Money and Agriculture: The Dynamics of Money-Financial Market-Agricultural Trade Linkages

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Abstract

This article investigates empirical relationships among the money supply, the interest rate, the exchange rate, the general price level, and agricultural exports and relative prices using three- and six-variable vector autoregressive models. Shocks to the money supply have little direct effect on agriculture, whereas positive interest rate, exchange rate, and general-price-level shocks have negative effects. The dynamic patterns characterizing monetary interactions with the financial variables do not preclude the possibility that monetary policies underlie the observed interest rate and exchange rate impacts, but the observed price-level shocks appear to be independent of the money supply Agricultural exports and prices demonstrate little impact on the macroeconomic variables.

Keywords

Macroeconomic-agricultural linkages, exchange rate effects on agriculture, inflation and agriculture

Introduction

This article investigates macroeconomic impacts on agriculture. The analysis focuses on relationships among the money supply, the interest rate, the exchange rate, the general price level, and agricultural exports and relative prices These relationships are central to recent discussions of macroeconomic-agricultural linkages, but they remain imperfectly understood. To help clarify the interactions among these variables, I use three- and six-variable vector autoregressive (VAR) models in which quarterly data are viewed as generated by own- and cross-variable dynamic responses.

Several issues arise at the outset. First, assessing macroeconomic impacts on agriculture is elusive despite the importance of these impacts to both private decisionmakers and agricultural policymakers This ambiguity is due in part to the diversity of plausible conceptual approaches that have been suggested about macroeconomics and linkages from macroeconomics to agriculture Thus, one of my objectives is to review some of these approaches

A second set of issues concerns the use of VAR models in economic analysis Given the diversity of theories suggested to characterize macroeconomic-agricultural linkages and the empirical evidence marshaled to support each of them, it seems appropriate to examine the historical evidence to see which views are consistent with past experience before imposing a particular model VAR models

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offer one useful approach to such an analysis VAR models can help us clarify theoretical and empirical controversies over these linkages and can help us evaluate the potential effects of alternative policies VAR models also provide a basis for assessing the importance of alternative sources of instability in the agricultural sector, and they can help us with economic forecasting

Considerable mystery has surrounded the recent use of VAR models for these purposes, and their use remains controversial The mystery arises primarily from a general lack of familiarity among applied economists with the analytic techniques, diagnostics, and standard methods of reporting associated with VAR models The controversy arises over whether appropriate characterizations of economic dynamics are provided by these models and whether policy interpretations can be associated with their outcomes

Because of the importance of these issues, I also describe some of the mechanics of VAR modeling and the basic controversies concerning their interpretation My objective is to help readers unfamiliar with VAR models place the empirical results in an appropriate perspective, not to break new ground in methodology [1]

Following the sections on methodology, I specify a six-variable empirical model of macroeconomic-agricultural linkages I compare dynamic interactions in the six-variable model with those in a simpler model restricted to the money supply, agricultural exports, and agricultural prices Although the agricultural variables seem largely independent of money in the restricted model, shocks to the financial market variables and the general price level have substantial impacts on agriculture Alternative theoretical perspectives are evaluated in light of this evidence

Theoretical Perspectives

The agricultural sector has long had an interest in relationships between agriculture and the rest of the economy With the rapid expansion of trade during the seventies, this attention centered on the impact of the exchange rate on agricultural exports and prices Early analytic and empirical studies focused on the effects of a currency realignment, taken as exogenous, on the domestic and foreign prices of a specific commodity and on the equilibrium quantity traded (*6, 15*) Later, it was recognized that potential cross-price effects arise from the simultaneous impact of an exchange rate realignment on the prices of many commodities (*5, 18*) The additional effects of income shifts associated with changes in the real exchange rate have recently been recognized (*20*).

Because exchange rates are a crucial transmission mechanism by which macroeconomic factors bear on agricultural trade, and thus on U S agriculture overall, it is not surprising that many recent empirical studies have focused directly on measuring these impacts Refining our estimates of key parameters and furthering our knowledge of conceptual issues related to these impacts are important in quantifying these effects Furthermore, when the exchange rate moves markedly, as it has over the past few years, the consequences for agriculture are of concern to the sector regardless of the underlying causes of the exchange rate realignment That is, the exchange rate itself is the macroeconomic variable of interest for some purposes

However, policy analysis cannot progress far without an understanding of the factors that underlie movement of variables such as the exchange rate Isolating policy-induced movements in these variables is crucial Following the pioneering work by Schuh (*22*), this effort has focused on the impacts of monetary and fiscal policies With flexible exchange rates and well-integrated international capital markets, Schuh argues, tight monetary policy and/or expansionary fiscal policy induces a capital inflow and an appreciation of the currency (*23*) Agriculture and other trade sectors bear the brunt of policy adjustment as exports decline and imports rise [2]

By focusing attention on monetary and fiscal policies, Schuh and others generalize the issue of

[1] In presenting a case for the utility of VAR analysis, I will leave it to others to present alternative views This omission is by no means intended to deny the importance of the controversy Interested readers should see (*3, 7, 12*) Italicized numbers in parentheses refer to items in the References at the end of this article

[2] Though Schuh has been instrumental in calling attention to the potential effects of monetary and fiscal policies on agriculture, his articles (*24, 25*) place the impact of these policies in a broad context

macroeconomic impacts on agriculture in two important respects First, macroeconomic policies may affect agriculture through many mechanisms other than the exchange rate Potential policy effects through interest rates, national incomes, international liquidity, and other facets of the economy need to be taken into account Second, and perhaps more important, the evaluation of macroeconomic impacts on agriculture confronts the contemporary issue in macroeconomic theory of whether, and if so, when, macroeconomic policies have real impacts Establishing a link from macroeconomic policy to agriculture requires establishing avenues by which macro economic policies affect the economy Alternative models suggest quite different perspectives on this issue

Two viewpoints illustrate some of the basic macroeconomic controversies In the first, the economy is viewed in terms of a stochastic equilibrium model in which all prices are flexible, agents have rational expectations, and markets clear In such a model, anticipated changes in the money supply have known effects on nominal income and proportionate effects on individual prices and the general price level Hence, real economic activity is not affected An unanticipated monetary shock, in contrast, is partly confused with shifts in relative demand, and it induces output responses If price elasticities of supply and demand differ across markets, a monetary shock may affect relative prices and have different impacts among sectors Thus, in a stochastic equilibrium model, changes in the money supply can have real impacts, but policymakers may be unable to exploit these effects systematically to influence developments in the economy

An alternative to the market-clearing equilibrium model is an approach in which some prices are less than perfectly flexible for some medium-length period [3] Commodities fall into one of two categories fixed-price or flex-price Two crucial characteristics then distinguish the fixed-price/flex-price model from the stochastic equilibrium model First, even anticipated monetary policy may have real effects because of the inability of some prices to adjust in the short run. Second, macroeconomic policies may cause excessive price movements (price overshooting) in flex-price markets where the burden of policy impact is initially absorbed A key result is that expansionary monetary policy, though inflationary, may benefit agriculture as flexible agricultural prices rise faster than the overall price level Rausser has characterized this overshooting in response to expansionary monetary policy as a subsidy to the agricultural sector (*21*)

The study of market structure has produced a third view of the effects of inflation on agriculture The market structure approach, like the fixed-price/flex-price macroeconomic model, is characterized by a dichotomy between flexible agricultural prices and administered (that is, fixed) industrial prices In this view, increases in input and other industrial prices arising in oligopolistic or price-setting industries are not necessarily passed on to agricultural output prices, which are determined in competitive markets (*29*) Rising industrial prices place agriculture in a cost-price squeeze, so farmers experience a decline in relative prices during inflationary periods This is just the opposite of what happens in the fixed price/flex-price macroeconomic model

One can understand the discrepancy between these latter two views of the effects of inflation on agriculture in terms of alternative assumptions about the causes of price changes and the behavior of the monetary authorities In the fixed-price/flex-price model, monetary expansion causes inflation and the associated upward overshooting of agricultural prices In the market structure approach, an increase in administered industrial prices causes relative agricultural prices to fall This exogenous price shock is associated implicitly with inflation, but the linkage of rising administered prices to the money supply and monetary policy is not precise Such an autonomous price shock arising in the fixed-price sector could also generate both inflation and a decline in flexible prices relative to fixed prices in a fixed-price/flex-price macroeconomic model

Opposed to each of the preceding analyses—which, despite their differences, center on responses of the agricultural sector to developments arising outside the sector—is a fourth line of reasoning concerning macroeconomic-agricultural linkages It focuses on agriculture as a source of instability within the overall economy This concern was particularly acute

[3]See (*8*) for a further discussion of stochastic equilibrium models and (*21*) for a review of the literature on fixed-price/flex-price models

in the early seventies when food and oil prices were explosive (*2, 11, 30*) From this perspective, explaining relative agricultural price movements as a function of general price movements may have cause and effect exactly reversed Models in which exogenous macroeconomic developments are assumed to affect agriculture, with impacts from agriculture on the macroeconomy precluded, are called into question

Vector Autoregressive Models

Vector autoregressive econometric analysis begins with selecting a set of variables perceived as relevant to an economic issue under investigation These variables may be transformed to remove nonlinearity, trend, or seasonal components The modeling begins with estimation of a set of regression equations in which the current value of each variable is expressed as a function of lagged values of the selected variables No variable is assumed to be exogenous *a priori*, and no variable is excluded from the autoregressive equation for any other variable Because each autoregressive equation has the same right-hand-side regressors, ordinary least squares (OLS) provides an efficient estimation procedure

Regression analysis is quite familiar and, were analysis of VAR models to proceed on the basis of the estimated autoregressive equations, it too would be familiar However, when there are no exogenous variables, the regression equations do not have a natural interpretation The autoregressive parameters explain how each variable evolves through time, given past values of the variables in the model But the usual types of analysis, such as determining the effect of an exogenous change in an independent variable on the dependent variable, are unnatural when all right-hand-side variables themselves evolve in a way specified by the estimated equations

A more natural approach to a VAR model is to distinguish between the expected evolution of the economy (represented by the autoregressive parameters) and the deviations from this evolution occurring over time as a result of unexpected shocks These shocks are measured by the error terms of the autoregressive equations One can evaluate interactions among variables in a VAR model by examining the effects of these errors on the subsequent evolution of all variables in the model

To accomplish this task, one transforms the estimated autoregressive equations to derive a moving-average representation of the VAR. This transformation may be viewed as the outcome of a sequence of substitutions in which lagged values of right-hand-side variables are replaced by their own autoregressive equation. Each substitution backdates the values of actual variables that appear in the initial equation by one period and introduces errors from an additional lag

To illustrate, consider the transformation of a two-variable, one-lag autoregressive model

$$x_t = d_{11}x_{t-1} + d_{12}y_{t-1} + e_t$$

$$y_t = d_{21}x_{t-1} + d_{22}y_{t-1} + h_t \qquad (1)$$

where the expected values of e_t and h_t are zero and the errors are not serially correlated. If one considers just the x variable, the first step of the transformation to the moving-average representation is

$$x_t = d_{11}(d_{11}x_{t-2} + d_{12}y_{t-2} + e_{t-1}) + d_{12}(d_{21}x_{t-2} + d_{22}y_{t-2} + h_{t-1}) + e_t \qquad (2)$$

Continuing this process, one derives:

$$x_t = e_t + a_{11}e_{t-1} + \quad + \quad a_{21}h_{t-1} + a_{22}h_{t-2} +$$

$$y_t = \quad b_{11}e_{t-1} + \quad . + h_t + b_{21}h_{t-1} + b_{22}h_{t-2} + . \qquad (3)$$

where the a_{ij}'s and b_{ij}'s are nonlinear combinations of the autoregressive parameters (d_{ij}'s) [4]

An advantage of the moving-average representation compared with the autoregressive equations is that the coefficients of the moving-average representation describe exactly how a shock to a particular variable at one moment in time shifts the expected time path of each variable in the model compared with its expected evolution had the shock not occurred For example, in equations (1) - (3), the effect of a one-unit shock to variable y at time t-1 on x_t is a_{21} and on y_t is b_{21}, while the effect of a shock to y at time t-2 on

[4]The autoregressive and moving-average representations can be expressed compactly in matrix notation See (*13*) for a good discussion of the methodology

x_t is a_{22} and on y_t is b_{22} Likewise, the effect of a shock to y at time t on the expected value of some future x, say x_{t+1}, is given by a_{21}, and so on Thus, the coefficients of the moving-average representation provide impulse response functions that trace either how current values of each variable are affected by shocks in the past or how expected future values of each variable are affected by a shock today These impacts are intractable in the autoregressive parameters because a specific shock has both direct and indirect effects on the evolution of each variable Notice too that the effects of a specific shock are computed assuming no additional shocks occur. Hence, the impulse response functions describe changes induced by an initial shock assuming all variables then evolve naturally, rather than holding all else constant in the usual sense

The moving-average representation also provides a second useful measure of the impacts of the variables in the model on one another Future values of each variable are forecast assuming all future shocks have their expected value of zero Because these shocks are random, the variance of these forecasts can be computed The variance for each forecast can then be apportioned or decomposed into components due to each variable This decomposition is based on the variance of the shocks to each variable (estimated from the error terms of the autoregressive equations) and the impacts of these shocks on each forecast (estimated by the coefficients of the moving-average representation) Such a decomposition provides a preliminary assessment of dynamic interactions among the variables

One complication that often arises is that the errors associated with specific variables (for example, e_t and h_t in equations (1) (3)) are contemporaneously correlated Cross-product terms in the forecast variance expressions then make it impossible to decompose forecast error variances The usual procedure in this case is to choose a particular ordering of the variables in the model and to remove from the shock to each variable that portion which is explained by contemporaneous shocks to variables earlier in the chosen order This procedure of orthogonal ordering is equivalent to including the current value of variables earlier in the order on the right-hand-side of autoregressive equations for variables that follow This procedure imposes a recursive causality on the variables selected for analysis A particular order must be chosen as part of the specification of the model, and altering the order may affect estimates of the dynamic relationships among the variables Hence, examining models with alternative orthogonal orders provides a guide to interpreting reported outcomes and is a useful test of the robustness of specific results

Interpretation of VAR Models

The preceding discussion clarifies some of the mechanics of VAR models Their interpretation in economic analysis and their use in policy evaluation raise a related, but somewhat different, set of issues Because there are no exogenous variables in a VAR model, each variable potentially affects all other variables This generality is appealing in cases where several plausible theories have been suggested concerning the economic dynamics, but it precludes usual identification of a structural model [5]

The moving-average representation of a VAR model focuses the analysis on the error terms associated with the autoregressive equations, own- and cross-variable dynamic impacts of these shocks are evaluated Interpreting a VAR model depends on connecting each of these shocks to a specific variable in the economy Usually such a connection is made between the equations of a structural model and specific variables The autoregressive equations from a VAR model are equivalent to the reduced-form equations from such a structural model But when a reduced form is derived from a structural model, the reduced-form errors are generally linear combinations of the errors from the structural equations Thus, no direct association is made between these errors and specific aspects of the economy

Under special circumstances, dynamic effects of shocks associated with VAR equations will exactly match those of shocks to equations of a structural model This situation occurs when the structural

[5]Formal arguments favoring this approach to econometric modeling have been presented by Sims (27) He suggests that a structure based on *a priori* exogeneity and exclusion restrictions is rarely justified His argument is based on the relatively small number of distinctions that imply appealing restrictions, the difference between exogenous and lagged endogenous variables with respect to structural identification when lag length and serial correlation are not known, and the effects of expectations on the behavior of economic agents, which tend to undermine potential exclusion restrictions

model is diagonal (only lagged values of other variables enter the structural equation for each variable) or when the structural model is recursive and the orthogonal ordering of the VAR model exactly matches this recursive order

The true model of the aspects of the economy under investigation is, of course, rarely known and will not necessarily satisfy the diagonal or recursive criterion Impulse response functions from a VAR model may then misrepresent the dynamics of shocks to the true structural equations Likewise, estimates of the dynamic effects of shocks to a misspecified structural model will also misrepresent the true dynamics [6] The fundamental controversy over using VAR models in economic analysis is based on this dilemma Using a VAR model rests on the conviction that important dynamics in the economy are usefully captured by its moving-average representation

A Model of Money, Financial Markets, and Agriculture

To provide some empirical insights into the relationships among money, financial market variables, inflation, and agriculture, I specified a six-variable VAR model. Variables in the model were (1) the seasonally adjusted U S money supply (M1), (2) the interest rate on 3-month Treasury bills, (3) a trade-weighted index of the value of the dollar ($*/$) against the currencies of 10 industrial countries, (4) the general price level as measured by the U S gross national product (GNP) deflator, (5) the value of U S agricultural exports, and (6) agricultural prices as measured by the index of prices received by farmers for all crops I estimated the autoregressive parameters of the model using quarterly data from 1960(1) through 1984(3) without allowing for parameter variation during the estimation period Four lags of each variable were included in the autoregressive equations, each autoregressive equation also included constant, trend, and seasonal terms I evaluated all variables, except the interest rate, in natural logarithms To account for contemporaneous correlations among the errors, I orthogonalized the model initially in the order in which these six variables appear This order allows the greatest opportunity for macroeconomic factors to affect agriculture, and not vice versa This order also allows the greatest possible influence for the money supply variable

I estimated the parameters of the model reported here using nominal values of the interest rate, the exchange rate, the value of agricultural exports, and the index of crop prices An alternative approach is to deflate these nominal values prior to estimation Using a deflated model is appealing for this analysis because real changes can be expected to be important among sectors of the economy However, constructing deflated values prior to estimation moves the analysis away from variables that are directly observable One result is to entangle the dynamics of price-level effects with the effects of other variables [7] Furthermore, one can generally derive the real effects of specific shocks from the model estimated in nominal terms by subtracting the simultaneous effects of various shocks on the price level from their effects on other nominal variables [8] The results from a nominal model are also more directly comparable with those from macroeconomic VAR models in which construction of deflated variables has generally been avoided

Table 1 shows the R-squares and standard deviations of errors associated with the autoregressive equations from the six-variable, macroeconomic-agricultural model Table 2 reports the results of F-tests for the null hypotheses, coefficients on lags associated with particular variables are zero in each of the autoregressive equations Table 2 shows the probability of the corresponding (but not reported) F-statistic occurring if the null hypothesis were true

The F-tests in table 2 have several implications First, they show substantial evidence of macroeconomic impacts on agriculture Lagged exchange rates are significant in the equation for agricultural exports, and lags of all four macroeconomic variables are significant in the equation for agricultural prices There is also evidence of complex interactions

[6] See (*1*) and (*14*) for a further discussion

[7] In a related paper (*19*), I presented the results from a model estimated using an *ex post* real interest rate, a real trade-weighted exchange rate, and deflated values of agricultural exports and prices Interested readers may want to compare the two sets of outcomes The key conclusions from the analysis are supported by comparable results from the two approaches to estimation

[8] The derivation is not possible for the exchange rate unless the nominal model includes an index of foreign price levels

Table 1—Measure of fit and standard deviation of the errors, autoregressive equations, six-variable macroeconomic-agricultural model

Variable	R-square	Standard deviation of errors
Money supply (M1)	0 9998	0 00465
Interest rate	9568	63926
Exchange rate	9732	01914
Price level	9999	00268
Agricultural exports	9907	07698
Agricultural prices	9908	03719

among the macroeconomic variables Lagged values of both the money supply and the interest rate are significant in the money supply and interest rate equations, and lags of three of the four macroeconomic variables are significant in the exchange rate equation In contrast, only own lags are significant in the price-level equation Effects of the agricultural variables are not significant in the equations for the macroeconomic variables

Table 3 shows the decomposition of variance for forecasts 4 and 12 quarters ahead for the six-variable model. Table 3 also shows the decomposition of forecast variance for a three-variable model that includes only the money supply, the value of agricultural exports, and the index of crop prices This comparison is particularly relevant in light of past observations that the explanatory power of money supply shocks in a three-variable macroeconomic model (money supply, real output, and the price level) is reduced substantially in expanded models that also include financial variables such as the interest rate.[9] One might also compare the results from the restricted model with other recent studies of macroeconomic-agricultural linkages in which the money supply is the only macroeconomic variable included in the analysis (*4, 10*)

[9]Sims reports that the money supply variable appears largely exogenous in a three-variable VAR model with real gross national product (GNP) and the price level (that is, own shocks explain 81 percent of its forecast error variance at 14 quarters ahead) and that money shocks explain a large fraction of the variance in forecasts of real output in this model (*28*) A positive monetary shock induces a temporary rise in output and a slower, steady rise in the price level These results are consistent with shortrun real effects of monetary shocks in a stochastic equilibrium model and with the hypothesis that instability in monetary policy has been a prime cause of price and output movements in the economy In autoregressive models that include financial variables, however, the role of money shocks is substantially reduced (*26, 28*) Much of the explanatory power of money in the three-variable model is transferred to the interest rate

Table 2—Significance of the lags of each variable, autoregressive equations, six-variable macroeconomic-agricultural model

Dependent variable	Lagged variables					
	Money supply	Interest rate	Exchange rate	Price level	Agricultural exports	Agricultural prices
	Significance level of the F-statistic					
Money supply (M1)	*	*	0 306	0 890	0 767	0 480
Interest rate	**0.024**	*	484	103	725	862
Exchange rate	112	*	*	**.037**	.784	144
Price level	151	0 396	743	*	.775	244
Agricultural exports	558	767	*	081	.255	*
Agricultural prices	*	**.006**	*	**.004**	137	*

Boldface indicates cases for which there is evidence for rejecting the null hypothesis at the 95-percent confidence level
* indicates a significance level of less than 0 001

Table 3—Decomposition of 4- and 12-quarters-ahead forecast error variances, three-variable and six-variable macroeconomic-agricultural models

Variable	Quarters ahead	Shocks to—					
		Money supply	Interest rate	Exchange rate	Price level	Agricultural exports	Agricultural prices
	Number	*Percent of forecast error variance*					
Money supply	4	60.3	36 1	0 2	1 4	1 5	0 5
	12	44 1	36 0	1 5	9 6	1 5	7 3
	4	(98 4)				(2 3)	(4 3)
	12	(65 6)				(6 1)	(28 3)
Interest rate	4	39 4	55 7	7	2 4	1 3	5
	12	23 8	28 4	22 6	8 2	1 1	15 9
Exchange rate	4	3.7	30 8	58 4	3 7	1 1	2 3
	12	15 8	34 6	42 2	3 8	6	3.0
Price level	4	14.3	1 7	3 6	78 1	1 3	1 0
	12	10 5	23 9	34 1	25 6	1 4	4 5
Agricultural exports	4	3 0	4 8	12 2	9 7	55 6	14 7
	12	12 0	36 9	22 7	5 4	17 3	5 7
	4	(2 5)				(86 9)	(10 6)
	12	(2 1)				(87 7)	(10 2)
Agricultural prices	4	1 8	13 3	2 3	8 5	16 0	58 1
	12	8 5	38 2	9 8	16 2	5 5	21 8
	4	(9 8)				(37 5)	(52 7)
	12	(8 8)				(56 7)	(34.5)

Numbers in parentheses indicate decomposition of forecast error variances for a three-variable model
Blanks indicate not applicable

In the three-variable macroeconomic-agricultural model, own shocks explain almost all the variance in 4-quarter-ahead forecasts of the money supply, a substantial fraction of this variance in a 12-quarter forecast horizon is explained by shocks to agricultural prices Shocks to agricultural exports have little effect on the forecast error variance for money

Despite the relatively large proportion of own forecast error variance explained by shocks to the money supply in the three-variable model, money shocks have only slight effects on the forecast error variance of the agricultural exports and price variables Indeed, agricultural exports appear largely exogenous, whereas shocks to exports have a substantial impact on the variance of agricultural price forecasts These results seem to suggest the importance to agriculture of sectoral, rather than macroeconomic, factors

When the interest rate, the exchange rate, and the price level are added to the three-variable model, the effects of money shocks on agricultural exports and relative prices remain relatively small Three important new results emerge, however

First, the proportion of own forecast error variance explained by money shocks declines, and money shocks affect the forecast error variance for the interest rate and the exchange rate These results are consistent with outcomes from macroeconomic models that include financial variables (*9, 28*) The interest rate and the exchange rate have a strong interaction in the macroeconomic-agricultural model Their shocks jointly explain over 50 percent of the variance in interest rate forecasts 12 quarters ahead and over 70 percent of the variance in exchange rate forecasts 12 quarters ahead

Second, the fraction of forecast error variance of the agricultural variables explained by sectoral shocks falls substantially Own shocks explain only 17 3 percent of the 12-quarter-ahead forecast error variance of agricultural exports in the six-variable model, compared with 87 7 percent in the three-variable model Likewise, agricultural export and price shocks explain only 5 5 percent and 21 8 percent, respectively, of the variance of 12-quarter-ahead agricultural price forecasts (compared with 56 7 and 34 5 percent, respectively, in the three-variable model) Most of the lost explanatory power is absorbed by the interest rate and the exchange rate, in the case of agricultural exports, and by the interest rate and the price level, in the case of agricultural prices

Third, the decomposition of forecast error variance for the six-variable model suggests very limited effects of the two agricultural variables on the forecast error variances of the macroeconomic variables The proportion of M1 forecast error variance attributable to agricultural price shocks is reduced compared with the three-variable model, and the agricultural variables explain little of the forecast error variance for the additional macroeconomic variables These results are invariant to placement of the agricultural variables ahead of the macroeconomic variables in the orthogonal order

Some further insight into the economic dynamics is provided by the impulse response functions for the three- and six-variable models In the three-variable model (not shown), a money supply shock declines slowly over eight quarters A shock to agricultural exports has negligible effects on the money supply, but a shock to agricultural prices is followed by a steady decline in the expected money supply Money supply and agricultural price shocks have positive effects on expected agricultural exports, but these impacts are slight compared with a 1-standard-deviation export shock The export shock has a positive effect on agricultural prices that peaks four quarters later at a level about equal to a 1-standard-deviation price shock A money supply shock also positively affects agricultural prices peaking with a four-quarter lag, but the magnitude of this impact is small compared with the impacts of price and export shocks

The figure shows the impulse response functions from the six-variable model Each column indicates the responses of one variable over eight quarters to an initial 1-standard-deviation positive shock to each of the six variables. Thus, by looking down a column, one can assess the relative impact on a particular variable of various shocks typical of those estimated to have occurred during the sample period For the interest rate, the value of agricultural exports, and the index of crop prices, the real effects of each shock are shown in the figure (that is, the simultaneous effects of each shock on the price level have been removed from their effects on the nominal values of these variables)

One can observe several aspects to the dynamic interactions among macroeconomic variables shown in the figure A positive shock to the money supply declines slowly and steadily raises the price level A money supply shock is also followed by a modest, but fairly persistent, rise in the interest rate In contrast, an interest rate shock affects the expected interest rate for a relatively short period. It is followed by a decline in the money supply, a persistent appreciation of the U.S dollar, and a lagged decline in the price level Shocks to the exchange rate and the price level tend to persist, but have negligible effects on the money supply and the interest rate [10]

The impulse response functions for the agricultural variables also show significant cross-variable interactions In particular, the figure illustrates several macroeconomic impacts on agriculture Money supply shocks have only small effects on the value of agricultural exports and relative agricultural prices, but an interest rate shock has an effect on exports which peaks with a magnitude about 50 percent of that of an export shock itself An interest rate shock

[10]The contemporaneous correlation between shocks to the interest rate and the exchange rate is 0 45 Thus, it is probably appropriate to view these two variables as jointly representing financial markets Specific effects attributed to one or the other of these variables should be interpreted cautiously For example, the decomposition of forecast error variance shown in table 3 and the impulse responses shown in the figure suggest that interest rate shocks have substantial effects on the exchange rate If the exchange rate is placed ahead of the interest rate in the orthogonal order, however, the proportion of exchange rate forecast error variance 12-quarters-ahead which is explained by own shocks rises to 70 5 percent, whereas the proportion explained by interest rate shocks falls to 6 3 percent Likewise, the response of the exchange rate to an interest rate shock is dampened considerably Other dynamic interactions among the macroeconomic variables remain similar to those displayed in the figure, although the effect of an exchange rate shock on the price level is greater

has a somewhat larger lagged effect on agricultural prices [11] Shocks to the price level also noticeably affect agriculture An unexpected increase in the price level has a strong negative effect on relative agricultural prices

The dynamic interactions displayed in the figure have several implications in terms of the alternative views of macroeconomic-agricultural linkages Except for the fairly large effect of a money supply shock on the interest rate, there is only slight evidence of direct impacts from the money supply on either the financial market variables or the agricultural sector variables If one views the money supply variable as a policy instrument of the monetary authorities, then the empirical results show little evidence that monetary policy affects agriculture [12] Direct effects on agriculture of shocks to financial variables, particularly the interest rate, are more evident

One possibility is that financial variables are very sensitive to expectations and move quickly in response to a shift in monetary policy If changes in monetary policy are correctly anticipated and if these expectations are reflected in shocks to the financial variables before they are reflected in reported monetary aggregates, then monetary policy could still be the driving force behind the observed data patterns This possibility requires that anticipated monetary policy have real effects, a proposition consistent with the fixed-price/flex-price macroeconomic model, but not with the stochastic equilibrium model Furthermore, this view suggests that particular dynamic patterns should appear in the data For example, an increase in the interest rate that correctly reflects an anticipated tightening of the money supply should be followed by such tightening and, perhaps, by a decline in the rate of inflation Failure to observe these results has caused some macroeconomic studies to reject this possibility (*17, 26*) However, responses to interest rate shocks in some macroeconomic studies (*9*) and responses to interest rate and exchange rate shocks in the figure support this interpretation

With respect to the general price level, the impulse responses shown in the figure do not suggest that price-level shocks arise in response to anticipated monetary policy (that is, the figure does not suggest that anticipated monetary expansion causes prices to rise now) Price-level shocks are not followed by changes in the money supply, and they cause relative agricultural prices to fall without an initial increase These results are consistent with the view that autonomous price increases in nonagricultural sectors place agriculture in a cost-price squeeze, but not with the notion of monetary-induced inflation and overshooting of flexible agricultural prices (in which case one might expect a positive price-level shock to be associated with an initial increase in relative agricultural prices and to be followed by an increase in the money supply)

Finally, with respect to agriculture as a source of instability in the overall economy, neither the decomposition of variance nor the impulse response functions from the six-variable model demonstrates substantial macroeconomic impacts arising from the agricultural export and price variables These outcomes are not altered appreciably when the agricultural variables are placed before the macroeconomic variables in the orthogonal order This result suggests that macroeconomic-agricultural linkages are primarily from macroeconomic developments to agriculture, not vice versa

Conclusions

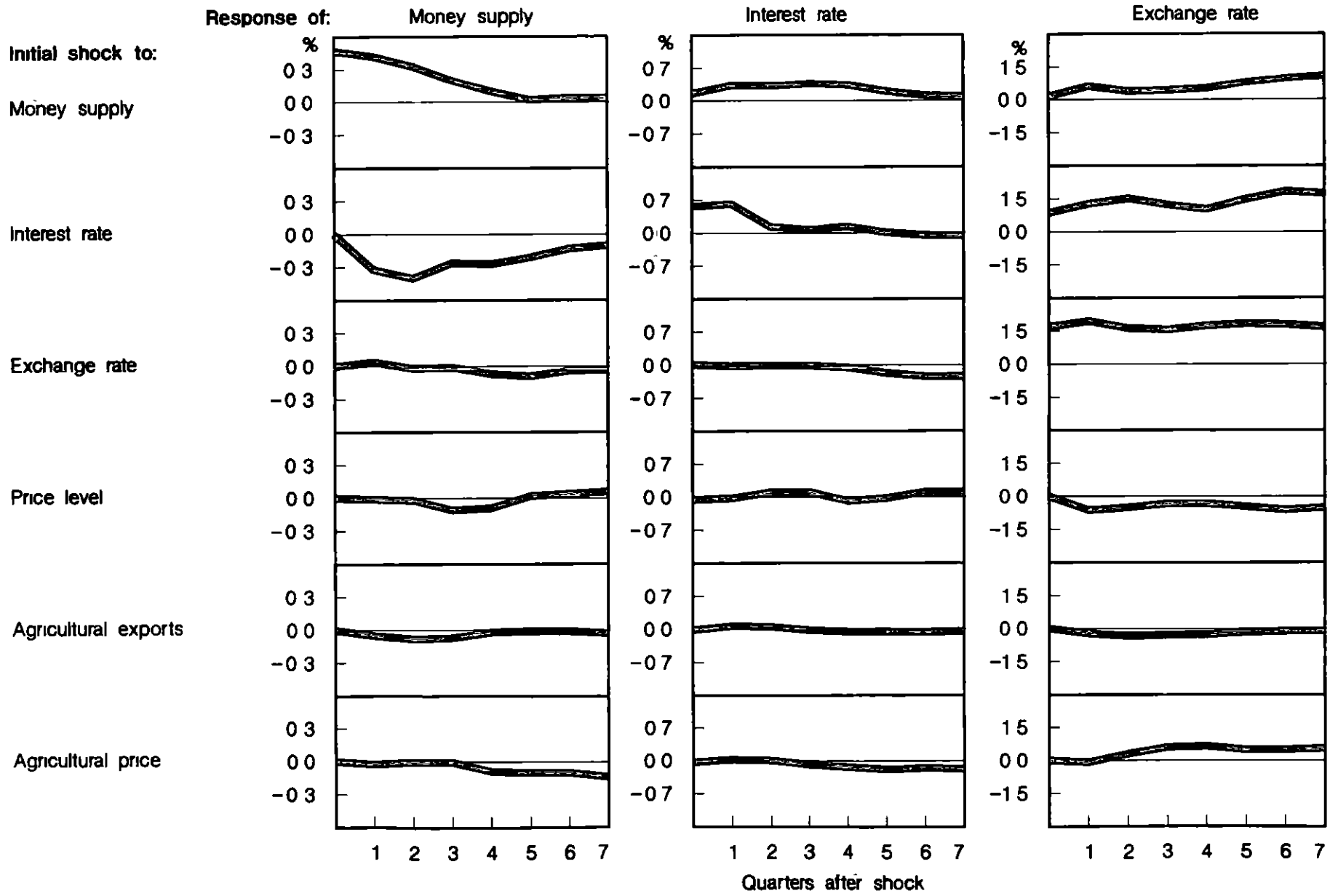
The relationships among monetary and agricultural variables have been at the center of recent discussion of macroeconomic impacts on agriculture Even so, definitive empirical evaluation of specific linkages has remained elusive In this article, I have specified three- and six-variable VAR models and evaluated interactions among the money supply, the interest rate, the exchange rate, the general price level, and agricultural exports and relative prices

The results suggest that there may be good reason for the ambiguity that characterizes discussion of

[11] In the results displayed in the figure, an exchange rate shock has a small effect on agricultural exports and little effect on agricultural prices Again, these results are sensitive to the orthogonal order When the exchange rate precedes the interest rate, the effects of an exchange rate shock on the agricultural variables exceed those of an interest rate shock An unexpected appreciation of the dollar depresses subsequent agricultural exports and prices

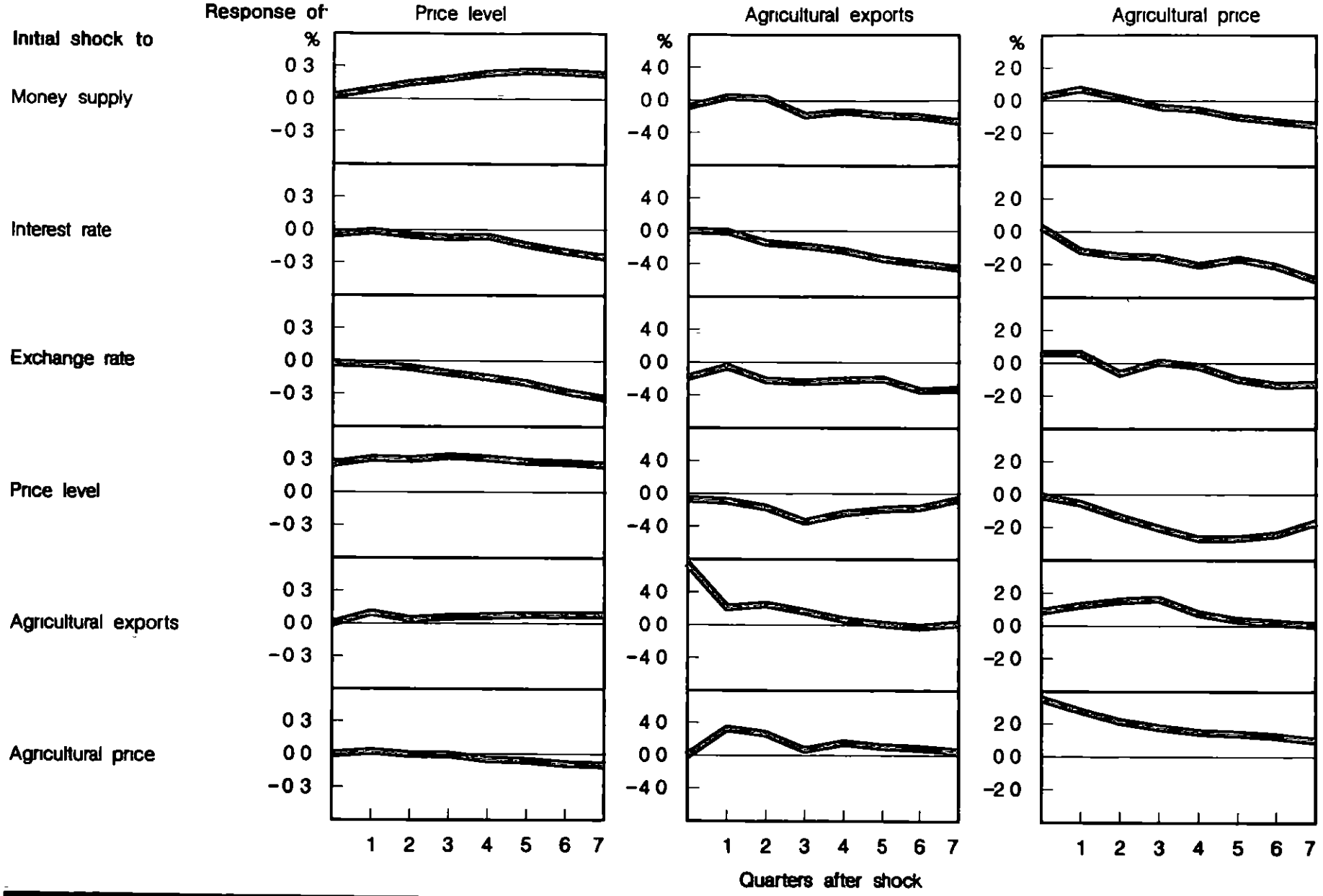
[12] Somewhat greater effects of money supply shocks on relative agricultural prices are suggested by a model estimated in deflated terms (see *19*)

Impulse Response Functions, Six-Variable Macroeconomic-Agricultural Model



Continued

Impulse Response Functions, Six-Variable Macroeconomic-Agricultural Model



macroeconomic-agricultural linkages Several linkages among macroeconomic and agricultural variables are isolated, and a number of these are quite important In particular, there is strong evidence both for the effects of financial variables on agricultural exports and prices and for the effects of autonomous changes in the price level In contrast, there is little evidence of impacts on the macroeconomic variables arising from shocks to agricultural exports or prices

Specific shocks are associated with specific variables in a VAR model Interpreting the results of these models as a basis for policy analysis must rest on this association of errors and variables, on the ability of policymakers to manipulate specific variables, and on such manipulation not affecting the estimated parameters of the model One interpretation of the results I have presented is that shocks associated with financial markets (that is, the interest rate and the exchange rate) are independent of policy intervention From this point of view, monetary policy does not have powerful effects on agricultural exports or relative prices Autonomous financial market shocks have greater effects on agriculture, but are not subject to control by macroeconomic policymakers

An alternative interpretation of the results is that monetary authorities may induce interest rate or exchange rate shocks through the instruments they control This control could be exerted directly or because changes in monetary policies affect financial market variables before they are recorded in money stock data.[13] In either case, the impact of monetary policy on agricultural exports and prices would be more pervasive than under the first interpretation Dynamic responses in the VAR model are consistent with the latter possibility

This point is clear when one applies similar considerations to the price-level variable Price-level shocks could also reflect monetary decisions In that case, one would expect an increase in the price level to affect agricultural prices like a decline in the interest rate This situation does not occur, suggesting a different interpretation price shocks not associated with monetary policy depress relative agricultural prices This interpretation is consistent with the hypothesis of agriculture's being caught in a cost-price squeeze, but not with the hypothesis of monetary-induced overshooting of flexible agricultural prices Such an outcome does not fit easily into recent analysis of the disinflationary effects of tight monetary policy and its specific effects on agriculture Even so, the data display strong evidence of such a phenomenon

[13]Litterman treats the Federal funds rate as an indicator of monetary policy and evaluates the impacts of changes in this rate on the money supply, other financial variables, and the real economy (*16*) A change in the Federal funds rate is assumed to affect the 3-month Treasury bill rate, stock prices, and the value of the dollar contemporaneously, but to affect the money supply only after a 1-month lag

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Nonfarm families typically have higher money incomes than farm families but lower net worths Considerable public money is channeled into the farm sector via farm commodity programs, directly affecting the level of well-being as measured here Economists often argue that many of the benefits from farm programs get capitalized into land values and thus may affect the level of net worth more than money income This is because benefits are tied directly to land resources rather than family need If these programs were expanded until the level of money income of farm families equaled that of nonfarm families, the economic well-being of farm families might well exceed that of the nonfarm group From society's point of view, it may be more desirable to provide direct income support to families in the farm sector than to further enhance the level of net worth

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