COWLES FOUNDATION FOR RESEARCH IN ECONOMICS

AT YALE UNIVERSITY

Box 2125, Yale Station

New Haven, Connecticut 06520

COWLES FOUNDATION DISCUSSION PAPER NO. 856-R

VAR MODELS AS STRUCTURAL APPROXIMATIONS

by

Ray C. Fair

March 1989

VAR Models as Structural Approximations

ABSTRACT

This paper presents a way of estimating how accurate VAR models are likely to be for answering structural questions. Data are generated from a dynamic deterministic solution of a structural model; a VAR model is estimated using a subset of these data; and the properties of the VAR model are compared to the properties of the structural model. This procedure has the advantage of eliminating the effects of error terms, since the data are generated from a deterministic simulation. The results show that the VAR models do not seem to be good structural approximations.

Ray C. Fair
Cowles Foundation
Box 2125, Yale Station
New Haven, CT 06520

Revised December 1988

VAR MODELS AS STRUCTURAL APPROXIMATIONS

by

Ray C. Fair[1]

I. Introduction

Although vector autoregressive (VAR) models have traditionally been used for forecasting, Sims (1982) has advocated their use for policy analysis.[2] He argues that his procedures differ "marginally" from those used for structural models in that "they take account of policy endogeneity and they avoid constructing behavioral stories about each individual equation in the model" (Sims, 1982, p. 150). This added generality comes, of course, at a cost. To estimate a reduced form absent conventional exclusion restrictions, the number of variables that enter the estimated reduced form must be very small relative to the number of variables in the reduced form of a structural model. Sims argues that a small set of variables captures most of the information available to the econometrician about the economy.

Are VAR models in fact good approximations to the true reduced form of the economy? Put another way, how costly is the unwillingness to impose a priori restrictions when one attempts to use a VAR model to uncover structural relationships in the economy? Although this question cannot be answered directly without knowing the true reduced form, indirect tests can be made. This paper is concerned with one such test.

---

[1]I am indebted to Matthew Shapiro for many helpful comments regarding this paper.

[2]See also Doan, Litterman, and Sims (1984). Blanchard and Watson (1986) and Bernanke (1986) use VAR models to ask questions about the structure of the economy, but they impose restrictions on the covariance matrix of innovations that are analogous to exclusion restrictions.

The test is to see if VAR models approximate well the properties of a large-scale structural model, specifically the Fair (1984) model (abbreviated FM). Data are generated from a dynamic simulation of FM; a VAR model is estimated using a subset of these data; and the properties of the VAR model are compared to those of FM. If the properties of the VAR model are quite different from those of FM, this is evidence against the VAR model being a good approximation of FM. If the properties are similar, this is evidence in favor of the VAR model.

Is this test of any interest? It should first be noted that the results are not as specific to FM as one might at first think. Although FM is assumed to be the "truth" in this study, the methodology is not based on the assumption that FM is literally the truth. No comparison is ever made, or needs to be made, of the actual values and the FM predicted values. What is needed for the results of this study to be trustworthy is that the actual way in which the data are generated in the economy is similar to the way in which the data are generated in a large-scale structural model _like_ FM. If this is true, then the use of FM seems sensible. If instead the data are generated from a much simpler structure, say from a structure similar to that of a VAR model, then the present results are not of much interest.

Sims and many others would argue that FM and models like it are too poor an approximation of the economy for it to be of any interest whether VAR models approximate these types of models or not. Again, without knowing the true structure of the economy, it is not possible to examine this view directly. Results that indirectly bear on this question are, however, presented in Fair and Shiller (1987), where encompassing tests are used to compare VAR models to FM. The results show that VAR forecasts contain very little information not in the FM forecasts and that the FM forecasts contain information not in the VAR forecasts. In this sense VAR models appear to be dominated by FM -- VAR models do not appear to aggregate information as efficiently as does FM. These results thus provide some support for the test used in the present paper.

The results in this paper show that the properties of VAR models are not good approximations of the properties of FM -- that VAR models are not good structural approximations in this sense. These results plus the results in Fair and Shiller (1987) thus call into question the usefulness of VAR models for macroeconomic purposes. As forecasting devices they are dominated by FM, and as structural approximations they do not seem to be very accurate.

II. The Procedure

The methodology used in this paper was outlined above: 1) data are generated from a dynamic simulation of FM, 2) a VAR model is estimated using a subset of these data, and 3) the properties of the VAR model are compared to those of FM. One of the key features of this procedure is that the simulation of FM that is used to generate the data is deterministic. One could generate the data from a stochastic simulation, where the error terms are drawn from the estimated distributions in FM, and one might at first think that this is preferable. For the question considered in this paper, however, there is good reason not to draw error terms. If the data have been generated from a deterministic simulation, the VAR model can fail to be a good approximation for only two reasons. First, the linear or log linear specification of the VAR model may not capture the nonlinearities in FM. Second, the VAR model may not include all the variables in FM. If error terms were drawn, there would be a third reason for the lack of agreement between the properties of the VAR model and FM, namely the noise introduced by the error terms. Drawing error terms would simply compound the problem of trying to decide how close the VAR model and FM agree.

To repeat, because of the use of a deterministic simulation of FM to generate the data for the VAR model, the VAR model will not capture the properties of FM if and only if the reduced form equations that it estimates are misspecified. If the estimated reduced form equations were correct (right functional forms and all relevant predetermined variables used), the VAR model would duplicate FM exactly. There are no random shocks (in the simulated data) to make the VAR model differ from FM if the VAR model is correctly specified. All the "error" is solely from the misspecification of the VAR model.

The case of a linear structural model may help clarify the procedure. Let the structural model be

$$(1) \quad YB + X\Gamma = U ,$$

where Y is T x m, B is m x m, X is T x n, Γ is n x m, and U is T x m. X may include lagged endogenous variables. Some of the equations may be identities. The elements of U corresponding to identities are identically equal to zero.

Given estimates of B and Γ, denoted $\hat{B}$ and $\hat{\Gamma}$, given values of the exogenous variables, and setting U equal to zero, the model in (1) can be solved dynamically over the period 1 through T. Let $\hat{Y}$ and $\hat{X}$ denote these solution values, where $\hat{X}$ differs from X if there are lagged endogenous variables in X.

Now, assume that n is less than T, and consider a regression of $\hat{Y}$ on $\hat{X}$. This regression will yield $-\hat{\Gamma}\hat{B}^{-1}$ as the estimated coefficient matrix for

$\hat{X}$ and will result in a perfect fit.[3] In other words, the solution data obey $\hat{Y}\hat{B} = -\hat{X}\hat{\Gamma}$, or $\hat{Y} = -\hat{X}\hat{\Gamma}\hat{B}^{-1}$, and so the regression of $\hat{Y}$ on $\hat{X}$ will simply give back $-\hat{\Gamma}\hat{B}^{-1}$. This is just a round about way of computing the reduced form coefficient matrix. If, on the other hand, $\hat{Y}$ is regressed on a subset of the variables in $\hat{X}$, one will not get back the reduced form coefficient matrix, and a perfect fit will not be achieved. The "estimated" reduced form will only be an approximation of the actual reduced form. The "errors" that are made are not due to any stochastic error terms (since the data were generated from a deterministic simulation), but are due solely to the misspecification of the estimated reduced form equations.

III. The Models

FM

FM is nonlinear, consists of 29 stochastic equations and 98 identities, and has over 100 predetermined variables. The version of the model used here is estimated (by two stage least squares) for the period 1954 I - 1987 I -- 133 observations. The overall data set begins in 1952 I. (Some observations before 1954 I are needed because of lagged values in the model.) The generated data set was constructed by simulating FM dynamically for the 1954 I -1987 I period. The outcome of this simulation is a data set consisting of solution values of each of the 127 endogenous variables for each of the 133 quarters.

---

[3] It is assumed here that $\hat{X}'\hat{X}$ is nonsingular, which is likely to be true as long as n is less than T.

The VAR Models

Three VAR models are considered in this paper. Each consists of eight variables: the real value of government spending (G), the import price deflator (PM), the three-month Treasury bill rate (R), the unemployment rate (U), the money supply (M), the nominal wage rate (W), the GNP deflator (P), and real GNP (Y). All but the unemployment rate and the bill rate are in logs. In the first model, denoted VAR4, each of the eight equations consists of each variable lagged one through four times, a constant, and a time trend, for a total of 34 coefficients per equation. This model is the same as the model used in Sims (1980) except for the addition of the government spending variable and the bill rate. This model is the same as the VAR4 model in Fair and Shiller (1987) except for the addition of the government spending variable.

The second model, denoted VAR2, uses two lags per variable rather than four, for a total of 18 coefficients per equation. It is of interest to see how sensitive the properties of VAR models are to decreasing the number of lags.

The third model, denoted VAR4P, has Bayesian priors imposed on the coefficients of VAR4. The Litterman prior that the variables follow univariate random walks has been imposed. The standard deviations of the prior take the form

(2) $S(i,j,k) = \gamma g(k) f(i,j)(s_j/s_i)$,

where i indexes the left-hand-side variable, j indexes the right-hand-side variables, and k indexes the lag. s_i is the standard error of the unrestricted equation for variable i. The following values are imposed: $f(i,i)=1.0$, $f(i,j) = .5$, $i \neq j$, $g(k) = k^{-1}$, and $\gamma = 0.1$. These are the values imposed by Litterman (1979, p. 49).

The VAR models were estimated for the 1954 I - 1987 I period using the simulated data. The data that were needed prior to 1954 I were taken to be the actual data. Also, actual data were used for government spending and the import price deflator because these variables are exogenous in FM.

IV. The Policy Experiments

The policy experiments for the VAR models consist of shocking a particular residual and examining the response of the system to the shock. Because the residuals are correlated across equations, there is no unique way to do this. The standard procedure (see Sims (1980), p. 21) is to choose a particular order of the equations and then triangularize the system. This is what was done here. The equations were ordered 1) government spending, 2) import price, 3) bill rate, 4) unemployment rate, 5) money supply, 6) wage rate, 7) GNP deflator, and 8) real GNP. The triangularization is done by adding the contemporaneous value of the government spending variable to equations 2 through 8, the contemporaneous value of the import price variable to equations 3 through 8, the contemporaneous value of the bill rate variable to equations 4 through 8, and so on. The equations are then estimated in this form.[4]

Three experiments were performed per model -- one in which the error term in the government spending equation was shocked, one in which the error term in the import price equation was shocked, and one in which the error term in the bill rate equation was shocked. The experiments were performed for the 1980 I - 1982 IV period.

---

[4]For the estimation of VAR4P, the system without the contemporaneous values added was estimated first (with the priors imposed) and then the system was triangularized.

It is common practice when computing multipliers from models to first add the estimated residuals to all the equations and take the estimated residuals to be exogenous. This means that when the model is solved with no shocks, a perfect tracking solution is obtained. The "base" values for the experiment are then merely the actual values. If the residuals are not added to the equations, two simulations have to be run for an experiment, the first in which there are no shocks or exogenous-variable changes and the second in which the shocks or exogenous-variable changes are made. The predicted values from the first simulation are the base values, to which the predictions from the second simulation can be compared. If a model is linear, it makes no difference which procedure is followed, but for nonlinear models the results are at least slightly different. For nonlinear models it generally seems best to make the changes off the perfect tracking solution.

The VAR models are nonlinear in the basic variables because of the use of logs, and the estimated residuals were added to the VAR equations before shocking the equations. It should be stressed, however, that this is not a critical decision. Because the VAR models are not very nonlinear, almost identical results would have been obtained had the estimated residuals not been added to the equations and instead two simulations run per experiment.

"Standard errors" of the multipliers were also computed for the VAR2 and VAR4 models. This was done by means of stochastic simulation using the procedure in Fair (1980). Let $\hat{\alpha}$ denote the n-component vector of coefficient estimates for VAR2 or VAR4, and let $\hat{V}$ denote the n x n estimated covariance matrix for $\hat{\alpha}$. For VAR2 n is 172, and for VAR4 n is 300. The coefficient vector includes the coefficients of the contemporaneous variables in the equations, which enter because of the triangularization, and $\hat{V}$ is a block diagonal matrix because the residuals are not correlated across equations after the triangularization. Let α^* be a particular draw of the coefficient vector. It is assumed that α^* is distributed as $N(\hat{\alpha}, \hat{V})$.

The standard errors are estimated as follows. 1) A value for α^* is drawn from $N(\hat{\alpha}, \hat{V})$. 2) Using this set of coefficient values, the given equation's residual is shocked and the system's responses are recorded. This is one trial. 3) Steps 1) and 2) are repeated J times, where J is the number of trials. In step 2) the shock to the residual is the same from trial to trial; only α^* changes. 4) Given the J values for each variable's response for each quarter, the variance (and standard error) of the response can be computed. For the results in this study, J was taken to be 500.

One should be careful in interpreting what these estimated standard errors are. They are the errors that the VAR model builders could compute from the data. They are the errors that the model builders would presumably use in deciding how much confidence to place on the results. The errors would, of course, be zero if the VAR models were correctly specified, because the data have been generated with no random shocks. In other words, if the VAR models were correctly specified, the coefficients would be estimated exactly and thus the estimated covariance matrix of the coefficient estimates would be zero. Standard errors were computed here because it is of interest to see if the errors that the VAR models make in approximating the properties of FM are within what the model builders would expect from their stochastic specifications.

V. The Results

The Government Spending Experiment

For this experiment the error term in the government spending equation (equation 1) in each VAR model was shocked by .016 for the first quarter (1980 I). The government spending equation is in logs, and this is a shock of about 10 billion dollars at an annual rate. The model was then solved for the 1980 I - 1982 IV period. The difference between the predicted value from this simulation and the actual value of each variable for each quarter is an estimate of the effect of the shock on the variable.

The results of this experiment are presented in Table 1 for the VAR4 model.[5] The "changes" in Table 1 are the differences between the solution value after the shock and the actual value. They are not the changes from quarter to quarter. Note first that the initial change in G is $10.0 billion, but that after the first quarter the changes are different from the initial change. This is simply the government spending equation in the VAR model at work.

The change in real GNP (Y) in the first quarter in response to this shock is $6.2 billion, and the change in the second quarter is $7.7 billion. The changes become negative beginning in the sixth quarter. The changes in the bill rate are all positive, and the changes in the money supply and the price level are all negative. The changes in the unemployment rate are initially negative and then essentially zero after about seven quarters.

---

[5] The results for VAR2 and VAR4P were very similar to those for VAR4, and so only the results for VAR4 are reported here. Results for VAR2 and VAR4P are available from the author upon request. This similarity of results across the VAR models is consistent with the forecasting comparisons in Fair and Shiller (1987), where the three VAR models performed about the same.

The VAR4 properties in Table 1 need to be compared to the properties of FM. The FM properties in Table 1 are based on the government spending changes in the first row in Table 1.[6] For these calculations the estimated residuals were first added to the FM equations and then taken to be exogenous. Government spending was then changed in each of the quarters by the amount in Table 1 and the model was solved. The difference between the solution value and the actual value for each endogenous variable and quarter is the estimated effect of the change on the endogenous variable. These differences are the FM values in Table 1.

The "errors" in Table 1 are the differences between the VAR4 properties and the FM properties. They are an indication of how badly VAR4 is misspecified. (Remember that the FM properties in this world are the truth.) In general, the errors in Table 1 seem fairly large. The GNP response is considerably underestimated, and the price and wage responses are of the wrong sign. The money supply responses are generally overestimated, although the interest rate and unemployment rate responses are fairly accurate. For GNP, wages, and prices, the initial errors are generally larger than the estimated standard errors that the model builders could compute from the data.

---

[6]As noted earlier, both government spending and the import price deflator are exogenous in FM. When government spending was changed in the FM for the first experiment, the import price deflator was <u>not</u> changed. One could have, for example, changed PM by the amounts of the VAR changes in Table 1. It seemed best not to do this, however, since in the generated data PM is exogenous. In the world that has been created, the VAR models erroneously takes PM to be endogenous, and this is simply another type of specification error whose quantitative importance is being estimated.

TABLE 1

Results of Government Spending Shock

		1980				1981				1982			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
VAR4 & FM	ΔG	10.0	9.0	7.1	6.1	5.2	4.2	4.0	3.3	2.7	2.0	1.5	1.1
VAR4	ΔPM/PM	.13	.23	-.30	-.90	-1.14	-1.06	-1.07	-1.03	-.96	-.87	-.80	-.73
FM	ΔPM/PM	0	0	0	0	0	0	0	0	0	0	0	0
ERROR		.13	.23	-.30	-.90	-1.14	-1.06	-1.07	-1.03	-.96	-.87	-.80	-.73
SE		(.18)	(.29)	(.36)	(.43)	(.49)	(.52)	(.54)	(.56)	(.57)	(.59)	(.61)	(.63)
VAR4	ΔR	.10	.15	.13	.10	.03	.02	.02	.03	.02	.01	.00	.01
FM	ΔR	.12	.16	.14	.11	.07	.05	.03	.03	.02	.01	.01	-.00
ERROR		-.02	-.01	-.01	-.01	-.04	-.03	-.01	.00	.00	.00	-.00	.01
SE		(.04)	(.06)	(.08)	(.09)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)	(.10)
VAR4	ΔU	-.10	-.14	-.16	-.10	-.05	-.02	-.01	-.00	.01	.01	.01	.00
FM	ΔU	-.07	-.15	-.16	-.14	-.11	-.08	-.05	-.03	-.01	.00	.01	.01
ERROR		-.03	.01	.00	.04	.06	.06	.04	.03	.02	.01	.00	-.01
SE		(.02)	(.04)	(.05)	(.06)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)
VAR4	ΔM	.0	-.5	-.2	-.6	-.7	-.8	-.7	-.8	-.8	-.9	-.9	-.9
FM	ΔM	-.1	-.2	-.3	-.4	-.4	-.4	-.4	-.4	-.4	-.3	-.3	-.3
ERROR		.1	-.3	.1	-.2	-.3	-.4	-.3	-.4	-.4	-.6	-.6	-.6
SE		(.2)	(.3)	(.3)	(.4)	(.4)	(.5)	(.6)	(.7)	(.8)	(.9)	(1.0)	(1.1)
VAR4	ΔW/W	-.03	-.06	-.06	-.06	-.09	-.12	-.16	-.18	-.20	-.22	-.23	-.24
FM	ΔW/W	-.00	.01	.02	.03	.04	.04	.04	.04	.04	.04	.03	.03
ERROR		-.03	-.07	-.08	-.09	-.13	-.16	-.20	-.22	-.24	-.26	-.26	-.27
SE		(.01)	(.02)	(.03)	(.04)	(.05)	(.06)	(.07)	(.07)	(.08)	(.09)	(.10)	(.10)
VAR4	ΔP/P	-.09	-.08	-.10	-.09	-.11	-.15	-.20	-.22	-.23	-.25	-.25	-.25
FM	ΔP/P	.00	.02	.02	.05	.06	.06	.06	.06	.06	.05	.05	.04
ERROR		-.09	-.10	-.12	-.14	-.17	-.21	-.26	-.28	-.29	-.30	-.30	-.29
SE		(.03)	(.04)	(.04)	(.05)	(.06)	(.07)	(.09)	(.10)	(.11)	(.11)	(.12)	(.13)
VAR4	ΔY	6.2	7.7	7.3	4.3	0.3	-1.0	-1.8	-2.2	-2.8	-3.2	-3.0	-2.4
FM	ΔY	8.3	11.8	11.3	9.2	6.6	4.1	2.5	1.2	.3	-.6	-1.2	-1.5
ERROR		-1.9	-4.1	-4.0	-4.9	-6.3	-5.1	-4.3	-3.4	-3.1	-2.6	-1.8	-.9
SE		(1.4)	(2.6)	(3.2)	(3.6)	(3.7)	(3.6)	(3.4)	(3.6)	(3.8)	(4.0)	(4.2)	(4.2)

Notation:

Δ = estimated effect of the shock on the variable
G = real value of government spending
PM = import price deflator
R = three-month Treasury bill rate
U = unemployment rate
M = money stock (M1)
W = nominal wage rate
P = GNP deflator
Y = real GNP
VAR4 = VAR4 model
FM = Fair (1984) model
ERROR = VAR4 value - FM value
SE = estimated standard error from stochastic simulation

Notes: Units are percentage points except for G, M, and Y. For G and Y the units are billions of 1982 dollars, and for M the units are billions of current dollars.

TABLE 2

Results of Import Price Shock

		1980				1981				1982			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
VAR4	ΔG	0	.1	-8.7	-7.6	-5.9	-3.1	.8	4.4	7.9	10.8	13.5	15.5
FM	ΔG	0	0	0	0	0	0	0	0	0	0	0	0
ERROR		0	.1	-8.7	-7.6	-5.9	-3.1	.8	4.4	7.9	10.8	13.5	15.5
SE		0	(3.8)	(5.4)	(6.0)	(7.1)	(7.6)	(8.1)	(8.8)	(9.3)	(9.8)	(10.5)	(11.3)
VAR4 & FM	ΔPM/PM	10.52	13.09	13.01	12.22	10.41	8.00	5.40	3.02	.81	-.90	-2.05	-2.88
VAR4	ΔR	.32	.50	.55	.63	.46	.40	.39	.33	.22	.09	-.04	-.17
FM	ΔR	.44	.41	.24	.12	-.03	-.18	-.31	-.41	-.49	-.52	-.51	-.54
ERROR		-.12	.09	.31	.51	.49	.58	.70	.74	.81	.61	.47	.37
SE		(.17)	(.27)	(.36)	(.43)	(.49)	(.52)	(.53)	(.53)	(.53)	(.53)	(.52)	(.52)
VAR4	ΔU	-.01	-.05	-.01	-.02	-.03	-.11	-.21	-.30	-.34	-.33	-.29	-.23
FM	ΔU	-.05	-.08	-.08	-.05	-.01	.04	.10	.15	.20	.21	.21	.19
ERROR		.04	.03	.07	.03	-.02	-.15	-.31	-.45	-.54	-.54	-.50	-.42
SE		(.09)	(.17)	(.24)	(.27)	(.29)	(.31)	(.31)	(.33)	(.35)	(.37)	(.38)	(.37)
VAR4	ΔM	2.1	2.0	1.8	.2	-.8	-1.4	-2.2	-3.2	-3.8	-4.2	-4.4	-4.3
FM	ΔM	-.6	-1.5	-1.5	-1.6	-1.6	-1.4	-1.1	-.7	-.2	.4	.9	1.5
ERROR		2.7	3.5	3.3	1.8	.8	.0	-1.1	-2.5	-3.6	-4.6	-5.3	-5.8
SE		(1.0)	(1.2)	(1.4)	(1.5)	(2.0)	(2.4)	(3.0)	(3.4)	(4.0)	(4.5)	(5.1)	(5.5)
VAR4	ΔW/W	.13	.22	.46	.80	1.01	1.08	1.10	1.08	.97	.81	.61	.40
FM	ΔW/W	.22	.58	.93	1.22	1.43	1.54	1.56	1.48	1.34	1.14	.92	.68
ERROR		-.09	-.36	-.47	-.42	-.42	-.46	-.46	-.40	-.37	-.33	-.31	-.28
SE		(.06)	(.10)	(.13)	(.16)	(.20)	(.24)	(.29)	(.33)	(.38)	(.41)	(.44)	(.48)
VAR4	ΔP/P	.31	.30	.76	1.44	1.61	1.70	1.79	1.71	1.51	1.27	1.00	.68
FM	ΔP/P	.52	1.02	1.41	1.74	2.00	2.12	2.10	2.01	1.84	1.60	1.33	1.06
ERROR		-.21	-.72	-.65	-.30	-.39	-.42	-.31	-.30	-.33	-.33	-.33	-.38
SE		(.12)	(.16)	(.20)	(.22)	(.28)	(.33)	(.39)	(.45)	(.50)	(.55)	(.59)	(.62)
VAR4	ΔY	-2.1	-2.1	-10.5	-16.9	-23.0	-22.9	-19.0	-15.4	-13.2	-13.8	-15.3	-17.6
FM	ΔY	-2.4	-6.3	-11.2	-17.0	-22.5	-27.4	-31.1	-33.2	-33.4	-31.8	-28.6	-24.4
ERROR		.3	4.2	.7	.1	-.5	4.5	12.1	17.8	20.2	18.0	13.3	6.8
SE		(6.3)	(11.8)	(14.1)	(14.9)	(15.8)	(15.6)	(15.3)	(16.6)	(18.7)	(20.7)	(22.0)	(22.8)

Notes: See Table 1.

The Import Price Experiment

For the second experiment the error term in the import price equation in each VAR model was shocked by .10 in the first quarter. The import price equation is in logs, and this is a shock in the import price deflator (PM) of 10.52 percent. The results are presented in Table 2 for VAR4. Note first that the change in PM is 13.09 percent in the second quarter, and it declines to -2.05 percent by the twelfth quarter. This is the PM equation at work. For the FM results, PM was changed in each of the quarters by the amount in Table 2 and the model was solved.[7]

Increasing the import price deflator in FM results in an increase in wages and prices and a decrease in GNP. The VAR4 model underestimates the fall in GNP and the rise in prices and wages. The eventual rise in the unemployment rate is completely missed; the VAR4 model has the unemployment falling throughout the period. The fall in the interest rate after four quarters (as the Fed in FM lowered interest rates to help counter the fall in output) was also missed. The fall was not predicted to take place until the tenth quarter.

Some of the estimated standard errors are quite large in Table 2. For example, the four-quarter-ahead standard error for GNP is $14.9 billion, which is large compared to the -$17.0 billion effect on GNP. A VAR model builder might conclude from the estimated standard errors that very little confidence could be placed on the results.

---

[7]In this case the government spending variable was not changed in FM, for reasons similar to those discussed in the previous footnote.

The Bill Rate Experiment

The third experiment, where the error term in the bill rate equation in each VAR model was shocked, requires a little more explanation. In FM the bill rate is determined by an interest rate reaction function, where the Fed is estimated to "lean against the wind." Monetary policy is thus endogenous in the model; the Fed uses open market operations (variable AG in the model) to achieve its bill rate target each quarter. Both AG and the bill rate are endogenous. The bill rate is thus endogenous in the generated data that have been used for the first two experiments. For the third experiment the bill rate should be exogenous, and so a new data set was generated by solving FM with the interest rate reaction function dropped and the bill rate taken to be exogenous (and equal to the historical values). Each of the three VAR models was then reestimated using this data set, and these are the versions that were used for the third experiment.

The error term in the bill rate equation in each VAR model was shocked by 1.0 in the first quarter. This is a shock of one percentage point. The results are presented in Table 3 for VAR4. The bill rate change for VAR4 was 1.0 in the first quarter, 1.22 in the second quarter, and then gradually lower after that. The FM values for the third experiment were obtained by changing the bill rate each quarter by the amount in Table 3 and solving the model. For these calculations the interest rate reaction function was dropped from FM and the bill rate was taken to be exogenous.[8]

An increase in the bill rate in FM results in a contraction in GNP from the first quarter on. The VAR4 model, on the other hand, has an expansion

---

[8]Neither government spending nor the import price deflator was changed in the third experiment for FM, which is consistent with the treatment for the other two experiments.

TABLE 3

Results of the Bill Rate Shock

		1980				1981				1982			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
VAR4	ΔG	0	.6	1.4	1.6	1.4	2.0	1.8	1.6	1.6	1.6	1.4	1.3
FM	ΔG	0	0	0	0	0	0	0	0	0	0	0	0
ERROR		0	.6	1.4	1.6	1.4	2.0	1.8	1.6	1.6	1.6	1.4	1.3
SE		0	(.9)	(1.3)	(1.5)	(1.7)	(1.9)	(2.0)	(2.3)	(2.4)	(2.6)	(2.8)	(3.0)
VAR4	ΔPM/PM	0	-.26	-.13	.43	.67	.92	1.02	.71	.23	-.27	-.87	-1.39
FM	ΔPM/PM	0	0	0	0	0	0	0	0	0	0	0	0
ERROR		0	-.26	-.13	.43	.67	.92	1.02	.71	.23	-.27	-.82	-1.39
SE		0	(.18)	(.30)	(.38)	(.46)	(.52)	(.58)	(.63)	(.67)	(.70)	(.72)	(.75)
VAR4 & FM	ΔR	1.0	1.22	.72	.71	.73	.59	.44	.37	.28	.18	.08	.00
VAR4	ΔU	-.04	-.09	-.10	-.03	.04	.11	.18	.22	.22	.21	.20	.17
FM	ΔU	.01	.04	.09	.13	.16	.18	.19	.19	.18	.16	.13	.09
ERROR		-.05	-.13	-.19	-.16	-.12	-.09	-.01	.03	.04	.05	.07	.08
SE		(.02)	(.04)	(.06)	(.07)	(.07)	(.08)	(.09)	(.09)	(.10)	(.11)	(.11)	(.11)
VAR4	ΔM	-2.1	-2.8	-4.1	-4.7	-5.5	-6.0	-6.9	-7.2	-7.6	-7.9	-8.3	-8.4
FM	ΔM	-1.1	-2.3	-3.2	-3.8	-4.5	-5.1	-5.4	-5.7	-5.8	-5.8	-5.8	-5.8
ERROR		-1.0	-.5	-.9	-.9	-1.0	-.9	-1.5	-1.5	-1.8	-2.1	-2.5	-2.6
SE		(.2)	(.3)	(.4)	(.6)	(.7)	(.9)	(1.1)	(1.3)	(1.5)	(1.7)	(2.0)	(2.3)
VAR4	ΔW/W	.04	.04	.04	.04	.04	.03	.02	.00	-.03	-.08	-.14	-.21
FM	ΔW/W	.00	-.00	-.00	-.00	-.02	-.03	-.04	-.05	-.06	-.07	-.08	-.08
ERROR		.04	.04	.04	.04	.06	.06	.06	.05	.03	-.01	-.05	-.13
SE		(.01)	(.02)	(.03)	(.04)	(.05)	(.06)	(.07)	(.08)	(.09)	(.10)	(.11)	(.12)
VAR4	ΔP/P	.05	.02	.03	.02	.05	.10	.09	.07	.06	.02	-.05	-.13
FM	ΔP/P	-.00	-.01	-.02	-.04	-.05	-.06	-.08	-.10	-.11	-.12	-.13	-.13
ERROR		-.05	.03	.05	.06	.10	.16	.17	.17	.17	.14	.08	.00
SE		(.03)	(.04)	(.05)	(.06)	(.07)	(.08)	(.10)	(.11)	(.12)	(.14)	(.15)	(.16)
VAR4	ΔY	3.9	6.5	2.7	-3.3	-9.1	-15.6	-20.9	-23.6	-24.0	-23.8	-22.6	-20.5
FM	ΔY	-1.2	-4.1	-7.4	-10.1	-12.2	-13.5	-13.9	-13.5	-12.6	-11.2	-9.4	-7.3
ERROR		5.1	10.6	10.1	6.8	3.1	-2.1	-7.0	-10.1	-11.4	-12.6	-13.2	-13.2
SE		(1.3)	(2.5)	(3.2)	(3.5)	(3.6)	(3.8)	(4.1)	(4.6)	(5.3)	(5.9)	(6.4)	(6.9)

Notes: See Table 1.

in GNP for the first three quarters, before the contraction sets in. By the end of the period the contraction is considerably overestimated by VAR4. The changes for the GNP deflator are positive for the first ten quarters for VAR4, whereas the FM values are negative. The FM changes in the unemployment rate are positive from the first quarter on, whereas the VAR4 model does not pick this up until the fifth quarter. The results for the money supply changes are fairly accurate.

General Remarks

What should one conclude from the results in Tables 1 - 3? It is clear that the estimated standard errors are generally much larger for the import price experiment than they are for the other two. A model builder using a VAR model for policy analysis would put less confidence on the response of the system to import price shocks than to government spending or interest rate shocks. More importantly, however, the VAR4 model[9] does not appear to be good approximation to the structural properties of FM (from which the data were generated). The errors are generally large, and many misleading conclusions would be drawn from the responses.

[9] And also the VAR2 and VAR4P models.

REFERENCES

Bernanke, Ben S., "Alternative Explanations of the Money-Income Correlation," Carnegie-Rochester Conference Series on Public Policy 25: 49-100, Autumn 1986.

Blanchard, Olivier J., and Mark W. Watson, "Are All Business Cycles Alike?" in The American Business Cycle: Continuity and Change, Robert J. Gordon, ed., University of Chicago Press, 1986.

Doan, Litterman, and Sims, Econometric Reviews, 1984.

Fair, Ray C., A Model of Macroeconomic Activity, Vol. 2: The Empirical Model, Ballinger Publishing Co., 1976.

Fair, Ray C., "Estimating the Uncertainty of Policy Effects in Nonlinear Models," Econometrica, 48: 1381-1391, September 1980.

Fair, Ray C., Specification, Estimation, and Analysis of Macroeconometric Models, Harvard University Press, 1984.

Fair, Ray C., and Robert J. Shiller, "Econometric Modeling as Information Aggregation," mimeo, December 1987.

Litterman, Robert B., "Techniques of Forecasting Using Vector Autoregression," Federal Reserve Bank of Minneapolis Working Paper No. 115, November 1979.

Sims, Christopher A., "Macroeconomics and Reality," Econometrrica, 48: 1-48, January 1980.

Sims, Christopher A., "Policy Analysis with Econometric Models," Brookings Papers on Economic Activity, 1: 107-152, 1982.