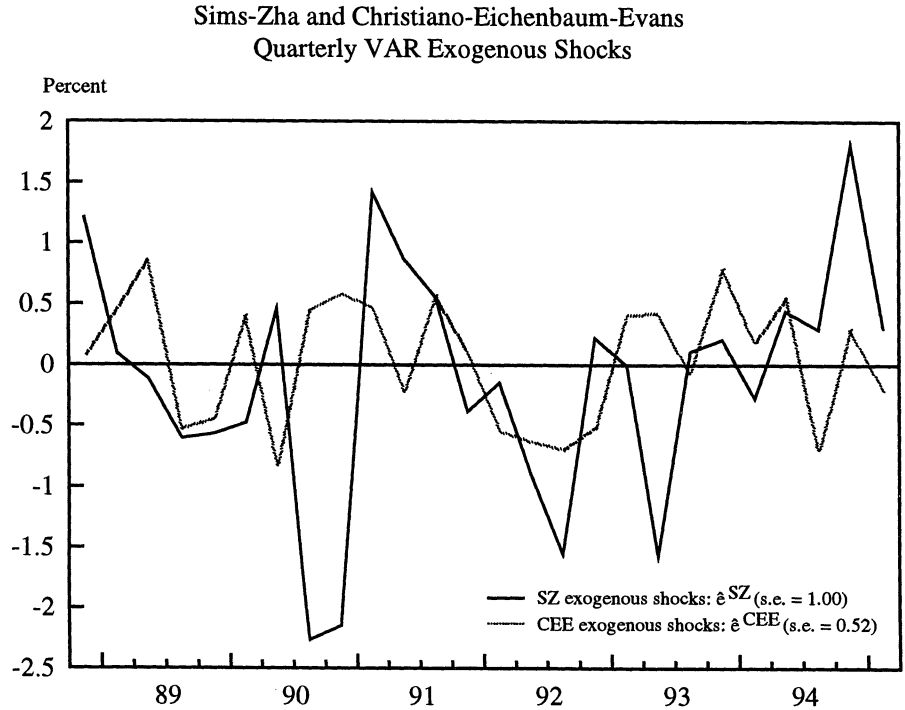

FIGURE 8

monetary policy shocks would seem to be a critical failing. Still, can VARs get the policy shocks wrong (as at least some obviously must have), and yet give the 'right' answers to interesting questions? This appears to depend somewhat on the question being asked.

Of course, if a primary object of interest is the identification of historical episodes as periods of tight or loose monetary policy, then it appears that VARs have made little progress so far. For example, the attempt by Bernanke and Mihov (1995) to "objectively" measure the historical "policy innovation and overall policy stance" appears to be unsuccessful. Clearly, all of the shocks from the different estimated VARs cannot make sense simultaneously as complete historical descriptions of monetary policy.

Similarly, using these suspect VAR shocks as inputs to further analysis is questionable. Variance decompositions, which attempt to parse out the variability in, say, output due to monetary policy shocks, will be of little interest without a credible series on the complete set of monetary policy shocks.[23] Thus, the conclusion of Leeper et al. (1996) that only a small proportion of output variation is accounted for

[23] As an example, suppose that two VARs both found that monetary shocks accounted for 10 per cent of the variation in output, but their respective monetary shock series were uncorrelated (as in Section 4.3). Then, assuming both series were valid, independent, component exogenous shocks, together monetary shocks would account for 20 per cent of the variation in output.

by monetary policy surprises is totally unsupported. Also, the use of VAR monetary policy shocks as instruments in a GMM analysis, as in Burnside et al. (1995), appears to be a very dubious exercise. Although these shocks may be exogenous, the analysis above suggests that it is unclear whether they are relevant for anything (in the sense of Hall et al. 1996).

For impulse response functions, the answer is more subtle. Typically, a VAR's estimated impulse responses will be only as good as its measure of exogenous shocks. Indeed, an appealing and completely correct way to think about a VAR analysis is that it identifies a policy shock time series and then finds the effects of policy essentially by regressing everything else on that policy shock series. Specifically, the n-period impulse response of a variable to a monetary shock can be calculated as the sum of the first n coefficients of a regression of the variable on lagged exogenous shocks.[24] As noted by Christiano et al. (1996a, 1996b), this procedure is asymptotically equivalent to the usual one based on interpreting the coefficients of a full VAR. From the evidence above, the measures of monetary shocks do not appear to be very good; thus, one likely cannot rely on the impulse responses. In particular, if a given VAR's measure of the monetary shocks equals the true measure of the monetary shocks plus white noise measurement error, then by the usual errors-in-variables arguments the estimated impulse responses will be biased and inconsistent. Similarly, if one VAR's exogenous policy shocks are another VAR's endogenous policy reactions and vice versa, then clearly the VAR approach has made little progress in overcoming the fundamental identification problem described in the introduction.[25]

The fact that different published VARs display different historical monetary policy shock series but broadly similar impulse responses may reflect the fact that different authors have mined the data in different ways to obtain impulse responses that accord with similar priors. Indeed, the main argument typically advanced by authors in favor of their VARs is that 'reasonable' results are obtained—in the sense that the associated impulse responses of output, prices, and other variables to the supposed monetary shocks have shapes that accord with the authors' priors. To the extent that they are consistent, the VAR impulse response results completely accord with conventional wisdom as recorded, for example, in intermediate macroeconomic textbooks. That is, tighter monetary policy leads to lower output and eventually lower inflation. Any inconsistency of results with priors (e.g., the famous price puzzle) is not addressed as a new fact but is eliminated through a reestimation of the VAR with different variables or restrictions. Thus, congruence with conventional priors may have enforced the consistency of reported impulse responses.

[24] The omission of other relevant explanatory variables is of no consequence because they are uncorrelated with the exogenous monetary policy shocks by construction.

[25] Chris Sims has hypothesized that if each VAR measured a different independent component of the true monetary policy exogenous shock, the VARs could each correctly estimate the appropriate impulse response. This seems unlikely because the VARs do not even agree on the reduced form shocks.

5. CONCLUSION

In VAR analyses, there is little direct justification for the funds rate equations and shocks that are estimated. This paper simply emphasizes that these equations and shocks are explicitly structural elements that should be useful in validating VAR analyses. The message of this paper is that the monetary reaction functions and shocks must be taken seriously as constructs in their own right, and that they should be routinely reported—at least as often as impulse response functions. In this spirit, this paper has presented some preliminary evidence on the adequacy of the reaction functions and shocks in recent VARs. These specifications appear to be severely deficient. The VAR reaction functions mischaracterize the Federal Reserve information set and exhibit fragile coefficient estimates; furthermore, their associated monetary shocks are contradictory and their innovations are essentially uncorrelated with financial market surprises.

To be quite clear, my critique is *not*, as others have characterized it, that the VAR approach is "generically invalid" or "so deeply flawed as to be useless." My critique is simply that *existing* monetary VARs appear to be deficient when judged by a few obvious structural benchmarks (like mutual consistency). Certainly, these VAR analyses have been too cavalier about the real-time information set of the central bank, especially given that the VAR methodology relies so completely on separating reactive policy actions from exogenous ones.

The next step, which is already being taken, is to try to improve these VARs by a more careful attention to economic structure. For example, Bagleano and Favero (1997) provide a useful VAR analysis incorporating econometric specification tests and regime shifts, Kozicki and Tinsley (1997) allow for time-varying endpoints in a VAR (an idea also fruitfully employed in Bomfim and Rudebusch 1997), and McKibbin et al. (1997) estimate a 'hybrid' structural model/VAR model.[26] Also, further efforts are underway to more fully examine the VAR information sets by adding omitted policy variables and using only the data available historically at each point in time. Whether one labels the resulting equations 'VARs,' or 'near-VARs,' or 'hybrid models,' or just 'structural models' is irrelevant. It seems clear that to make progress, this literature will take the same level of structural modeling attention that current 'structural VARs' have placed on modeling the contemporaneous correlation matrix and apply it to the selection of variables, regimes, and lags.

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[26] Interestingly, on page 7, they note that they "...do not think it is productive to treat the residuals from an estimated VAR as if they were measures of policy actions."

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