Capital Flows, the Exchange Rate, and Agricultural Commodity Markets

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ABSTRACT

The impact on agricultural commodity markets of the exchange rate and other macroeconomic factors is addressed in this dissertation. The price-adjustment role of the exchange rate is analyzed in a general equilibrium trade model, and relative impacts on the world corn market of macroeconomic and sector-specific factors are evaluated for the period 1970-1980.

In the general equilibrium model, a trade imbalance induce a shift in equilibrium prices, with the primary impact that the price of the nontraded good relative to traded goods rises in the deficit country and falls in the surplus country. Appreciation of the currency of the deficit country may facilitate these relative price movements. The efficacy of monetary and exchange-rate policies depends on the monetary specification. When exchange rates are fixed, these policies affect market equilibrium: income transfers are induced by policy actions. When exchange rates are flexible, monetary policy has no real effects.

On the basis of these considerations, partial equilibrium analysis of exchange-rate effects on particular markets is critically reviewed. That constraints on exchange-rate elasticities of price and export quantity derived from such analysis--constraints that have played a central role in the debate regarding the magnitude of exchange-rate impacts on agriculture--simply need not apply to deflated prices and the real exchange rate is illustrated.

To assess the relative impact on agriculture of macroeconomic versus sectoral factors, parameters of a 12-variable vector autoregressive (VAR) model are estimated. Shocks to the value of the U.S. dollar, to income transfers from the U.S. to others, and, to a lesser extent, to the oil sector, as well as shocks arising within agriculture, are identified as sources of unanticipated corn-market developments. Specifically, effects on U.S. corn exports attributed to agricultural factors exceed those of specific macroeconomic factors in seven of eleven years. Macroeconomic effects on exports are broadly distributed among the exchange-rate, income-transfer, and oil-sector variables. Exchange-rate effects are more dominant as a source of unanticipated price developments: exchange-rate effects exceed those of other macroeconomic variables in eight of eleven years. Exchange-rate effects on price also exceed effects attributed to agricultural variables in eight years.

PREFACE

Perhaps it is appropriate that a thesis on the subject of transfers be dedicated simply to debts. The most tangible that I have incurred (to the Federal government by way of student loans) will be the most easily repaid. My suspicion is that taxes on additional earnings will more than offset the interest rate subsidy.

Quite the opposite, intellectual debts to my committee members are likely to go unpaid in a lifetime. G. Edward Schuh provided unwavering support. Contributions by others were timely and essential.

My family, of course, had to bear with me throughout. There were some low moments, but the route has taken us some interesting places. My wife, Denise, helped greatly with perspective and production; neither a small task. Hopefullly there will be enough time for us to share benefit.

Debts to my parents for their guidance and support will also, I hope, be repaid: in kind to the next generation if not directly.

So.... to debts. Despite their burden, we should be less well-off without them.

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I. INTRODUCTION

PROBLEM STATEMENT: MACROECONOMIC VERSUS SECTORAL IMPACTS ON AGRICULTURE

Just over a decade ago, G. Edward Schuh suggested that the value of the U.S. dollar during the post-World-War-II era was an important omitted variable explaining developments in the U.S. farm sector. The exchange rate pegged at an overly high value, Schuh reasoned, had discriminated against export and import-competing industries, including agriculture. Tight monetary and fiscal policies, induced by concern with a persistent gold outflow and trade deficit, had further exacerbated resource adjustment flows, placing agriculture in a double squeeze.

The proposition that the exchange rate plays a crucial role in agricultural commodity markets has generated considerable debate among agricultural economists. Schuh's thesis was initially interpreted, rightly or wrongly, as suggesting that devaluations of the dollar in the early 1970s were a primary determinant of subsequent increases in agricultural prices and export quantities. That this suggestion was received somewhat skeptically is not surprising, given the relative magnitudes of the devaluations and of price developments. Deflated U.S. prices of corn, soybeans, and wheat rose 90.2, 95.0, and 167.0 percent, respectively, from 1971 to 1974, while the value of the dollar declined less than 25 percent. The antithesis was simply that other factors, particularly sector-specific factors, had a larger causal role with respect to these price movements.

More recently, since 1980, large exchange-rate realignments relative to agricultural price movements have enhanced reception of the notion of significant exchange-rate impacts. The observed facts are not at variance with the further suggestion by Schuh (1976, 1979, 1983) that the burden of monetary and fiscal policies is borne more directly by trade sectors under flexible than fixed exchange-rate regimes, if there are well-integrated world capital markets. With flexible exchange rates, the reasoning is, tight monetary policy induces high interest rates, a capital inflow, and appreciation of the currency. Relative prices turn against traded goods and the output of trade sectors is constrained. In short, the desired capital inflow is realized by deterioration of the trade balance. Under fixed exchange rates, in contrast, tight monetary policies have a broader effect on interest-rate-sensitive industries throughout the economy, but less direct effect on trade sectors.

Some prima facia evidence favoring the assertion that macroeconomic factors have had a large influence on agriculture is presented in Table 1.1. The rate of increase in the real value of U.S. agricultural exports during the 1970s was over eight times that achieved during the preceeding decade. The value of agricultural exports rose from $10.1 billion in 1970 to $26.9 billion in 1980, in constant 1975-dollars. This expansion ocurred during a period in which the exchange value of the U.S. dollar was relatively low. This period followed devaluations in 1971 and 1973, breakdown of the Bretton-Woods

Table 1.1 Agricultural trade of the United States, summary statistics, 1960-1983

	Agricultural Exports		
	Nominal Value (billion dollars)	Real Value (billion constant 1975 dollars)	Proportion of Total Value of Merchandise Exports (percent)
1960	4.8	8.7	23.5
1965	6.2	10.6	22.9
1970	7.3	10.1	17.1
1971	7.7	10.2	17.7
1972	9.4	12.1	19.2
1973	17.7	21.4	25.2
1974	21.9	23.9	22.5
1975	21.8	21.8	20.4
1976	23.0	21.7	20.2
1977	23.6	20.9	19.8
1978	29.4	24.2	20.8
1979	34.7	25.7	19.4
1980	41.2	26.9	19.0
1981	43.3	25.6	18.9
1982	36.6	20.4	17.7
1983	36.1	19.5	18.4

Source: U.S. Department of Agriculture, _U.S. Foreign Agricultural Trade Statistical Report_ (Washington, D.C., 1983).

monetary conventions, the shift to a regime of flexible exchange rates, and development of well-integrated world capital markets, associated, in part, with the recycling of OPEC oil revenues. Nonagricultural sectors of the U.S. economy also became increasingly trade oriented during this period. As a consequence, the proportion of the total value of U.S. exports attributed to agriculture exhibits no upward trend, despite the farm export boom. Likewise, from 1981 to 1983, as the value of the dollar rose sharply, a decline of 16.6 percent in the nominal value of agricultural exports has been matched by a similar decline of 13.9 percent in the value of nonagricultural exports.

RESEARCH OBJECTIVES

The role in agricultural commodity markets of the exchange rate and, more generally, other macroeconomic factors is investigated in this dissertation. Though Schuh's proposition draws implicitly on a specification of the workings of the macroeconomy, much of the discussion of the magnitude of exchange-rate effects on agriculture has been based on conceptual and empirical analysis with a strongly partial equilibrium, market-specific character (e.g., Kost, 1976; Bredahl, 1976; Chambers and Just, 1979; Collins, Meyers, and Bredahl, 1980; Chambers and Just, 1981; Longmire and Morey, 1982). The partial equilibrium approach has an historical analog in the elasticities approach to the balance of payments (e.g., see Dornbusch, 1975). Focus of a partial equilibrium analysis is solely on the response of a selected subset of all prices (often only one) to an exogenous change in the exchange rate, with income and other prices assumed constant. Neither an explanation of exchange-rate determination nor an account of the simultaneous impact of the exchange rate on many markets is offered.

The effort to understand the role of the exchange rate in goods markets is explored in a wider context in this study. The effects on equilibrium relative prices of a shift in the trade balance are evaluated in a general equilibrium model. An imbalance in trade may occur as a result of loans or foreign-aid granted from one country to another. In either case, income is transferred from the surplus country to the deficit country, at least for the given time period, and relative prices must adjust to maintain market equilibrium. In the case of a loan, any imbalance in trade in goods is associated with an equivalent capital flow. The lending country incurs a trade surplus and capital outflow, and the borrower a trade deficit and capital inflow.

The effects of the trade balance on equilibrium nominal prices and, conversely, the impact of monetary policies can be determined explicitly if the trade model is appended to characterize demand for money and a monetary regime. A framework in which to evaluate the role of the exchange rate in goods markets is provided in this case. Two concepts emerge as crucial: the potential of the exchange rate, versus prices of specific commodities, to accomodate price shifts induced by transfers of income via the trade balance, and dependence of the efficacy of monetary and exchange-rate policies on the extent of control asserted by the monetary authorities.[1]

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[1] Previous papers that have attempted to expand on partial equilibrium analysis of exchange-rate effects on agricultural markets (e.g., Van Duyne, 1979; Lawrence and Lawrence, 1982) have drawn on portfolio balance theory to emphasize the storable quality of agricultural

The role of the exchange rate in the context of the trade model suggests a significant modification of the analysis of exchange-rate effects as commonly undertaken in a partial equilibrium framework. The first objective of this study is to critically evaluate such partial equilibrium analysis as it has been applied to the agricultural sector. To argue that reliance on partial equilibrium analysis has resulted in failure to recognize the potential magnitude of exchange-rate effects on particular markets is one burden of the evaluation. This results from the absence of an association of the exchange rate and capital flows in a partial equilibrium context. A second burden of the evaluation is to suggest that lack of an explanation of exchange-rate determination in partial equilibrium analysis has resulted in too little consideration of the policy implications of observed interactions between the exchange rate and goods-market variables.

Having developed these points, the second objective of this study is to reconsider empirical evidence that has been presented concerning exchange-rate effects on agricultural commodity markets. Recent attempts to quantify the magnitude of these effects have resulted in a wide range of estimates. Past studies have suffered from one or more serious deficiencies: partial-equilibrium constraints were imposed on exchange-rate effects, the exchange rate was the only macroeconomic variable considered, or the structural specification of the model did not facilitate comparison of the relative impacts attributable to sectoral

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commodities and the role of asset markets. The approach undertaken in this dissertation differs from these studies by emphasizing the distinction between traded and nontraded goods and the role of the exchange rate in accomodating goods-market equilibrium.

versus macroeconomic factors.

To provide a more coherent analysis of the magnitude of the macroeconomic, as opposed to the more narrowly sector-specific influences on agriculture, an analysis of the world corn market is undertaken. Macroeconomic and sectoral sources of unanticipated developments in U.S. corn exports and price during the 1970s are identified.

The empirical analysis presented herein is based principally on estimation of the parameters of a 12-variable vector autoregressive (VAR) model. A VAR model provides a framework for dynamic analysis of economic time-series without imposition of a priori restrictions on interactions among variables. Focus of a VAR analysis is on the effects of unanticipated shocks on the expected future values of variables in the model.

The 12-variable VAR model developed in this study provides a basis for assessing the strength vis à vis agriculture of the association among income transfers, the exchange rate, and goods markets that is implied by a general equilibrium analysis. At the same time, other possibilities are not precluded: the possibility that agricultural-market developments arise primarily from factors within the sector, the possibility of measurable sectoral influence on the macroeconomy (as suggested by Van Duyne, 1979, or Fischer, 1981), or the possibility of monetary phenomena, such as short-run overshooting of some equilibrium prices, that do not arise in the general equilibrium model (e.g., Barnet, 1980; McCalla, 1982).

AN OVERVIEW OF THE DISSERTATION

A critique of partial equilibrium analysis of exchange-rate effects on specific markets is presented in Chapter II. The partial equilibrium analysis of exchange-rate impacts on a single market is reviewed. The role of the exchange rate in the general equilibrium trade model is then introduced, and limitations inherent in a partial analysis are evaluated in light of the general equilibrium approach. An effort is made to keep presentation of the general equilibrium model nontechnical, in order to facilitate clarification of the relevent issues. Chapter II closes with a discusion of policy impacts under fixed versus flexible exchange-rate regimes. Comparative-static properties of the general equilibrium model are considered in an appendix. An explicit illustration of the failure of partial equilibrium analysis to appropriately quantify the effects of a change in the real exchange rate on deflated prices, and the inadequacy of past multi-market extensions of partial equilibrium analysis as a basis for evaluating exchange-rate effects are also examined in appendices.

In Chapter III, the relative magnitude of the effects on the world corn market of shocks to macroeconomic versus sectoral factors are evaluated for the period 1970-1980. Theoretical concepts underlying the VAR methodology are reviewed, and the use and interpretation of VAR models in an economic context is considered. Variables selected as a basis for the analysis are described, choice of an orthogonal order among the variables included in the corn-market model is examined, and forecast errors from the model are reported. Estimated interactions among variables (impulse response functions) are then evaluated, and sources of unexpected developments in U.S. corn exports and price are identified. That shocks to income transfers, the exchange rate, and to a lesser extent the oil sector, as well as shocks to agricultural variables, had a strong impact on corn markets is shown. By way of comparison, estimated paramaters of a possible structural model of the world corn market--based on the variables included in the VAR model, but treating macroeconomic and some sectoral variables as exogenous--are reported in an appendix. These latter results facilitate comparison of the inferences drawn in Chapter III to those drawn from previous studies of the relative influence on agriculture of macroeconomic versus sectoral factors.

II. EXCHANGE-RATE EFFECTS: PARTIAL EQUILIBRIUM ANALYSIS AND A GENERAL EQUILIBRIUM MODEL

INTRODUCTION

Partial equilibrium analysis of the effects of the exchange rate on goods markets is critically reviewed in this chapter. The limitations inherent in such analysis have been recognized to various degrees within past literature, but often they are only briefly noted. The limitations of a partial equilibrium analysis are highlighted herein. The role of the exchange rate is evaluated in the context of a general equilibrium model of a world economy in which there are traded and nontraded goods. Partial equilibrium analysis of exchange-rate effects on goods markets is shown to be consistant with this evaluation of the role of the exchange rate only under very specific conditions. Based on the properties of the general equilibrium model, some questions are then raised about the source of macroeconomic impacts on agriculture.

A PARTIAL EQUILIBRIUM ANALYSIS

In its simplest version, a partial equilibrium analysis focuses on a particular good, say the i-th good, assumed to be traded between two countries. Residents of each country (denoted the home and foreign country, the latter indicated by an asterisk in the notation) evaluate nominal prices and income in their local currency. Arbitrage and the absence of transportation costs or trade barriers imply that prices of traded goods are linked by the exchange rate. Hence, $p^*_i = ep_i$, when the exchange rate is defined as $e = S^*/S$.

To make the model specific, assume that the home country is the exporter of the i-th good. Excess supply from the home country and excess demand in the foreign country are implicitly derived from the general functions

$$\text{(1)}\quad \begin{aligned} &\text{a)}\quad ES_i = S_i(p_1, \ldots, p_n) - D_i(p_1, \ldots, p_n, I) \\ &\text{b)}\quad ED^*_i = D^*_i(p^*_1, \ldots, p^*_n, I^*) - S^*_i(p^*_1, \ldots, p^*_n) \end{aligned}$$

where n is the number of goods in the economy, supply functions are increasing functions of own-price and homogeneous of degree zero in prices, and demand functions are decreasing functions of own-price and homogeneous of degree zero in prices and income. For purposes of a partial equilibrium analysis, however, these functions are treated as dependent on own-price only. Excess-supply and excess-demand functions are then defined by

$$\text{(2)}\quad \begin{aligned} &\text{a)}\quad ES_i(p_i) = S_i(p_i: \ldots) - D_i(p_i: \ldots) \\ &\text{b)}\quad ED^*_i(ep_i) = D^*_i(ep_i: \ldots) - S^*_i(ep_i: \ldots) \end{aligned}$$

where $\partial ES_i/\partial p_i > o$ and $\partial ED^*_i/\partial ep_i < 0$. Equilibrium is characterized by the condition

$$\text{(3)}\quad q_i = ES_i(p_i) = ED^*_i\,(ep_i)$$

Changes in the exchange rate are taken as exogenous in a partial equilibrium model. The effects of a change in the exchange rate in the market for the i-th good are measured by related changes in equilibrium price, p_i, and exports, q_i. Algebraically these results are derived by differentiating (2) in light of (3) to find

$$\text{(4)}\quad \begin{aligned} &\text{a)}\quad E_{p_i} = \frac{e\,dp_i}{p_i\,de} = \frac{-z^*_{ii}}{z^*_{ii} - \varepsilon_{ii}} \qquad -1 \le E_{p_i} \le 0 \\ &\text{b)}\quad E_{q_i} = \frac{e\,dq_i}{q_i\,de} = \frac{-z^*_{ii}\varepsilon_{ii}}{z^*_{ii} - \varepsilon_{ii}} \qquad -\varepsilon_{ii} \le E_{q_i} \le 0 \end{aligned}$$

where z^*_{ii} is the elasticity of foreign excess-demand with respect to own-price and ε_{ii} is the elasticity of home country excess-supply with respect to own-price.

A linear version of the partial equilibrium model is shown graphically in Figure 2.1. A standard interpretation of a devaluation by the exporting country is illustrated. For given values of p_i, the foreign price p^*_i falls, increasing the quantity demanded abroad and reducing foreign supply. To maintain equilibrium, home currency price, p_i, and exports, q_i, both rise.

Partial equilibrium analysis implies that price response to a change in the exchange rate is less than proportionate, while export quantity response is constrained by supply price-elasticity, as shown by (4). These constraints have played an important role in the controversy regarding the magnitude of exchange-rate impacts on agriculture. Assessment of the tightness of these constraints gave rise to two initial analytic issues. The first issue had to do with the appropriate magnitude of the price elasticities appearing in the expressions. The implication of these being elasticities of excess supply and excess

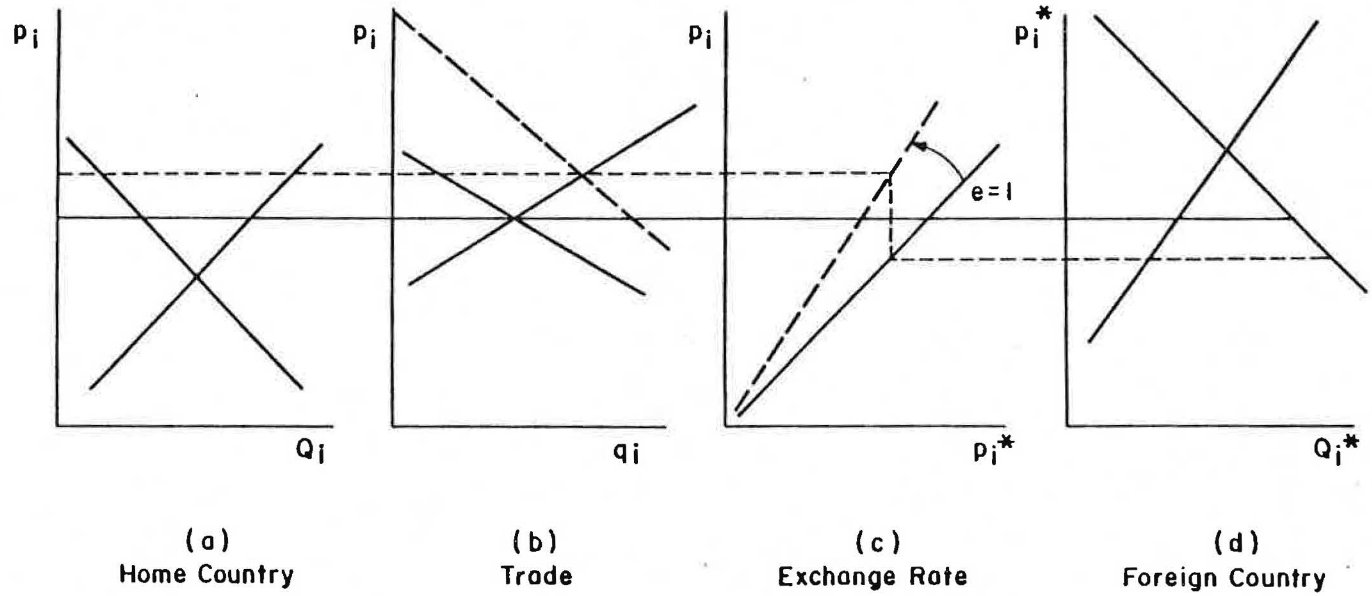

Figure 2.1 Effects of devaluation in a partial equilibrium model of one market, standard interpretation (nominal income implicity held constant and no cross-price effects)

demand--that the constraints are less binding than would be the case if elasticities of underlying total supply and demand were to apply--is now widely understood. The second issue has to do with the effects of exchange rates when some countries insulate their domestic markets from fluctuations in world prices. The partial equilibrium analysis depends on transmission of exchange-rate movements into effects on foreign price. With trade interventions the price transmission mechanism may fail, reducing exchange-rate impacts (Bredahl, Meyers, and Collins, 1979).

Regardless of specification on these points, the partial equilibrium constraints (4) place rather strong restrictions on the absolute magnitude of the impact of a given change in the exchange rate. Within these limitations, interpretation has varied. The constraint that percentage change in price never exceeds percentage exchange-rate shift has been cited as supportive of the case for limited impacts, especially when applied to observed data from the early 1970s (Collins, Meyers, and Bredahl, 1980). Even so, in defense of his position, Schuh (1975) asserts only that a 13-percent devaluation could result in an increase in the relative price of agricultural products of 10 percent. Schuh's analysis is also consistent with imposition of partial equilibrium constraints. More recently, D. Gale Johnson (1982) has suggested there will be a change in the export price of U.S. grains and soybeans of 0.6 to 0.7 percent six months following a 1-percent change in the exchange rate.

A GENERAL EQUILIBRIUM MODEL

A Model of Goods Markets

To understand some of the conceptual limitations inherent in a partial equilibrium analysis of exchange-rate effects on a particular market, it will be instructive to consider the role of the exchange rate in a general equilibrium trade model. To develop this analysis, consider a competitive-economy model in which there are two countries (denoted by superscripts k = 1, 2). Let each country be endowed per unit of time with a fixed quantity of three factors of production. These endowments (denoted $\ell^k = (\ell_1^k, \ell_2^k, \ell_3^k))$ are taken to be completely and costlessly mobile among industries within a country but completely immobile between countries.

Within a country, endowments of productive factors may be used to produce three consumption goods. The first two goods (denoted by subscripts i = 1, 2) are assumed to be traded internationally with no barriers to free trade and zero transportation costs. The third good (denoted by subscript i = 3) is assumed not to be traded between countries. Absence of trade of the third good may be attributed to either technological factors or high (and in the limit, infinite) transportation costs.

In the trade model, transformation of factors of production into consumption goods is assumed to be based on production functions

$$(5) \qquad y_i^k = f_i^k(\ell_{1i}^k, \ell_{2i}^k, \ell_{3i}^k) \qquad (i = 1, 2, 3 \quad k = 1, 2)$$

where (ℓ_{ji}^k) is the quantity of the j-th factor used in the production of the i-th good in country k. Production functions are defined for all non-negative values of their arguments and are assumed to be continuous, nondecreasing in each argument, concave, and positively homogeneous of degree one.

Given a country's resource endowment, the efficient set of feasible production possibilities $y^k(\ell^k)$, is the set of all vectors of outputs $y^k = (y_1^k, y_2^k, y_3^k)$ such that each good is produced according to the appropriate production function and total use of productive factors satisfies the constraints

$$(6) \qquad \sum_{i=1}^{3} \ell_{ji}^k \le \ell_j^k \qquad (j = 1, 2, 3)$$

For a given vector of prices, $p^k = (p_1^k, p_2^k, p_3^k)$, the value of national production is $p^k \cdot y^k$. Equilibrium output will maximize the value of national production over the feasible production set. If the equilibrium output combination is unique for each price vector, then single-valued national supply functions, which are homogeneous of degree zero in prices (for fixed ℓ^k), may be defined by

$$(7) \qquad y_i^k = Y_i^k (p^k, \ell^k) \qquad (i = 1, 2, 3 \quad k = 1, 2)$$

In this case (which will be assumed), the production possibility frontier is strictly concave and production occurs at a point of tangency between the production surface and a plane defined by output prices: a three-dimensional version of our usual notion of output determination.[2] The value of national output is then described by

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[2]Output prices determine equilibrium output quantities uniquely (for fixed factor endowments) if there are three factors of production and, given prices and factor endowments, a country produces all three goods, or if there are only two factors of production and a country

$$\pi^k(p^k, \ell^k) = p_1^k\ Y_1^k(p^k, \ell^k) + p_2^k\ Y_2^k(p^k, \ell^k)$$
$$+ p_3^k\ Y_3^k(p^k, \ell^k) \qquad (k = 1, 2) \tag{8}$$

Given that production functions are nondecreasing in all arguments, resources will be fully employed.

On the consumption side, let preferences in each country be represented by an aggregate utility function, assumed to be twice continuously-differentiable, strongly increasing in each argument, and strictly quasi-concave. Let $x^k = (x_1^k, x_2^k, x_3^k)$ be a consumption vector. Market behavior, based on maximizing aggregate utility subject to disposable national income, may be described by single-valued and continously-differentiable aggregate demand functions

$$x_i^k = h_i^k(p^k, I^k) \qquad (i = 1, 2, 3 \quad k = 1, 2) \tag{9}$$

where I^k is income. Demand functions (9) are homogeneous of degree zero in prices and income.

The role of the trade balance arises in determination of disposable income in each country. Income in a given time period has two components: the value of national production, $\pi^k(p^k, \ell^k)$, and the value of the country's balance on goods-trade account (defined as the value of imports less the value of exports). A trade imbalance creates

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specializes in the production of its nontradeable and one export good. In the case of three factors of production, if a country specializes in production of any two goods, then the production possibility frontier is a ruled surface and output quantities are not uniquely determined by prices.

a transfer to the deficit country of part of the surplus country's production of traded goods. At a given set of prices, the consumption possibility set of the surplus country is reduced and that of the deficit country is increased.

Formally, if it is assumed that country one (k = 1) is the surplus country and country two (k = 2) is the deficit country, the value of the trade balance, in the domestic prices of each country, may be expressed as

$$D^k = (-1)^k(p_1^k v_1 + p_2^k)t \qquad (k = 1, 2) \tag{10}$$

where v_1 is a fixed coefficient that determines the ratio between goods one and two in which the trade balance is measured, and t is a parameter, assumed initially to be non-negative and determined exogenously, which indicates the magnitude of any imbalance. Using this definition, a change in the parameter t may not be reflected by a proportionate change in the trade balance, since t affects its value directly and through changes in prices. From (8) and (10), disposable incomes, in domestic prices, are given by

(11)

$$\text{a)} \quad I^1 = \pi^1(p^1, \ell^1) - (p_1^1 v_1 + p_2^1)t$$

$$\text{b)} \quad I^2 = \pi^2(p^2, \ell^2) + (p_1^2 v_1 + p_2^2)t$$

Incomes are functions of endowments, prices, and the transfer parameter, t. Aggregate demand functions may now be defined by

$$X_i^k(p^k, t, \ell^k) = h_i^k(p^k, I^k) \qquad (i = 1,2,3 \quad k = 1, 2) \tag{12}$$

Excess-demand functions are then defined by

$$(13) \qquad Z_i^k(p^k, t, \ell^k) = X_i(p^k, t, \ell^k) - Y_i^k(p^k, \ell^k)$$

$$(i = 1,2,3 \quad k = 1, 2)$$

The distinction between traded and nontraded goods has an important implication with respect to conditions for goods-market equilibrium. For traded goods, the world market must clear, whereas for nontraded goods, a separate market must clear within each country. Hence, there are four markets to consider in the trade model (two world markets for traded goods and a market for each nontraded good). Applying Walras' Law, equilibrium conditions can be expressed as

$$\text{a)} \quad Z_2^1(p_1^1, p_2^1, p_3^1, t, \ell^1) + Z_2^2(p_1^2, p_2^2, p_3^2, t, \ell^2) = 0$$

$$(14) \quad \text{b)} \quad Z_3^1(p_1^1, p_2^1, p_3^1, t, \ell^1) = 0$$

$$\text{c)} \quad Z_3^2(p_1^2, p_2^2, p_3^2, t, \ell^2) = 0 .$$

In a nonmonetary model (i.e., $p_i^1 = p_i^2$ for i = 1, 2), standard arguments can be used to establish the existence of goods-market equilibrium for some vector of positive prices $(p_1^1, p_2^1, p_3^1, p_3^2)$. The equilibrium conditions (14) can be solved for three relative prices, say p_2^1/p_1^1, p_3^1/p_1^1, and p_3^2/p_1^1.

Equilibrium conditions (14) provide a basis on which to evaluate the effect of an exogenous change in the trade balance on relative prices. An increase in the trade surplus of a country lowers its disposable income, and raises disposable income in the deficit country.

Generally, demand for all goods, including the nontraded good, will fall in the former and rise in the latter. That the equilibrium price of the nontraded good must fall relative to at least one traded good in the surplus country and rise relative to at least one traded good in the deficit country can be shown formally under very broad assumptions (Chipman, 1974).[3] In particular, if the terms of trade do not change between traded goods, then the price of the nontraded good must fall relative to prices of both traded goods in one country, and rise relative to prices of both traded goods in the other. Essentially, equilibrium is maintained in the nontraded-good market of the surplus country, where demand falls due to the decline in income, by a strengthening of demand and reduction in supply induced by a decline in the relative price of the nontraded good. The opposite occurs in the deficit country: relative price shifts partly choke-off increased demand for the nontraded good that results from higher income, and production of the nontraded good is increased.

The effects of a change in the trade balance on equilibrium relative prices among traded goods is less definite than the effect on the relative prices of nontraded goods versus traded goods. A decline in demand for a traded good in the surplus country is offset to some degree by an increase in demand for the same good in the deficit country. The net impact on relative prices among traded goods depends on preferences and production decisions in both countries, in contrast to shifts in the prices of nontraded goods relative to traded

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[3] See Appendix A for further consideration of the comparative static properties of the general equilibrium model.

goods, which depend primarily on changes within a country.

Thus, two distinct types of price effects are associated with a change in the trade balance in a general equilibrium model. The fundamental effect is to create shifts in prices of nontraded goods relative to traded goods, the direction of the shift being negative in the surplus country and positive in the deficit country. Secondarily, shifts in relative prices among traded goods may be induced. There is no clear presumption as to the direction of the impact of a change in the trade balance on relative prices among traded goods.

The Role of the Exchange Rate

Analysis of the effects of a change in the trade balance on relative prices sets the stage for evaluation of the potential price adjustment role of the exchange rate. To consider this issue, it is necessary to introduce monies explicitly. It may be assumed that each country has a monetary authority that maintains its own currency and central bank, that the money of each country is held only by residents of the country, and that residents evaluate nominal prices and income in terms of their own domestic currency. Demand for money is assumed to be proportional to nominal income, with the same factor of proportionality, μ, between countries. Demand for money is then given by

(15)

$$\text{a)}\quad d_m^1 = \mu I^1 = \mu\{\pi^1(p^1, \ell^1) - (p^1 v_1 + p_2^1)t\}$$

$$\text{b)}\quad d_m^2 = \mu I^2 = \mu\{\pi^2(p^2, \ell^2) + (p_1^2 v_1 + p_2^2)t\}$$

Monetary equilibrium within a country is established when demand for money is equal to supply of money. Money supply is determined by the monetary authorities.

The exchange rate may now be defined as the value of the first country's currency in terms of the second country's currency ($e = \$^1/\$^2$). Perfect arbitrage and the absence of trade barriers or transportation costs imply that nominal prices of traded goods are linked by the exchange rate, so

$$(16) \qquad p_i^1 = ep_i^2 \qquad (i = 1, 2)$$

It follows that the value of the first country's trade surplus is equal to the value of the second country's trade deficit, when both are expressed in a common currency. Hence

$$(17) \qquad D^1 = -eD^2$$

Money supply may be defined by a variety of rules that describe the behavior of monetary authorities. A case characteristic of present world monetary conditions is that of a flexible exchange rate and unbacked currencies. Under this regime, each monetary authority is assumed to control its money supply to attain some policy objective, allowing nominal prices and the nominal exchange rate to adjust endogenously. Alternative objectives, such as stabilizing the price level, stabilizing the price of the nontraded good, or stablizing nominal income, are equally feasible.

To illustrate the adjustment process, suppose the objective of monetary authorities is to stabilize a Laspeyres price index, defined in relation to an initial equilibrium by

$$(18) \qquad P^k = \bar{\alpha}_1^k p_1^k + \bar{\alpha}_2^k p_2^k + \bar{\alpha}_3^k p_3^k \qquad (k = 1, 2)$$

where

$$\bar{\alpha}_i^k = X_i^k(\bar{p}^k,\ \bar{t},\ \ell^k)/I^k(\bar{p}^k,\ \bar{t},\ \ell^k) \tag{19}$$

$$(i = 1,\ 2,\ 3 \quad k = 1,\ 2)$$

is the ratio of consumption of the i-th good to income, evaluated with prices and the trade-balance parameter t at their initial values. From equality of the budget constraint and income of each country, it follows that

$$\bar{P}^k = \bar{\alpha}_1^k \bar{p}_1^k + \bar{\alpha}_2^k \bar{p}_2^k + \bar{\alpha}_3^k \bar{p}_3^k = 1 \qquad (k = 1,\ 2) \tag{20}$$

at the initial equilibrium. Thus, the stabilization objective of each monetary authority is to maintain the value of P^k at unity. To accomplish this objective in face of disturbances such as a change in the trade balance, respective money supplies would be adjusted to force changes in the nominal exchange rate and nominal prices consistant with goods-market equilibrium and constant price levels.

In the trade model, the specific objectives assumed for monetary authorities will determine nominal but not relative price outcomes. This is an important characteristic of the model. An equivalent assertion is that effects of disturbances to goods-market equilibrium are invariant with respect to choice of monetary objectives when nominal price outcomes are deflated by a price index, such as (18).

This invariance of deflated equilibrium prices is easily seen by considering the effect of a change in the trade balance (or other disturbance) in two steps: first in terms of relative prices, determined in goods markets, and then in terms of nominal prices, determined by the monetary regime. First, from an initial pre-disturbance equilibrium, a new set of post-disturbance relative prices are established. Given these relative prices, if the monetary authorities follow a particular rule, say stabilizing the price level in each country, then a new set of nominal prices can also be determined. Deflated prices can be computed based on these nominal values. If the monetary authorities have an alternative objective, for example to maintain initial nominal incomes rather than to stabilize price levels, a new monetary and goods-market equilibrium is attainable with all prices changing equiproportionately from their post-disturbance, price-level-stabilizing equilibrium values. Since all prices change proportionately, equilibrium in goods markets is not disturbed, and deflated prices remain constant.

The distinction between nominal and deflated values of equilibrium variables applies to the exchange rate as well as to prices of goods. The effect of a disturbance to initial equilibrum on the nominal exchange rate depends on monetary objectives. This is not the case for the price-level-adjusted rate (often called the real or purchasing-power-parity-adjusted exchange rate), defined by $\tilde{e} = eP^2/P^1$. This result follows directly from the invariance of equilibrium deflated prices, since

$$(21) \qquad (p_i^1/P^1)/(p_i^2/P^2) = (ep_i^2/P^1)/(p_i^2/P^2) = (eP^2)/P^1) = \tilde{e}$$

$$(i = 1,\ 2)$$

The potential of the exchange rate to facilitate price adjustments induced by a change in the trade balance may be derived from the preceding discussion of goods-market and monetary equilibrium. Realignment of a flexible nominal exchange rate may accomodate the relative price shifts associated with the change in trade balance, while allowing monetary authorities to achieve their stabilization objectives. Under usual assumptions, an increase in the capital outflow from a surplus country results in lower deflated income, a decline in the deflated price of the nontraded good relative to deflated prices of traded goods, and a real depreciation of the currency. Opposite changes occur in the deficit country: deflated income and the relative price of the nontraded good rise, and the price-level-adjusted exchange rate appreciates.

To illustrate the adjustment role of the exchange rate, suppose the monetary authorities seek to stabilize price levels. Relative price shifts then imply that nominal traded-good prices move in opposite directions in the currencies of the surplus and deficit countries (in the surplus country, nominal prices of traded goods rise and the nominal price of the nontraded good falls, while in the deficit country, nominal prices of traded goods fall and the nominal price of the nontraded good rises). Given the goods-market arbitrage condition (16), this price adjustment pattern is only feasible if the currency of the surplus country depreciates.

If the nominal exchange rate is pegged, in contrast, nominal prices of traded goods cannot diverge. Price adjustment in response to a change in the trade balance is then more dependent on movements in the nominal prices of nontraded goods. With the nominal exchange rate pegged, changes in nominal prices of traded goods that might facilitate equilibrium relative price adjustments in one country exacerbate the price adjustment process in the other. One country may be assumed to stablize its price level when the nominal exchange rate is pegged, but a stable price level cannot be maintained by both countries.

When the exchange rate is flexible, the burden of price adjustment it may carry is a uniform shift in prices of traded goods relative to nontraded goods. This may be adequate to fully accomodate goods-market equilibrium in special cases. If so, brief consideration of the algebra implies that the percentage change in the deflated price of any traded good, expressed in a single currency, will be less than the percentage change in the price-level-adjusted exchange rate. This provides a general equilibrium analog to the elasticity constraint (4a) derived from a partial equilibrium analysis.

More generally, a uniform shift in the price of nontraded to traded goods will carry only part of the burden of price adjustment induced by a change in the trade balance. Differences in preferences and production possibilities will necessitate changes in relative prices of traded goods as well.

The percentage change in the deflated price of one of the traded goods may exceed the percentage shift in the price-level-adjusted exchange rate when a change in the trade balance affects relative prices among traded goods. Sufficient conditions for this to occur are developed explicitly for an example based on Cobb-Douglas preferences and fixed endowments of consumption goods, in Appendix B. In this event, the deflated price of one traded good will be observed to rise (or fall) in the currency of both surplus and deficit countries. Joint observation of an increase in the deflated price of a particular traded good in the currency of the deficit country and an increase in the quantity of the good that is imported is not seen to be at variance with a common-sense notion of market equilibrium, once the underlying role of the income transfer associated with the trade balance is recognized.

PARTIAL EQUILIBRIUM ANALYSIS ONCE AGAIN

Limitations of a partial equilibrium analysis of exchange-rate effects can now be evaluated on the basis of concepts developed in the general equilibrium model. Changes in the exchange rate are associated with transfers of disposable income via the trade balance in the general equilibrium context. This association is implicitly ignored in a partial equilibrium analysis, wherein the effects of a change in the exchange rate are determined on the basis of movements along supply and demand curves that do not shift in each country's domestic-currency-price/quantity plane, as illustrated in Figue 2.1, panels (a) and (d). Alternatively, rather restrictive assumptions are required to justify the lack of income effects in a partial equilibrium analysis. For example, it could be assumed that income does not affect demand for the particular good under consideration, or that monetary authorities stabilize their respective money supplies. In the latter case, effects of a trade imbalance on real incomes would be exactly offset by changes in nominal prices, so that nominal incomes remain constant.

With respect to price changes per se, movements in the exchange rate are generally associated with other price shifts in the trade model. The exchange rate plays a useful role in relative price adjustment only in circumstances in which a uniform shift carries some of the burden of individual price movements. A trade imbalance creates just such a circumstance in a model in which there are traded and nontraded goods.

In the presentation of a partial equilibrium model it is often not clear what other goods are assumed to exist. Nevertheless, the distinction between traded and nontraded goods and, further, very specific assumptions about these goods implicitly underlie the standard interpretation. To justify the partial equilibrium analysis as represented in Figure 2.1, it must be assumed, in general, that there are no other traded goods or, alternatively, that all cross-price effects between other traded goods and supply and demand for the i-th good are zero in both countries. In addition, it must be assumed that the nominal price of any nontraded good with cross-price effects in the i-th market is held constant.

Two examples will serve to illustrate the preceding discussion. In each case, it is assumed that money demand is proportional to nominal income, as in the trade model. It is also assumed, for simplicity, that each country receives a fixed endowment of goods per unit of time, so supply functions are perfectly inelastic. In the first example, there is one nontraded good in each country and two traded goods. Aggregate utility functions are of the Cobb-Douglas type, so a preference representation and ordinary demand functions are

$$\text{(22)} \quad \begin{aligned} &a)\quad U^k = (x_1^k)^{\theta_1^k}(x_2^k)^{\theta_2^k}(x_3^k)^{\theta_3^k} \\ & \qquad\qquad (0 < \theta_i < 1 \quad \theta_1 + \theta_2 + \theta_3 = 1 \quad k = 1,\ 2) \\ &b)\quad x_i^k = (\theta_i^k I^k)/p_i^k \\ & \qquad\qquad (i = 1,\ 2,\ 3 \quad k = 1,\ 2) \end{aligned}$$

and all cross-price effects are zero. If monetary authorities stabilize their respective money supplies (and, hence, nominal incomes), then a partial equilibrium evaluation of the effects of a change in the nominal exchange rate on the market for a particular traded good is consistent with evaluation of these effects in the trade model. A monetary policy that stabilizes nominal money supply also stabilizes the price of the nontraded good, since equilibrium consumption of the nontraded good is fixed.

Alternatively, suppose the aggregate utility function for each country is of the form

$$\text{(23)} \qquad U^k = x_1^k + 2(x_2^k)^{.5} \qquad (k = 1,\ 2)$$

where x_1 is a nontraded good and x_2 is traded. For these preferences ordinary demand functions are

$$\text{(24)} \qquad x_1^k = I^k/p_1^k - p_1^k/p_2^k \qquad x_2^k = (p_1^k/p_2^k)^2 \qquad (k = 1,\ 2)$$

In this example, if it is assumed that both goods are consumed in positive amounts, demand for the traded good depends only on relative prices, while income and prices affect demand for the nontraded good. Cross-price elasticities are nonzero in this case. Partial equilibrium and trade-model analyses of the effects of a change in the exchange rate in the market for the traded good are consistent if both monetary authorities stabilize the price of the nontraded good, but not if monetary authorities stabilize nominal incomes. Under the first monetary rule, the price of the traded good rises in the devaluing country (the surplus country). Cross-price effects are zero in the market for the traded good, since the price of the nontraded good is constant. The price shift creates excess demand for the nontraded good unless nominal income falls, but such a change in nominal income does not affect the demand for the traded good. Under the latter monetary rule, changes occur in the nominal prices of both the traded and nontraded good. This creates cross-price effects in the traded-good market that are not accounted for in a partial equilibrium analysis.

The preceding discussion and examples illustrate that consistency of a partial equilibrium analysis of exchange-rate effects with analysis of the role of the exchange rate in the trade model requires fitting of specific monetary policies to particular cases. It is revealing to contrast this exercise with practical application of the partial equilibrium constraints (4). Though the partial equilibrium model (1)-(3) is usually described in terms of nominal variables, the large inflation component of economic time-series has resulted in almost universal application of these constraints to deflated prices and price-level-adjusted exchange rates.

The correspondence between the trade balance, relative prices, and the real exchange rate in the trade model implies that it is appropriate to evaluate exchange-rate impacts in terms of deflated prices and the price-level-adjusted exchange rate. This analysis should be invariant with respect to the objectives of monetary authorities. Evaluation of nominal outcomes, in contrast, is not independent of monetary objectives.

Application of partial equilibrium analysis to deflated prices and the price-level-adjusted exchange rate is not subject to a similar broad justification. Rather, such an approach leads to a simple but startling inconsistency. The absence of income effects in a standard partial equilibrium analysis cannot be justified in the trade model by the assumption that real income is constant. Constant real income would be associated with no change in the real trade balance, no change in deflated prices, and no change in the real exchange rate. Partial equilibrium analysis along the lines of (a)-(d) of Figure 2.1 would not be correct! Applied to deflated prices and the real exchange rate, partial equilibrium analysis can only be sustained in the context of the trade model if it is assumed that changes in real income do not affect the particular market considered, as in the second example given above.

POLICY RELEVANCE OF EXCHANGE-RATE OBSERVATIONS

In the preceding sections, it has been demonstrated that partial equilibrium analysis of the effects of an exogenous change in the exchange rate on a particular market is quite restrictive compared to the role of the exchange rate in a general equilibrium trade model.[4]

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[4]Previous efforts to establish that the partial equilibrium constraints (4) are overly restrictive have centered on extending the partial equilibrium model to account only for effects of the exchange rate on more than one price. Such efforts retain many of the limitations inherent in the one-

Having established this result, the question arises as to the appropriate interpretation of the association of the trade balance, relative prices, and the real exchange rate observed in the general equilibrium model. That is, concern is not only with constraints that may be placed on the relative magnitude of movements in price and exchange-rate variables, but on the implications of their association. Treating the trade balance as exogenous is useful as long as the objective is confined to demonstrating the limitations of a partial equilibrium analysis. For discussion of the effects of macroeconomic policies on agriculture it is necessary to take a less restrictive view of trade-balance/exchange-rate/price and export quantity interactions.

The relevant issue is to identify conditions under which government policies effectively impact on the exchange rate, relative prices, and goods-market equilibrium. The trade model (augmented by specification of monetary regimes) provides a basis for addressing this issue: policies that affect the trade balance (and corresponding capital flows) induce associated price and exchange-rate shifts.

The invariance with respect to monetary regime of the association of the trade balance, relative prices, and the real exchange rate in the trade model has already been noted. The efficacy of monetary policy, in contrast, is regime-dependent, and is determined by the number of variables assumed to be controlled by the monetary authorities.

Under a regime of flexible exchange rates, monetary authorities are assumed to control money supplies but not the nominal exchange

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market approach. For a discussion of these models, see Appendix C.

rate. Monetary policies are incapable of affecting the real economy in this case. To illustrate, consider a monetary expansion in one country, while the second country stabilizes its money supply. If the nominal price of the nontraded good rises proportionately to the money supply, the currency of the first country depreciates by the same proportion, and all prices remain constant in the second country, then no shifts in relative prices are induced. Nominal income and demand for money rise in proportion to money supply in the first country. Initial goods-market equilibrium is not disturbed. Hence, monetary policy is neutral.

Under a regime of pegged exchange rates, both money supplies and the nominal exchange rate are controlled by monetary authorities. With this additional fixity monetary policies do affect the trade balance. A monetary expansion by one country, given a fixed nominal exchange rate and a stable money supply in the second country, will raise the price level in both countries. The increase in the price level will be proportionately greater in the country pursuing the expansionary monetary policy. The price of the nontraded good will rise relative to the average of traded-good prices and a trade deficit will be incurred; that is, expansionary monetary policy induces a capital inflow. Similarly, nominal appreciation of a pegged currency will induce a decline in the price level, an appreciation of the real exchange rate, and a trade deficit, if both countries stabilize their money supply.[5]

The outcomes of monetary policies derived from the monetary-

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[5]The comparative static properties of the monetary-regime augmented general equilibrium model are considered further by Chipman (1980) and in Appendix A.

regime-augmented trade model have some interesting interpretations. Consequences of these policies in the case of pegged exchange rates seem to reasonably describe the experience of many developing countries, where large trade deficits have been associated with nominal exchange-rate adjustments that have lagged monetary expansion and domestic inflation. More controversial is the discrepancy between the neutrality of monetary policies under flexible exchange rates in the trade model, and Schuh's assertion that agriculture and other trade sectors are more sensitive to monetary policies under flexible than fixed exchange-rate regimes.

Raising some question concerning Schuh's reasoning is not to suggest that the model developed herein is definitive for analysis of the effects of macroeconomic policies. Quite to the contrary, results from the trade model can not be taken directly as counter to the notion that monetary policy induces capital flows through its impact on interest rates, since interest rates and other determinants of intertemporal asset demands are not explicitly considered in the static model.[6] Nontheless, the trade model does provide a formal basis for policy evaluation--one that focuses on equilibrium in goods markets in a general context. That the outcomes are not fully supportive of the claim that monetary policy has a large influence on agriculture under a flexible exchange-

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[6]Effects of monetary and fiscal policies on agriculture have also been considered recently by--among others--Barnet, 1980; Chichilnisky and Taylor, 1980; Hughes and Penson, 1980; Johnson, 1980; Lamm, 1980; Fischer, 1981; Gardner, 1981; Shei and Thompson, 1981; McCalla, 1982; Pagoulatos and Canler, 1982; Battan and Belongia, 1984, and Chambers, 1984. Conclusions drawn in several of these studies are considered at appropriate points in the text.

rate regime is noteworthy.

In fact, reasoning such as Schuh's is rather controversial from the perspective of a range of modern and not-so-modern macroeconomic models. Neutrality of monetary policy is a common feature of these models. Schuh's reasoning falters on such neutrality.[7]

That government expenditures and tax policies may affect an economy even when pure monetary policy is neutral is also a controversial assertion. Nevertheless, the association of the trade deficit, relative prices, and the real exchange rate in the trade model is at least suggestive of such an outcome. Though the analysis has not been carried out formally, the intuition is that a budget deficit by the government would be a logical cause of expenditures exceeding income; in which case, a trade deficit must be incurred. Reasoning along these lines is certainly consistent with recent government-budget and trade-deficit observations for the United States. Tracing back through fiscal expenditures for domestic spending and the Vietnam War in the late 1960s and the income transfers resulting from oil-price shocks in the 1970s, one might build a case that fiscal policies and real shocks, rather than monetary phenomena, have played the central role in determining the effect of macroeconomic factors on agriculture.

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[7]The neutrality of monetary policy with respect to agriculture is implicit in Gardner (1981) and asserted strongly by Battan and Belongia (1984). The open-economy model by Van Duyne (1979) also has the property that monetary policy is neutral.

SUMMARY

In this chapter, the role of the exchange rate in a monetary-regime-augmented general equilibrium trade model is considered as a basis for a critical evaluation of partial equilbrium analysis of exchange-rate effects on goods markets. The crucial concept to emerge in the general equilibrium model is that of income transfers via the trade balance inducing shifts in equilibrium prices, with the primary impact that the price of the nontraded good relative to traded goods rises in the deficit country and falls in the surplus country. Realignment of currency values may help facilitate these price adjustments when exchange rates are flexible.

Though constraints on the exchange-rate elasticities of equilibrium price and export quantity derived from partial equilibrium analysis have been central to the controversy about the magnitude of exchange-rate impacts on agriculture, such constraints are shown to be justified in a general equilibrium model only when appplied to nominal variables under very specific assumptions. That such constraints simply need not apply to deflated prices and the real exchange rate has been shown.

The results obtained in this chapter suggest that a priori imposition of elasticity constraints derived from partial equilibrium analysis are overly restrictive, but not simply for previously considered reasons related only to the number of goods in the model. More generally, the implication is that evaluation of the effects of the exchange rate on agriculture should be based on a more comprehensive framework than is provided by either a one-market or multi-market partial equilibrium analysis.

In addition, on the basis of the properties of the general equilibrium model some questions have been raised concerning the source of macroeconomic impacts on agriculture. The possibility has been tendered that fiscal and other real shocks, rather than monetary phenomena, may be central to the influence of macroeconomic factors on agriculture under a regime of flexible exchange rates.

III. CAPITAL FLOWS, THE EXCHANGE RATE, AND AGRICULTURAL COMMODITY MARKETS: SOME EVIDENCE FROM A VECTOR AUTOREGRESSIVE MODEL

INTRODUCTION

In this chapter attention is directed to empirical measurement of the effects of macroeconomic factors on agricultural commodity markets, with particular focus on the impact of the exchange rate and income transfers on the world corn market. The objectives of the analysis are twofold. The first objective is to provide an assessment of the magnitude of macroeconomic and nonagricultural, as opposed to more narrowly sector-specific, influences on U.S. agriculture during the decade of the 1970s. The second objective is to determine the extent to which effects on agriculture commonly attributed to the exchange rate can be attributed to income transfers, as implied by the general equilibrium trade model developed in Chapter II.

As a basis for inferences with respect to these two objectives, parameters of a 12-variable vector autoregressive (VAR) model were estimated. Basic concepts underlying VAR methodology are reviewed, and the use and interpretation of VAR models in an economic context is considered. The variables included in the model of the world corn market are described, choice of an orthogonal order among these variables is examined, and forecast errors from the model are reported. Impulse response functions are then evaluated, and sources of unexpected developments in U.S. corn exports and price are identified. The chapter closes with consideration of some implications of the analysis with respect to the impact on agricultural markets of macroeconomic versus sectoral factors.

EXPLANATION OF THE VAR METHODOLOGY*

The starting point for VAR analysis is the view of an appropriately detrended and seasonally-adjusted univariate economic time-series $\{x_t\}$ as a covariance stationary stochastic process with an autoregressive representation

$$(25) \qquad x_t = \sum_{s=1}^{\infty} a_s x_{t-s} + e_t$$

and a normalized moving average representation

$$(26) \qquad x_t = \sum_{s=0}^{\infty} d_s e_{t-s} = e_t + d_1 e_{t-1} + d_2 e_{t-2} + \ldots$$

where e_t is a serially uncorrelated one-step-ahead prediction error.

The relationship between the autoregressive and moving average representations can be illustrated by an example.[8] Suppose a stochastic process has a known moving average representation

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*Readers familiar with the use and interpretation of VAR models may choose to go directly to the empirical results.

[8]A necessary and sufficient condition for existence of both moving average and autoregressive representations is that all roots, r, of $\sum_{s=0}^{n} d_s r^s = 0$ lie outside the unit circle. See Sargent, 1974, pp. 262.

$$(27) \qquad x_t = e_t + de_{t-1} + d^2e_{t-2} + \ldots \qquad |d| < 1$$

$$= (1 + dL + d^2L^2 + \ldots)e_t$$

$$= e_t/(1-dL)$$

where L is the lag operator (i.e. $L^n x_t = x_{t-n}$). The autoregressive representation is then

$$(28) \qquad (1-dL)x_t = e_t \quad \text{or} \quad x_t = dx_{t-1} + e_t$$

In autoregressive estimation, an estimator $\hat{d}$ would be attained by ordinary regression techniques. The estimated moving average representation would then be

$$(29) \qquad x_t = e_t + \hat{d}e_{t-1} + \hat{d}^2e_{t-2} + \ldots$$

In this example, the autoregressive representation depends on only one lag and only one parameter is estimated statistically. Estimates of the coefficients of the moving average representation (which includes an infinite sequence of lagged one-step-ahead forecast errors) are derived from the single estimated autoregressive parameter.

The moving average representation has several useful interpretations. First, a specific coefficient, say d_j, measures the effect on x_t of an unanticipated shock of size one at time t-j. Alternatively, the effect on x_{t+j} of a unit shock to x_t is given by d_j. Thus, the set (d_1, d_2, ..., d_k) traces the effects on k future values of $\{x_t\}$ of a unit shock at time t. This is known as an impulse response function. Its utility comes from describing how future values of a variable are affected by a current shock. The size of a shock at time t is measured by the difference between observed x_t and the predicted value of x_t at time t-1.

A second important interpretation of the moving average representation concerns the decomposition of forecast error variance. From (26) the variance of the forecast error of x_{t+k} at time t is given by

$$(30) \quad Var(x_{t+k} \mid x_t, x_{t-1} \ldots)$$

$$= Var(e_{t+k} + d_1 e_{t+k-1} + \ldots \mid x_t, x_{t-1}, \ldots)$$

$$= Var(e) + d_1^2 var(e) + \ldots + d_{k-1}^2 \; var(e)$$

Decomposition of the variance in this way proportions the k-step-ahead forecast error variance into components due to each of the periods between t and t+k. In a multivariate system, a similar decomposition has the more useful attribute of proportioning forecast error variance among components due to shocks to different variables.

It is also possible to decompose observed values of a time-series variable on the basis of the moving average representation. For purposes of historical analysis a useful decomposition is

$$(31) \quad x_{t+k} = \sum_{s=0}^{k-1} d_s e_{t+k-s} + \sum_{s=k}^{\infty} d_s e_{t+k-s}$$

The second term on the right-hand-side of (31) is the conditional expectation of x_{t+k} at time t, since future shocks have an expected mean of zero. Values from x_{t+1} onward are thus decomposed by (31) into a sum of a conditional forecast plus the effects of subsequent shocks. The cumulative effect of these shocks on the deviation of actual x_{t+k} from its conditional forecast at time t depends on the immediate impact of the error in period t+k and the lagged effects of shocks in previous periods. Hence, the decomposition (31) accounts for the dynamic effects of each shock.

Discussion of univariate stochastic processes generalizes easily to vector stochastic processes, representing sets of time-series variables. In the multivariate case, the autoregressive representation expresses the current value of each variable as a function of lagged values of all variables, and the moving average representation of each variable includes forecast errors for all variables.[9] Impulse response functions in the multivariate model trace the effects on expected future values of each variable of shocks to the variable itself, and of shocks to all other

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[9] In matrix notation, a multivariate stochastic process has the moving average representation

$$x_t = \ell_t + D^1\ell_{t-1} + D^2\ell_{t-2} + \ldots = D(L)\ell_t$$

where

$$x_t = \begin{bmatrix} x_{t,1} \\ \cdot \\ x_{t,m} \end{bmatrix}$$ = an (m x 1) vector of observations on m variables at time t

$$\ell_t = \begin{bmatrix} e_{t,1} \\ \cdot \\ e_{t,m} \end{bmatrix}$$ = an (m x 1) vector of one-step-ahead prediction errors for x_t, given all past observations $(x_{t-1}, x_{t-2}, \ldots)$. For all t, $E\ell_t = 0$ and $Cov(\ell_t) = M$, and for all t and s, $E\ell_t\ell_s = 0$, $t \neq s$.

D^s = an (m x m) matrix of moving average coefficients, $s = 1, 2, \ldots$

variables. The source of forecast error variance for each variable can be proportioned among variables, as noted above, and by a decomposition similar to (31) deviations of specific variables from their conditional expectation are proportioned among components due to effects of current and lagged shocks to each of the variables.

A complication introduced in a multivariate model is that the one-step-ahead forecast errors are correlated when contemporaneous shocks are not independent. In this case, impulse response patterns generated by a unit shock to one variable, holding all other shocks equal to zero, may not generate expected future paths that are realistic given past historical experience.

One solution to the problem of contemporaneous correlations among the forecast errors is to choose a particular order of the variables in the model and remove that portion of the shock to each that is explained by contemporaneous shocks to variables earlier in the order. For an m-variable model, the shocks considered would be of the form

$$v_{t,i} = x_{t,i} - E(x_{t,i} \mid \text{all lagged } x_{s,j} \text{ for } s < t,\ j = 1\ldots m, \text{ and } x_{t,j} \text{ for } j < i) \tag{32}$$

The shock to a particular variable at time t is defined by (32) as the component of the observed value of the variable at time t that was not predicted from historical data or contemporaneous shocks to variables

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$$D(L) = \sum_{s=0}^{\infty} D^s L^s \text{ , where } D^0 = I$$

In a multivariate moving average representation, D^s_{ij} gives the effect on variable i at time t of a unit shock to variable j at time t-s. Analogously to the univariate case, for a vector stochastic process the matrices $\{D^s\}_1^k$ form an impulse response function.

earlier in the order. Such shocks are called orthogonal innovations or orthogonal errors.[10]

It should be noted that for a given set of variables there are many possible orthogonal orders. As a general rule, when contemporaneous correlations are low, reordering of the variables will have little effect on the orthogonalized moving average representation. Otherwise, this may not be the case. Consequently, when contemporaneous correlations are large, the plausibility of a particular orthogonal order and sensitivity of empirical results to changes in the order merit explicit consideration in evaluation of vector autoregressive models.

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[10] To compute orthogonal innovations, the covariance matrix of contemporaneous errors among the m variables in the model, (M), is decomposed as M = CC', where C is lower triangular and invertible. This decomposition is unique for a given M, and enables the random vector of contemporaneous errors, ℓ_t, to be expressed as a linear combination of independent random variables: $\ell_t = C\nu_t$, where Cov ν_t = I. Substituting into the moving average representation

$$x_t = C\nu_t + D^1 C\nu_{t-1} + D^2 C\nu_{t-2} + \ldots = D(L)C\nu_t$$

To evaluate the effects of shocks typical of those that have occurred historically, a shock to the j-th variable is taken as the j-th column of C. The marix element c_{jj} has the value of a standard deviation orthogonal innovation in variable j, while c_{ij} measures the contemporaneous effect of this shock on the i-th variable. Since C is lower triangular, a shock to the first variable in the order may affect all of the following variables contemporaneously, while a shock to the last variable in the order has no contemporaneous effects on other variables.

In an orthogonal model, impulse response functions are generated as vector products. For example, the effect of a shock to variable j at time t on variable i at time t+k is given by the product of the i-th row of D^k and the j-th column of C. Impulse responses generated in this fashion should more realistically reflect the historical evidence than would nonorthogonal impulse responses generated by the $\{D^s\}_{s=1}^k$ matrices alone.

USE AND INTERPRETATION OF VAR MODELS*

As an approach to evaluating economic data, a VAR model has a number of features unlike those of more familiar simultaneous equation econometric models. Initially, either empirical analysis is conditioned by selection of a particular set of variables chosen to reflect important aspects of the economic phenomena under investigation. Having specified such a set, analysis in a VAR framework, unlike within a standard model, proceeds without a priori assumptions that relations among variables take a particular form. No distinction is imposed separating variables between endogenous and exogenous. Rather, shocks to all variables are viewed as potentially influencing all other variables. The objective of estimating the parameters of a VAR model is to evaluate these interactions empirically in the absence of asymmetric

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Likewise, the forecast error variance for a vector stochastic process is $Var(x_{t+k} \mid x_t, x_{t-1} \ldots) = \sum_{s=0}^{k-1} D^s M D^{s'}$, which is a matrix measure of the k-step-ahead forecast error variance, with the i-th diagonal element of the matrix being a measure of forecast error variance for $x_{t+k,i}$. If M is not a diagonal matrix (i.e., the components of ℓ_t are correlated contemporaneously), then forecast error variances can not be proportioned among components due to shocks to each variable since each forecast error variance includes contemporaneous covariance terms for which assignment to a specific variable is problematic. Again an ordering of the variables can be used to attain a decomposition of variance

$$Var(x_{t+k} \mid x_t, x_{t-1} \ldots) = \sum_{s=0}^{k-1} (D^s C)(D^s C)'$$

Letting $d^s c_{ij}$ be the ij-th element of $D^s C$, the i-th diagonal element of $(D^s C)(D^s C)'$ is simply the sum of squared terms $(d^s c_{ij})^2$, j = 1...m. Hence the component of variance in the k-step-ahead forecast of $x_{t+k,i}$ due to orthogonal innovations in variable j is the sum of terms $(d^s c_{ij})^2$, s = 1...k-1.

assumptions.[11]

To see how a VAR model might be utilized in an economic context, suppose there is interest in whether unusually high agricultural prices during a period beginning at time t can be attributed to unusually low levels of production. An analysis of this question might begin with estimation of the parameters of a VAR model that includes price, production, and other appropriate variables. Whether or not there were large innovations in production and prices around t could be determined from the residuals of the estimated autoregressive equations. If there were no large innovations, then observed changes in prices and production are explained by usual historical patterns, given realized past values of the variables in the model. In this case, no <u>unusual</u> observations warrant explanation, even if changes in prices and production were large. Positive price innovations (e.g., prices that are not only high, but unexpectedly high) without production inovations would suggest that the unusual observed price behavior not be attributed to production shocks. Even if production were low, if there were no production innovations then it was not unexpectedly low, and hence should not cause unexpected price effects. In contrast, that unusual price movements be attributed to unexpected production levels

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*A useful general reference is Sims (1981).

[11]For this reason VAR models are often described as "nonstructural." However, VAR equations may be viewed as structural in the alternative sense of policy invariance raised by Lucas (1976). Analysis utilizing VARs proceeds on the assumption that estimated parameters are invariant with respect to changes in regime--be they policy intervention or otherwise. The reduced form equations of a traditional model are likewise considered to have such a "structural" interpretation if the estimated parameters are invariant with respect to changes in values of exogenous variables.

would be suggested by both price and production shocks near t, and impulse response functions showing substantial effects of production shocks on prices.

Interpreting a VAR model along the lines suggested above rests on assuming a connection between shocks to a variable and events originating in a distinct sector, each sector being represented by an autoregressive equation with a particular variable on the left-hand-side. The autoregressive representation of a VAR is equivalent to the reduced form of a standard simultaneous equation model with no exogenous variables.[12] The proposed interpretation rests on making a connection between reduced-form residuals and sectors. In a standard econometric model, no such connection need exist.[13]

When a priori restrictions are imposed on a VAR model, all

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[12]The idea of simultaneous equation models that do not impose exogeneity and exclusion restrictions is attractive in light of three arguments: the relatively small number of powerful distinctions that imply appealing restrictions; the distinction concerning identification between exogenous and lagged endogenous variables when exact lag lengths and serial correlation are not known a priori; and recent developments vis à vis the role of expectations which tend to undermine exclusion restrictions. These arguments are carefully developed by Sims (1980).

[13]In a standard econometric model sectors are associated with "structural" equations. Residuals from structural equations might be interpreted as shocks originating in the corresponding sectors. But, in general, reduced-form-equation residuals are related to structural-equation residuals by an arbitrary linear transformation. In matrix notation, the structural model $Y = YB + XC + U$ has the reduced form $Y = XC(I-B)^{-1} + U(I-B)^{-1}$.

In the context of the standard econometric approach, the VAR association of innovations and sectors is justified only if $(I-B)$ is a block diagonal matrix. In this case the reduced-form residuals for each block are a linear combination of residuals from structural equations within the same block. Reduced-form residuals are then associated with shocks to a sector as represented by a block of structural equations.

variables, or at least blocks of variables, are treated symmetrically. One example of such restrictions is a limitation on lag length, with a single criterion for selecting a uniform optimal length for all variables in all equations.

Another example of symmetric restrictions on a VAR model arises in the application of Bayesian priors. In principle, a VAR should provide more realistic impulse respone functions and more accurate forecasts than a set of univariate autoregressive equations, unless there are no interactions among variables. However, given the limited number of observations for most economic time-series, the large number of parameters to be estimated may constrain performance of an unrestricted VAR. As a solution to this problem, it has been suggested by Litterman (1979) that Bayesian priors be utilized in the estimation of VAR models.

Parenthetically, a block diagonal form does not fit the standard textbook example of simultaneous determination of contemporaneous price and market-clearing quantity through static supply and demand equations. Given the conventional just-identified specification

$$q_t^D = a_1 + a_2 p_t + a_3 z_t + u_t$$
$$q_t^S = b^1 + b_2 p_t + b_3 r_t + v_t$$
$$q_t^D = q_t^s$$

and normalizing the second equation with respect to p_t, the structural equations are

$$\begin{bmatrix} q & p \end{bmatrix} \begin{bmatrix} 1 & 1/b_w \\ -a_2 & 1 \end{bmatrix} + \begin{bmatrix} z & r & 1_t \end{bmatrix} \begin{bmatrix} -a_3 & 0 \\ 0 & b_3/b_2 \\ -a_1 & b_1/b_2 \end{bmatrix} = \begin{bmatrix} \mu & -\nu/b_2 \end{bmatrix}$$

where q, p, z, r, 1_t, μ, and ν are (m x 1) column vectors, and m is the number of observations. In this model the (I-B) matrix is not diagonal for finite parameter values.

Using the Bayesian approach, parameters of a VAR are estimated under assumption of distributions centered on short-lag, univariate representations of each variable. Often this will improve the forecasting performance of the model. At the same time, a Bayesian approach allows expression of cross-variable interactions when they are strongly suggested by the data.

In the most general case, a Baysian prior is applied uniformly to the variables in a VAR model. In more specialized cases, variables may be divided into blocks and the prior that is imposed may reflect different assumptions about interactions among variables within the different blocks, or among variables across blocks. In this case, some asymmetric structure is imposed, but not in nearly the stringent fashion that is characteristic of standard econometric models.

When contemporaneous correlations among errors are large, application of a particular orthogonal order again imposes some a priori structure on an unrestricted VAR model. The interpretation of a VAR model suggested above does not require an absence of contemporaneous correlations among errors, but the presence of large correlations does strain the assumption that the sectors are in fact distinct. A given orthogonal order implies that correlations among innovations are explained by the effects of current shocks to variables higher in the order on those lower in the order. An orthogonal order thus imposes an essentially recursive structure.[14] This does not rule out the

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[14]The recursive structure imposed by orthogonal ordering can be seen clearly in the autoregressive representation of a VAR model. Orthogonalizing contemporaneous errors can be shown to be equivalent

possibiity that innovations in lower variables influence future values of higher variables, but different orthogonal orders may affect the magnitude and timing of these impacts.

A VECTOR AUTOREGRESSIVE MODEL OF THE WORLD CORN MARKET

To evaluate the relative effects on the world corn market of macroeconomic and nonagricultural versus sector-specific factors, parameters of a 12-variable VAR model were estimated for the period 1954-1980, using annual data. The estimated autoregressive equations included one lagged value of each variable. Inclusion of more than one lag was precluded by data availability and the number of equations in the model.

The focus of the VAR analysis is to decompose unanticipated developments in U.S. corn exports and price over the period 1970-1980

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to including current values of variables higher in the order in the autoregrressive equations for variables lower in the order. The equation for the first variable includes only lagged variables on the right-hand-side, the equation for the second includes the current value of the first variable and lags of all variables, and so on (e.g., see Gordon and King, 1982).

With this structure, equations for variables low in an orthogonal order take a form somewhat closer to the reduced form of a standard econometric model than do equations from an unrestricted VAR model. For example, suppose an m-variable VAR model is orthogonalized such that the first m-k variables in the order correspond to the variables considered exogenous in a standard econometric model based on the same m variables. The VAR autoregressive equation for the (m-k+1)-th variable (with current values of the preceeding m-k variable and lags of all variables on its right-hand-side) could then, in principle, be identical to the reduced-form equation for variable (m-k+1) from the standard econometric model. The VAR equations for remaining variables would differ from standard-model reduced-form equations, since they include on the right-hand-side current values of one or more of the variables considered endogenous in the latter.

into the net effects of shocks from different sources. Following the approach suggested by (31), the historical analysis is based on separating the observed value of the export and price variables in each of these years into a sum of distinct components: the expected value of the variable that was predicted as of 1970, and components measuring the cumulative effect of own-errors and of errors in other variables from that date forward. This decomposition depends on the magnitude of orthogonal errors each year, estimated by the residuals from the autoregressive equations, and the contemporaneous and future effects of these errors, measured by the estimated impulse response functions.

Relevant Economic Time-series

The variables selected as a basis for the impact analysis may be classified into two categories--seven sectoral variables and five macroeconomic and nonagricultural variables--as shown in Table 3.1. In the first category, two variables--the price of corn, p_c^{US}, and the quantity of corn exported from the United States to an aggregate rest-of-world importing region, z_c^{ROW}--provide indicators of the effects of world corn-market developments on U.S. agriculture. Prices and exchange rates adjusted for movements in general price levels provide an appropriate basis for empirical analysis, as previously shown. Consequently, the corn price-series, p_c^{US}, is the nominal price of yellow corn on the Chicago market deflated by the U.S. consumer price index, base 1975 = 100.[15]

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[15]The sources for all data series are provided in Appendix E.

Table 3.1 Economic time-series, selected as a basis for analysis of factors affecting the world corn market

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Sectoral Variables

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p_c^{US} price of corn, deflated by the U.S. consumer price index, constant 1975 dollars per metric ton

z_c^{ROW} quantity of U.S. corn consumed by an aggregate corn-importing region, thousand metric tons

x_{cc}^{US} quantity of U.S. corn consumed domestically in the United States, thousand metric tons

p_b^{US} price of beef, deflated by the U.S. consumer price index, constant 1975 dollars per hundredweight

y_c^{US} quantity of corn produced in the United States, thousand metric tons

y_c^{ROW} quantity of corn produced in the aggregate corn-importing region, thousand metric tons

s_c^{*} quantity of corn exported by non-U.S. competing suppliers, thousand metric tons

Table 3.1 continued

Macroeconomic and Nonagricultural Variables

e	an index of the rate of exchange between a basket of 16 foreign currencies and the U.S. dollar, adjusted for movements in foreign and U.S. consumer price indices, units of rest-of-world currency per U.S. dollar
GNP^{ROW}	an index measure of the value of returns to all domestic factors of production in the aggregate corn-importing region, deflated by appropriate foreign consumer price indices, billion constant 1975 U.S. dollars
GNP^{US}	value of returns to all domestic factors of production in the United States, deflated by the U.S. consumer price index, billion constant 1975 dollars
T^{ROW}	value of income transfers received by the aggregate corn-importing region through trade and factor payment accounts, deflated by the U.S. consumer price index, billion constant 1975 U.S. dollars
OIL^{US}	value of oil imports by the United States, deflated by the U.S. consumer price index, billion constant 1975 dollars

To complete a description of total world corn demand, a variable measuring corn consumption in the United States, x_{cc}^{US}, is also included among sectoral variables.[16] A variable measuring the price of beef steers on the Omaha market, p_b^{US}, again deflated by the U.S. consumer price index, is included in the analysis to reflect effects arising from the cyclical demand for corn in the livestock sector.

The influence of supply factors on the world corn market is measured by three variables--the quantity of corn produced in the United States, y_c^{US}, the quantity of corn produced domestically in the aggregate corn-importing region, y_c^{ROW}, and the level of corn exports by countries that compete with the U.S. on the world market, s_c^*.[17] Brazil and France, countries that often export their domestically produced corn while importing U.S. corn, are included in the aggregate importing-region. Competing exporters are Argentina, Australia, South Africa, and Thailand.

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[16] An end-of-period-stocks variable, often included in models of agricultural markets, was excluded from the estimated VAR model since the identity that current stocks equal lagged stocks, plus production, less consumption and exports implies that innovations in end-of-period stocks are exact linear combinations of shocks to the production, consumption, and export variables.

[17] Foreign corn production and net shipments by competing corn exporters are taken from annual reports of the Food and Agriculture Organization of the United Nations. Mainland China is excluded from the analysis, since a consistent series on Chinese corn production was not available. The 1979 FAO Production Yearbook reports corn production in China as 27,820 thousand metric tons on average during 1969-71, and 27,595, 31,607 and 40,520 thousand metric tons in 1977, 1978 and 1979, respectively. The Production Yearbook for 1980 revises the 1969-71, 1978 and 1979 figures to 42,653, 53,107 and 60,099 thousand metric tons respectively, and reports 1980 production as 59,705 thousand metric tons. No explanation is provided for these revisions, which would have exceeded 16 percent of aggregate production in the corn-importing region. The official agricultural

The second category of variables included in the analysis reflects the effects on the world corn market of macroeconomic and nonagricultural factors. The first variable in this category is the exchange rate, e, measured by an index of the rate of exchange between a basket of foreign currencies and the U.S. dollar (s^{ROW}/s^{US}).[18] The exchange-rate index is adjusted for changes in U.S. and foreign price levels, so it measures the real value of the dollar. The deflated U.S. corn price is converted to a specific deflated foreign-currency price by the real exchange rate. The exchange-rate index utilized herein provides an average conversion of this type.[19] An increase in the value of the index represents an appreciation of the U.S. dollar.

The second, third, and fourth variables included to measure the

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statistical bulletin published by the People's Republic of China (1983) does not provide an historical production series for corn.

[18]The exchange-rate index includes all countries that are important importers of U.S. corn for which appropriate monetary data is reported by the International Monetary Fund (IMF). These are: Austria, Belgium-Luxemborg, Canada, Denmark, France, Germany, Greece, Ireland, Israel, Italy, Japan, Mexico, Netherlands, Norway, Portugal, South Korea, Spain, Turkey, and United Kingdom. The weight given to each currency is based on the proportion of U.S. corn exports to these countries that were destined to each, during the period 1954-1980.

[19]In the recent literature concerning exchange-rate effects on agriculture it has been common for the exchange rate to be measured by the rate-of-exchange between the U.S. dollar and a unit Standard Drawing Right (SDR) issued by the International Monetary Fund. As an aggregate index, the U.S.-dollar/SDR exchange rate is not a price-level-adjusted measure of the values of domestic and foreign currencies. Changes in the U.S.-dollar/SDR rate-of-exchange reflect changes in the real value of the dollar only when inflation differentials between the U.S. and other countries are small, or when they average out in computation of the SDR value. Even in this case, due to the weight attached to the dollar itself in the SDR, a given change in the U.S.-dollar/SDR rate-of-exchange implies a much larger underlying

influence of macroeconomic and nonagricultural factors serve to divide national expenditures in the United States and the corn-importing region into returns to domestic factors of production, GNP^{US} and GNP^{ROW}, and income transfers to the importing region, T^{ROW}. This distinction is based on the system of national accounts of the United Nations, reported by the IMF. The basic identity underlying these accounts is that total expenditures of all types, E, are equal to the value of gross domestic production, GDP, plus imports, M, less exports, X. In turn, GDP is the sum of returns to domestic factors of production, GNP, and returns to foreign factors of production employed domestically, NFPA. In a given time period, the value of the income transfer received by a country is measured by the extent to which expenditures exceed earnings of domestic production factors. That is

(33) $T = E - GNP = NFPA + M - X$

A country receives a transfer of income by which expenditures exceed domestic-factor income whenever the value of exports falls below the combined value of imports plus factor payments owed to foreigners. When a nation receives net payments for factors of production that it owns but are used in other countries (NFPA < 0, as is often the case

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change in the value of the dollar in terms of other currencies. As a consequence, if the impact of the U.S.-dollar/SDR rate-of-exchange is interpreted as "the exchange-rate effect", say in the derivation of elasticities, the true impact of a given change in the value of the dollar in terms of other currencies (which may be the interpretation implied) will be overstated.

For a description of the derivation of SDR values, and of problems associated with construction of aggregate exchange-rate indices, see International Monetary Fund (1981).

for the United States), a transfer is made to those other countries, unless the factor payments are offset by a sufficiently large deficit on the goods trade account.[20]

The final variable included in the analysis of factors affecting the world corn market is the deflated value of U.S. oil imports, $\dot{OIL}^{US}$.[21] One of the principal shocks to the world economy during the 1970s was the rising real cost of oil and related energy products resulting from cartel behavior of the Organization of Petroleum Exporting Countries (OPEC). In contrast to the attention directed towards the role of the exchange rate, little analysis of the aggregate impact of oil prices on agricultural commodity markets has been undertaken.[22]

Inclusion of an oil-sector variable in the empirical analysis represents an important departure from the theoretical discussion of the

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[20]The historical series for income transfers from the U.S. and other corn exporters to the aggregate corn-importing region was developed by deflating nominal transfers, derived in U.S. dollars following (33), by the U.S. consumer price index. To prepare an aggregate historical series for deflated domestic factor-income of the corn-importing region, a series for the real value of domestic-factor income in local currency was constructed for individual countries. Aggregate GNP for the region was then derived by multiplying the deflated GNP of each country by the exchange rate of its currency per U.S. dollar, and summing these values. For all periods, constant exchange rates as of 1975 were used to derive the aggregate corn-importing-region GNP series.

Empirical results reported in this chapter are not particularly sensitive to choice of base period for the real exchange rates by which country-specific GNP series are converted to U.S. dollars for purposes of aggregation. More problematic is the fact that historical data to compute deflated GNP is not available for a large number of countries. As a result, the importing-region GNP series, based on the same 16 countries as the exchange-rate index, is incomplete, and biased as a proxy toward the developed industrial countries.

[21]Two variables--oil price and value of U.S. oil imports--are readily available as proxies for oil-related shocks. Neither variable is a

trade model. The analysis of income transfers presented in Chapter II focuses on observed trade imbalances, under the assumption of lending among countries that is either voluntary or induced by monetary and exchange-rate policies. Inclusion of the oil-sector variable, in contrast, reflects the well-known fact that involuntary income transfers may be extracted from other market participants through cartel or monopoly behavior. Income transfers need not be observed as trade deficits when the vehicle of the transfer is an imposed increase in the price of a particular good that is included in the trade account.

To illustrate, cartel behavior in the face of inelastic foreign demand results in increased export revenue and higher real income for cartel countries, and lower real income for noncartel countries. Trade may remain in balance if purchases of imported goods by the cartel countries also increase. Even with a balanced-trade constraint, cartel behavior may have effects on trade and relative prices not unlike those

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perfect measure of income transfers associated with OPEC cartel behavior. The price variable reflects both cartel price-setting and changes in price that would have occurred under more competitive conditions. It does not provide a basis for distinguishing between historically observed prices and prices that might have been observed in the absense of cartel intervention. The import-value variable reflects both cartel price-setting and market response, in terms of quantity demanded, to imposed prices--including, incidently, those in the regulated U.S. energy sector.

In the analysis undertaken, inclusion of either the price or import-value variable resulted in similar inferences with respect to the impact of oil-sector shocks on agricultural trade, with respect to the effect of accounting for oil-sector shocks on the impacts attributed to other factors affecting the corn marlet, and with respect to the effect of oil-sector shocks on macroeconomic variables. For this reason, only models including the import-value variable are reported.

[22]A related topic, the effect of a mineral export boom on the farm sector in Australia, has been examined by Gregory (1976) and Stoeckel (1978).

resulting from a trade imbalance in a competitive-economy model. That goods-market equilibrium in the case of cartel behavior requires higher prices of nontraded goods relative to traded goods in cartel countries, and lower relative prices of nontraded goods among noncartel countries, is not difficult to imagine. These relative price adjustments could be facilitated by appreciation of the currencies of cartel countries, in which real income rises, and depreciation of the currencies of noncartel countries, in which real income falls. This is just as in the case of income transfers considered in the trade model. However, in the trade model changes in currency values arose precisely as a result of trade surpluses and deficits, whereas in the case of cartel-induced income transfers changes in currency values could serve to facilitate balanced trade.

That income transfers induced by the OPEC cartel (and not necessarily associated with a trade imbalance) may partly explain developments in the world corn market during the 1970s does not seem implausible in light of data on U.S. trade, summarized in Table 3.2. Over the decade, the deflated price of Saudi-Arabian crude oil rose over 900 percent. The increased value of imported oil explains over 40 percent of the increase in the total real value of U.S. imports. Had real oil prices remained constant at the level prevailing in 1970, the nominal cost of actual 1980 oil imports would have been $7.4 billion. The reported value of these imports was $76.9 billion, giving some idea of the magnitude of the income transfer. In real terms, the increase in the value of U.S. oil imports during the period 1970-1980 was $46.9 billion. The U.S. trade balance deteriorated by only $12.8 billion, so

Table 3.2 Trade accounts of the United States, summary statistics, 1970-1980

Year	1970...	1973	1974...	1978	1979	1980
	....................nominal value (billion dollars)...................... ....(deflated value (billion dollars, base = 1975))..............					
Total Oil Imports	2.76 (3.83)	7.55 (9.14)	26.12 (28.51)	41.60 (34.32)	58.59 (43.43)	76.94 (50.25)
Merchandise Imports	39.86 (55.28)	70.47 (85.31)	103.64 (113.14)	175.82 (145.10)	211.81 (157.00)	249.57 (163.01)
Total Imports	54.50 (75.30)	89.30 (108.10)	124.70 (136.10)	206.40 (170.30)	245.90 (182.30)	284.90 (186.10)
Merchandise Trade Balance	2.59 (3.59)	.95 (1.15)	-5.33 (-5.82)	-33.77 (-27.86)	-27.34 (-20.27)	-25.34 (-16.55)
Total Trade Balance	-0.60 (-0.80)	-1.80 (-2.20)	-6.40 (-6.90)	-30.70 (-25.30)	-29.30 (-21.70)	-20.90 (-13.60)
Transfer Through Trade and Factor-Payment Accounts	-6.70 (-9.30)	-14.20 (-17.19)	-13.40 (-14.82)	1.10 (.90)	-13.30 (-9.85)	-25.20 (-16.45)
Price of Petroleum						
U.S.$/barrel (nominal)	1.30	2.70	9.76	12.70	16.97	28.67
U.S.$/barrel (deflated)	1.80	3.27	10.65	10.48	12.58	18.73

Source: <u>International Financial Statistics Yearbook, 1982</u>. International Monetary Fund, Washington, D.C.

less than one-third of the net increase was reflected as a net trade deficit. The remaining two-thirds was absorbed by reductions in U.S. consumption of other traded goods, and by expenditures of oil revenues by foreigners to purchase U.S. exports.

A second significant departure from the theoretical discussion of the trade model arises in the treatment of the exchange rate and income transfers through the trade balance as separate variables. The trade model developed in Chapter II provides a set of "structural" equations in which either the exchange rate is endogenous and capital flows are exogenous, or, alternatively, capital flows are endogenous and the exchange rate and monetary policies are exogenous. Hence, the trade model might be interpruted to suggest that a well-specified empirical analysis would include either the exchange rate or capital flows, but not both, as an independent variable.

The unique relationship between the exchange rate and capital flows in the trade model is derived, however, holding constant other exogenous variables, including factor endowments and parameters defining preferences and money-demand behavior. Changes in these variables would influence the exchange rate/capital flows relationship. Even if the trade model were a "true" model, a unique correspondence between these variables would only be observed empirically if other factors remained constant, or if additional variables were adequately specified to account for changes in these other relevant factors.

In this context, inclusion of an oil-sector variable may be viewed as accounting for one factor that, among its effects, may have caused a substantial shift in the relationship between the exchange rate and capital flows during the 1970s. Estimating a model to account for all such changes would be a large undertaking in its own right, even without specific consideration of the agricultural sector. For this reason, in the empirical evaluation of the world corn market it seem appropriate to treat the exchange rate and capital flows more independently than implied formally by the general equilibrium trade model.

Further, specific theoretical specifications of the relationship between the exchange rate and capital flows--including that based on the general equilibrium model--remain controversial, as previously noted. In this respect, a VAR analysis with treatment of the exchange rate and capital flows as separate variables is not restrictive. Interactions among macroeconomic variables may play an important role in determining the net effect on the world corn market of particular macroeconomic shocks. Interactions among exchange-rate, income-transfer, and oil-sector shocks are evaluated in the VAR model reported herein, and account is taken of these interactions in evaluating the impact on agriculture of each of these factors. By way of comparison, within the recent literature in which macroeconomic effects on agriculture have been evaluated, the exchange rate has often been treated not only as exogenous, but as the only exogenous macroeconomic variable (e.g.,Fletcher, Just and Schmitz, 1978; Konandreas, Bushnell, and Green, 1978, and Chambers and Just, 1981).[23]

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[23]In a few cases (e.g., Chambers and Just, 1982, and Canler, 1983), standard econometric models have been specified with the exchange rate

Orthogonal Order: Inclusion of Sectoral and Macroeconomic Variables in a VAR Model

Inclusion in a VAR model of both macroeconomic and sector-specific variables raises issues with respect to choice of an orthogonal order that might not arise in other applications. Placing sectoral variables high in the order conforms to the notion that close interactions among related variables defines a specific sector of the economy. But attributing large effects on macroeconomic variables to shocks to sectoral variables, as would tend to occur with such an order, contradicts a sense of scale that suggests specific sectors have relatively small causal effects on broad, across-economy measures. Placing macroeconomic variables before sectoral variables might be more appropriate in the latter respect, but may result in the effects of macroeconomic variables on the sector being overstated compared to interactions among sectoral variables themselves.

To determine the magnitude of these difficulties, two specifications of the 12-variable VAR model were considered. In the first order, sectoral variables measuring world corn production, y_c^{US}, and y_c^{ROW}, were placed before macroeconomic and nonagricultural variables, which in turn preceded the remaining sectoral variables. An asymmetric Bayesian prior was imposed to reduce the possibility of attributing too large an effect on macroeconomic and nonagricultural variables to shocks to corn production. This prior centered the distribution for each

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determined in a specific recursive manner relative to agricultural and other trade. No theoretical model of exchange-rate determination has been articulated in these cases, and the authors have acknowledged that their "structural" specifications are ad hoc.

variable on a unitary coefficient on own-lag. Relative to own-lag, each sectoral variable was given a weight of 0.5 in equations for other sectoral variables, but of only 0.1 in equations for macroeconomic and nonagricultural variables. A weight of 0.5 was given to macroeconomic and nonagricultural variables in all but own equations.

In the second order, the two corn-production variables were placed below the macroeconomic and nonagricultural variables, and before other sectoral variables. The same Bayesian prior was imposed.[24]

Aside from placement of the corn-production variables, the two orthogonal orders shared a common arrangement of variables. Among macroeconomic and nonagricultural variables, the order was OIL^{US}, T^{ROW}, e, GNP^{US}, and GNP^{ROW}. Among sectoral variables the order was s_c^*, p_b^{US}, p_c^{US}, x_{cc}^{US}, and z_c^{ROW}. Each of these orders is subject to alternative specification. For sectoral variables, neither the association of errors and variables in a VAR model, nor any ordering of variables within a particular market is consistent with a model of simultaneous determination of market-clearing price and quantity through interaction of "structural" supply and demand equations, as illustrated in footnote (13). Among macroeconomic and nonagricultural variables, placing the value-of-U.S.-oil-imports and income-transfer variables before the exchange rate is consistent with the notion that

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[24]The prior imposes a relatively strong presumption against effects of sectoral shocks on nonsectoral variables when used in conjunction with the second orthogonal order. However, loosening the prior on sectoral variables in equations for macroeconomic and nonagricultural variables to 0.5 does not qualitatively change reported estimates of autoregressive or moving average parameters.

contemporaneous correlations between the errors in these variables reflect response of the latter to real shocks and autonomous savings decisions. Reversing this order would reflect an alternative assumption that contemporaneous correlations among these variables reflect response of real sectors and savings to shocks to the exchange rate, somewhat more of a monetary view.

In the VAR model, four types of interactions among variables may be evaluated: the effects of shocks to macroeconomic and nonagricultural variables on one another, the effects of shocks to macroeconomic and nonagricultural variables on sectoral variables, the effects of shocks to sectoral variables on one another, and the effects of shocks to sectoral variables on macroeconomic and nonagricultural variables. The parameter estimates from the two alternative orthogonal orders were quite similar with respect to interactions among macroeconomic and nonagricultural variables, and with respect to interactions among sectoral variables. Estimated effects of shocks to agricultural variables on macroeconomic and nonagricultural variables were also similar, with the exception that the order with corn-production variables first resulted in relatively larger estimated effects of production shocks on U.S. and foreign domestic-factor incomes. To a large extent this may merely reflect the time trend prevalent in these variables.

The greatest difference in the parameter estimates from the two alternative orthogonal orders arose in the estimated effects of macroeconomic and nonagricultural shocks on agricultural variables. The results differ primarily in the estimated responses of corn production. The estimated effects appeared most plausible in the model with production variables lower in the order, and only these parameter estimates are reported. This choice of orthogonal order does not prejudice the empirical results against an hypothesis such as Fischer's (1981), since effects of sectoral variables on macroeconomic and nonagricultural variables were quite similar between the alternative orthogonal models.

Forecast Errors and Decomposition of Variance

Observed values of the macroeconomic and nonagricultural variables, together with year-by-year orthogonal errors, are shown for the period 1969-1980 in Table 3.3. Sharp increases in the value of U.S. oil imports in 1974 and 1979 reflect OPEC pricing policies. There are large positive innovations in each of these years (i.e., the anticipated value of oil imports based on the model underestimates the actual value of oil imports), but in each case there are relatively large negative innovations in both the preceding and following years. This pattern of errors does not closely resemble more heuristic notions of surprises arising in the oil sector during the decade.

In contrast, orthogonal innovations closely parallel movements in observed values of the exchange rate. The model predicts the U.S. dollar to be weaker in 1969 and 1970 and stronger in 1971-75 than observed, so innovations reflect the surprise commonly associated with the devaluations of 1971 and 1973. A large negative error in 1978 also corresponds to a sharp fall in the observed value of the dollar that year.

Table 3.3 Observed values and orthogonal errors, macroeconomic and nonagricultural variables, 12-equation VAR model, 1969-1980

	OIL^{US}		T^{ROW}		e	
Year	Observed	Error	Observed	Error	Observed	Error
1969	3.76000	.475511	3.97700	-2.73667	1.39150	.365190E-01
1970	3.83000	-.930934	6.12900	1.20594	1.38634	.535765E-01
1971	4.41000	.634841	1.74730	-3,19223	1.32904	.216681E-01
1972	5.53000	1.09812	1.35290	-2.75969	1.19672	-.560420E-01
1973	9.14000	-2.17533	18.9984	8.28359	1.07199	-.564000E-01
1974	28.5100	4.47970	10.5354	-1.95393	1.03908	-.856431E-02
1975	26.5300	-2.74338	21.7355	5.15521	1.00000	.106568E-01
1976	32.2400	-.203865	10.3222	-1.03652	1.03354	.449354E-01
1977	39.2200	2.38134	-5.35580	-5.76675	.991902	-.177341E-01
1978	34.3200	-1.90883	-2.10870	-4.13427	.901474	-.626104E-01
1979	43.4300	3.31290	9.11660	7.24401	.887033	.116534E-01
1980	50.2500	-1.53714	12.0734	-.248596	.914158	.422336E-01

	GNP^{US}		GNP^{ROW}	
Year	Observed	Error	Observed	Error
1969	1386.20	15.2454	1868.77	21.1193
1970	1376.84	-25.2153	1981.43	14.8480
1971	1432.98	.518131	2098.90	7.63131
1972	1526.25	-.791789	2226.62	-.0282020
1973	1605.81	11.9109	2383.03	24.0021
1974	1565.72	-50.8077	2398.40	-11.4214
1975	1549.20	-44.7229	2404.74	-21.5719
1976	1623.02	66.5004	2516.21	11.3042
1977	1701.77	30.1898	2583.18	-27.1533
1978	1785.40	-.252814	2699.10	21.3467
1979	1792.29	27.6855	2809.64	5.53325
1980	1719.86	-59.6939	2929.65	-3.36386

The observed value of income transfers exhibits frequent, quite unpredictable fluctuations compared, for example, to the value-of-oil-imports variable. Innovations in U.S. and foreign domestic-factor incomes are small relative to observed values. Domestic-factor income in both the U.S. and rest-of-world is lower than predicted in 1974-75 and 1980, so the model reflects unanticipated recessions in those years.

Observed values and orthogonal innovations are shown for agricultural variables in Table 3.4 and Table 3.5. Large declines in U.S. production in 1970, 1974, and 1980, and smaller declines in production by corn importers in 1974 and 1977, are associated with corresponding negative errors. Similarly, positive errors are associated with increases in U.S. production in 1971, 1975, and 1979, and with increases in production in the importing region in 1975 and 1980. Observed exports by competing suppliers exceed predicted values in 1971 and 1974, and are lowest relative to predictions in 1977 and 1980. Observed beef prices are generally higher than expected in the early 1970s and lower than expected in the late 1970s (except 1979, when beef prices rose suddenly).

For U.S. corn price, U.S. corn consumption, and U.S. corn exports, both innovations based on the orthogonal model and one-step-ahead nonorthogonal forecast errors are shown in Table 3.5. These variables are last in the order of the orthogonal VAR model. The importance of contemporaneous correlation of errors is illustrated by a general reduction in errors for these variables between the nonorthogonal and orthogonal models. For example, sharp increases in observed corn price in 1973 and 1974 are associated with forecast errors

Table 3.4 Observed values and orthogonal errors, agricultural variables, 12-equation VAR model, 1969-1980

	y_c^{US}		y_c^{ROW}	
Year	Observed	Error	Observed	Error
1969	119056.	-645.84	105211.	1815.20
1970	105467.	-12889.51	107103.	-3215.00
1971	143416.	19428.14	109306.	-88.09
1972	141740.	-3244.71	115998.	5614.55
1973	144051.	-8968.02	117524.	-2099.67
1974	119412.	-22065.53	116668.	-293.53
1975	148370.	10708.36	122081.	-238.48
1976	159749.	-2539.82	123553.	-764.74
1977	165236.	-2258.91	121337.	-1303.61
1978	184617.	5337.11	127614.	1128.78
1979	201662.	21397.65	133883.	-1606.65
1980	168792.	-6216.44	143651.	2288.07

	s_c^*		p_b^{US}	
Year	Observed	Error	Observed	Error
1969	8305.7	-1926.48	42.9369	-.88021
1970	11065.0	370.30	40.9369	-1.87565
1971	14382.8	1532.12	42.5931	.51453
1972	11348.3	-786.03	45.6757	-.56968
1973	9753.6	-849.24	52.6877	1.53214
1974	14577.7	1390.32	45.7314	.94745
1975	12399.0	93.22	44.6100	1.34346
1976	10211.0	-159.26	36.9660	-1.34248
1977	9827.0	-998.87	35.8296	-1.73810
1978	11070.4	1077.45	43.1848	-2.00972
1979	10971.8	219.72	50.2224	3.34622
1980	10079.7	-1136.51	43.7361	-.53654

Table 3.3 Observed values, one-step-ahead forecast errors, and orthogonal errors, U.S. corn price, consumption, and exports, 12-equation VAR model, 1969-1980

Corn Price (p_c^{US})

Year	Observed	Forecast Error	Orthogonal Error
1969	69.8032	-0.63774	3.37828
1970	73.9408	-2.03448	-4.70631
1971	72.6472	-3.94850	2.35686
1972	66.0790	-6.37179	-7.69358
1973	104.415	18.4035	3.08677
1974	138.103	11.0133	4.42143
1975	113.840	-4.11328	-1.82069
1976	100.278	0.67027	5.31859
1977	77.3461	-6.73502	-1.61117
1978	74.9762	7.64591	3.58784
1979	77.0666	-1.83816	-2.37987
1980	77.3146	-3.84322	-0.52867

Corn Consumption (x_{cc}^{US})

Year	Observed	Forecast Error	Orthogonal Error
1969	102289.	-1620.13	-1779.01
1970	106703.0	-668.361	594.540
1971	106900.0	884.270	233.074
1972	116048.0	2192.05	1807.50
1973	119991.0	349.835	1405.76
1974	111254.0	-2880.58	107.127
1975	93711.0	-2943.67	-4101.18
1976	104966.0	2674.05	1446.75
1977	108057.0	-1949.12	-1186.48
1978	115189.0	-1876.23	-1386.80
1979	128216.0	2639.94	2438.39
1980	132203.0	894.974	724.309

Corn Exports (z_c^{ROW})

Year	Observed	Forecast Error	Orthogonal Error
1969	13872.0	-2076.01	-1633.61
1970	14359.8	-606.908	-471.110
1971	12867.7	-2783.57	-943.967
1972	21993.2	1726.04	1503.99
1973	31760.8	4243.06	-1799.08
1974	28945.2	-2805.27	-183.711
1975	33169.0	-480.695	-91.8396
1976	44039.1	3420.09	2834.69
1977	40363.8	-5229.34	-2649.55
1978	48872.4	1100.00	951.552
1979	56652.9	1901.78	-196.803
1980	61007.0	546.264	1346.75

of 18.4 and 11.0 in the nonorthogonal model, compared to prediction errors of 3.1 and 4.4 in the orthogonal model. Observed U.S. corn consumption falls in 1974, both absolutely and relative to the value forecast by the nonorthogonal model, but rises slightly compared to the value expected on the basis of the orthogonal model. Exports of U.S. corn, which rose sharply for two years after 1971, were above the level forecast by the nonorthogonalized model in 1973, but below the level predicted for that year by the orthogonal model.

The standard errors of nonorthogonal, one-step-ahead forecasts, and the proportion of forecast error variance attributed to a variable's own inovations in the orthogonal model, are shown for forecast horizons one to four periods ahead in Table 3.6. Among macroeconomic variables, own-innovations account for most of the forecast error variance for income transfers, the exchange rate, and U.S. domestic-factor income. Less than 50 percent of forecast error variance is explained by own-innovations in the value-of-oil-imports variable, after more than one period. This is so despite placement of this variable first in the orthogonal order. The two variables with dominant effects on the variance of oil-imports forecast errors are income transfers and the exchange rate. Shocks to these variables explain, respectively, 0, 23.0, 22.2 and 20.1, and 0, 8.6, 18.1 and 21.2 percent of the oil-imports forecast error variance, one to four steps ahead.[25]

Among other cross-variable effects, shocks to oil imports explain about 10 percent of the variance in income-transfer forecast errors at

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[25]Cross-variable effects on forecast error variances are not shown in Table 3.6.

Table 3.6 Standard error of one-step-ahead forecasts and proportion of forecast error variance attributed to own-innovations, 12-equation VAR model

	Macroeconomic and Nonagriculutral Variables				
	OIL^{US}	T^{ROW}	e	GNP^{US}	GNP^{ROW}
Standard Error of One-Step-Ahead Forecast	1.76	4.50	0.031	38.09	30.50
Forecast Variance (percent due to own-innovations)	100.0	88.7	89.7	71.9	26.8
	44.1	80.3	86.0	75.2	22.6
	27.9	74.9	80.5	78.0	18.6
	23.2	73.2	75.0	80.2	15.2

	Agricultural Variables						
	y_c^{US}	y_c^{ROW}	s_c^*	p_b^{US}	p_c^{US}	x_{cc}^{US}	z_c^{ROW}
Standard Error of One-Step-Ahead Forecast	10,879.7	3,412.9	1,091.1	2.62	6.48	2,363.2	2,050.8
Forecast Variance (percent due to own-innovations)	79.3	71.6	77.4	73.4	28.0	58.5	33.9
	78.3	65.5	68.8	61.3	21.6	24.5	27.9
	77.1	59.0	57.9	56.1	17.5	15.6	23.5
	75.6	52.9	47.7	54.4	16.2	12.2	21.1

all forecast horizons, but less than one percent of forecast error variances for the exchange rate. Shocks to income transfers explain about 10 percent of the variance of forecast errors in the exchange rate, while shocks to the exchange rate explain a somewhat smaller fraction of the variance in income-transfer forecast errors. Exchange rate shocks also explain over 10 percent of the variance in forecast errors for U.S. domestic-factor income. Shocks to U.S. domestic-factor income explain over 65 percent of the forecast error variance for rest-of-world domestic-factor income, underscoring the contemporaneous movement of these two variables.

Revising the orthogonal order among the oil-sector, income-transfer, and exchange-rate variables results in only slight alteration of forecast-error-variance decompositions. Placing the exchange rate before income transfers slightly increases the effect of exchange-rate shocks on transfers, and reduces the effect of income-transfer shocks on the exchange rate. Revision of the order does not alter the relatively large own-shock component of exchange-rate, income-transfer, and U.S. domestic-factor-income forecast error variances, or the relatively large effects of shocks to the exchange rate and income transfers on the variance of value-of-oil-imports forecasts.

With respect to sectoral variables, own-innovations explain a relatively large proportion of forecast error variance for corn production in the U.S. and the importing region, competitors' corn exports, and U.S. beef price. Shocks to the three sectoral variables--U.S. corn price, U.S. corn consumption and U.S. corn exports--explain a relatively small proportion of their own forecast error variance, and contribute little to forecast error variances for other agricultural variables. A complete error-variance decomposition for these variables is shown in Table 3.7. Sources of variance in the forecast errors are widely distributed among variables in the model. Shocks to income transfers and the exchange rate explain over 30 percent of the variance in forecast errors for corn exports and price, with income transfers explaining the greatest proportion for exports and the exchange rate explaining the greatest proportion for price. Corn-production variables explain over 30 percent of the variance of forecast errors for U.S. corn consumption, for forecasts more than one step ahead.

In terms of sectoral effects on the macroeconomy, shocks to agricultural variables have little effect on the variance of forecast errors for the macroeconomic and nonagricultural variables in the 12-variable orthogonal VAR model. In particular, the impacts of shocks to U.S. corn price, U.S. corn consumption, and U.S. corn exports are negligible. However, the orthogonal order and Bayesian prior impose a strong presumption against effects of agricultural variables on macroeconomic and nonagricultural variables. Much larger effects would be suggested by radical revision of the model, such as placement of all sectoral variables before all macroeconomic and nonagricultural variables and relaxation of the prior that gives relatively little weight to agricultural factors in equations for nonsectoral variables.

Table 3.7 Decomposition of forecast error variance, U.S. corn price, consumption and exports, 12-equation VAR model.

Corn Price (p_c^{US})

OIL^{US}	T^{ROW}	e	GNP^{US}	GNP^{ROW}	y_c^{US}
0.513	13.982	16.952	2.437	11.006	11.100
1.620	13.899	26.031	2.001	8.465	9.825
1.402	10.862	30.384	3.726	7.600	9.207
1.335	10.955	29.114	5.113	7.311	9.465

y_c^{ROW}	s_c^*	p_b^{US}	p_c^{US}	x_{cc}^{US}	z_c^{ROW}
5.427	0.252	0.355	37.973	0.000	0.000
5.470	4.792	5.985	21.652	0.249	0.005
6.706	5.379	6.767	17.514	0.228	0.217
8.215	5.135	6.272	16.250	0.244	0.585

U.S. Corn Consumption (x_c^{US})

OIL^{US}	T^{ROW}	e	GNP^{US}	GNP^{ROW}	y_c^{US}
7.700	0.000	3.013	9.439	2.256	0.969
5.317	3.899	1.305	15.708	0.901	30.799
3.403	10.107	5.266	15.671	0.750	29.524
2.642	9.425	10.176	19.059	0.597	25.296

y_c^{ROW}	s_c^*	p_b^{US}	p_c^{US}	x_{cc}^{US}	z_c^{ROW}
13.986	0.482	3.407	0.207	58.535	0.000
8.686	0.498	2.413	5.918	24.552	0.000
8.133	1.448	2.923	7.151	15.601	0.018
7.992	2.118	4.271	6.200	12.197	0.011

U.S. Corn Exports (z_c^{ROW})

OIL^{US}	T^{ROW}	e	GNP^{US}	GNP^{ROW}	y_c^{US}
6.021	29.394	6.286	4.196	7.813	0.596
5.250	22.761	14.954	3.358	7.316	8.401
7.864	21.087	15.639	4.535	7.942	10.520
9.415	23.016	14.323	5.085	10.032	10.282

y_c^{ROW}	s_c^*	p_b^{US}	p_c^{US}	x_{cc}^{US}	z_c^{ROW}
0.657	3.126	3.537	0.048	4.460	33.860
0.431	2.136	3.030	1.417	3.081	27.860
0.357	1.919	2.377	1.867	2.411	23.478
0.451	1.620	1.957	1.861	1.981	20.150

Impulse Response Functions

A complete set of impulse response functions for the 12-variable orthogonal VAR model is shown in Table 3.8 through Table 3.11. Responses of all variables to shocks of one standard deviation in each variable are shown. Estimated effects of each shock are reported for the period in which the shock occurs and three future periods. Since the orthogonal order is taken into account, responses to own initial shocks are smaller in magnitude than the nonorthogonal standard errors reported in Table 3.6, for variables other than the value of oil imports (first in the orthogonal order). Similarly, shocks to variables lower in the order have no contemporaneous effects on variables higher in the order.

Effects of shocks to macroeconomic and nonagricultural variables on one another are reported in Table 3.8. Effects of shocks to the three trade-related variables--oil imports, income transfers, and the exchange rate--are of particular interest. An unanticipated increase in the value of U.S. oil imports causes expected U.S. and foreign domestic-factor incomes to fall, and the expected income transfer to the corn-importing region (primarily from the U.S.) to decline. An oil-sector shock also causes the expected value of the dollar to appreciate slightly (e rises), then depreciate (e falls). For all time periods, depreciation caused by an oil-sector shock is less than 10 percent of the magnitude of an orthogonal shock to the exchange rate itself. An unanticipated increase in the income transfer also causes the expected value of the U.S. dollar to depreciate. The magnitude of this effect is one-third that of a direct orthogonal shock to the exchange rate.

Table 3.8 Effects of macroeconomic and nonagricultural shocks on the expected contemporaneous and future values of macroeconomic and nonagricultural variables, 12-equation VAR model

	OIL^{US}	T^{ROW}	e	GNP^{US}	GNP^{ROW}
Time Period					
0	<u>1.8</u>	-1.5	.0030	-6.7	-2.4
1	0.5	-0.3	-.0023	-5.7	-3.1
2	0.5	0.01	-.0028	-5.6	-4.5
3	0.6	0.2	-.0024	-6.1	-6.4
0	0	<u>4.2</u>	-.0098	-7.8	4.5
1	1.3	1.3	-.0069	-8.2	-0.9
2	1.1	0.1	-.0054	-7.7	-4.3
3	0.8	-0.3	-.0041	-7.2	-6.5
0	0	0	<u>.0289</u>	-17.3	-3.4
1	-0.8	-0.9	.0195	-11.0	0.3
2	-1.3	-0.9	.0111	-5.9	4.3
3	-1.2	-0.3	.0046	-2.7	6.7
0	0	0	0	<u>32.2</u>	25.3
1	-0.03	-0.6	-.0006	29.8	31.6
2	-0.6	-0.5	-.0019	29.3	37.1
3	-0.9	-0.3	-.0039	29.5	42.4
0	0	0	0	0	<u>15.8</u>
1	0.7	-0.5	-.0032	0.8	15.7
2	0.7	-0.4	-.0056	1.7	15.1
3	0.7	-0.3	-.0069	2.3	14.1

___: indicates initial shock.

Table 3.9 Effects of agricultural shocks on the expected contemporaneous and futures values of agricultural variables, 12-equation VAR model

Time Period	y_c^{US}	y_c^{ROW}	s_c^*	p_b^{US}	p_c^{US}	x_{cc}^{US}	z_c^{ROW}
0	9686.8	553.9	181.5	.47	-2.1	232.7	-158.4
1	2757.3	968.4	-153.8	.12	-2.3	2063.4	717.0
2	996.8	664.4	-35.8	.19	-1.4	1485.5	568.8
3	458.5	398.9	6.9	.05	-1.2	823.1	404.5
0	0	2888.2	-65.7	-.008	-1.5	883.8	-166.3
1	663.6	1412.2	-9.6	.23	-1.9	659.5	-1.9
2	336.4	754.4	24.0	.07	-1.8	761.3	-40.5
3	126.4	423.8	60.7	-.009	-1.7	691.4	-125.5
0	0	0	960.1	-.42	.3	164.2	-362.6
1	108.1	26.7	154.4	-.27	-2.2	206.8	74.9
2	32.3	37.7	10.8	-.12	-1.5	499.9	142.6
3	-3.0	45.7	32.8	.03	-.5	531.8	66.0
0	0	0	0	2.2	.4	436.2	385.7
1	-370.1	14.0	45.4	.9	2.5	384.2	213.8
2	-319.8	-54.7	41.4	.03	1.7	-554.6	-21.6
3	-130.4	-105.8	-40.2	-.3	.03	-754.7	-20.6
0	0	0	0	0	4.0	-107.6	45.3
1	-86.4	-22.8	56.8	-.19	2.6	-903.9	-298.2
2	31.1	-30.5	-2.3	-.19	.9	-866.3	-249.3
3	89.3	-19.4	-34.7	-.05	.2	-430.0	-121.4
0	0	0	0	0	0	1808.1	433.1
1	-96.2	-9.3	70.8	.08	.5	410.3	101.0
2	-108.8	-24.0	34.4	-.11	.2	-84.6	.4
3	-48.5	-35.7	-4.3	-.15	-.2	-159.2	-3.1
0	0	0	0	0	0	0	1193.3
1	6.4	-7.9	-59.1	-.14	-.08	2.5	603.2
2	95.4	-7.2	-69.1	-.08	-.5	-63.3	370.7
3	114.1	.006	-70.0	-.02	-.7	48.4	293.0

___: indicates initial shock.

Table 3.10 Effects of agricultural shocks on the expected contemporaneous and futures values of macroeconomic and nonagricultural variables, 12-equation VAR model

Initial Shock to:	Time Period	Effect of Shock On: OIL^{US}	T^{ROW}	e	GNP^{US}	GNP^{ROW}_{w}
y_c^{US}	0	0	0	0	0	0
	1	.3	-.1	.0025	-1.8	3.0
	2	.5	.2	.0027	-2.0	3.7
	3	.5	.3	.0020	-1.9	3.9
y_c^{ROW}	0	0	0	0	0	0
	1	-.02	.15	.0055	-.2	-.3
	2	-.01	.03	.0068	-.06	.9
	3	-.13	-.13	.0060	.5	2.4
s_c^{*}	0	0	0	0	0	0
	1	-.7	.4	-.0002	.9	.7
	2	-.5	.08	-.0002	1.4	1.4
	3	-.3	.1	-.0004	1.5	1.8
p_b^{US}	0	0	0	0	0	0
	1	.7	.7	.0006	-2.0	-1.3
	2	.8	.5	.0009	-3.0	-2.8
	3	.5	.06	.0010	-3.0	-3.5
p_c^{US}	0	0	0	0	0	0
	1	.2	-.2	.0002	-.4	-.6
	2	.06	-.4	.0002	-.3	-.7
	3	-.07	-.4	.0002	.03	-.4
x_{cc}^{US}	0	0	0	0	0	0
	1	.1	.4	-.0001	-.4	-.4
	2	.1	.3	-.0001	-.7	-.8
	3	.06	.08	-.0001	-.6	-.9
z_c^{ROW}	0	0	0	0	0	0
	1	.5	-.2	.0002	-.4	-.4
	2	.4	-.2	.0002	-.5	-.5
	3	.3	-.2	.0002	-.5	-.6

Table 3.11 Effects of macroeconomic and nonagricultural shocks on the expected contemporaneous and future values of agricultural variables, 12-equation VAR model

Initial Shock to:	Effect of Shock on: y_c^{US}	y_c^{ROW}	s_c^*	p_b^{US}	p_c^{US}	x_{cc}^{US}	z_c^{ROW}
OIL^{US}							
0	-99.7	-942.6	177.3	.09	.5	-655.8	-503.2
1	176.5	-538.7	-129.3	.34	-1.2	-560.7	289.3
2	66.2	-353.1	-175.9	.30	-.4	83.4	555.0
3	-32.1	-291.3	-153.6	.21	.2	18.3	543.0
T^{ROW}							
0	-645.2	943.6	-397.2	.25	2.4	-2.3	1111.9
1	-120.8	229.8	-81.9	-.82	2.9	-738.9	473.8
2	362.1	-65.0	-183.3	-.72	.3	-1298.4	518.2
3	471.7	-168.1	-290.8	-.30	-1.1	-670.4	753.6
e							
0	-2665.2	1041.2	182.5	-.96	-2.7	410.2	-514.2
1	-781.5	110.1	130.6	-.64	-4.4	120.4	-833.2
2	-245.4	-108.1	84.3	-.001	-3.7	990.0	-568.2
3	-157.2	-108.9	138.6	-.42	-1.2	1316.1	-383.1
GNP^{US}							
0	3722.2	-200.2	-90.9	-.38	-1.0	726.0	420.1
1	1214.1	845.7	283.0	-.65	-1.0	1293.1	-197.5
2	1095.1	1188.9	418.8	-.40	-1.7	1122.9	-395.5
3	1238.3	1368.7	471.0	-.22	-1.5	1400.6	-368.4
GNP^{ROW}							
0	1774.7	310.0	25.6	.54	2.1	-355.0	573.2
1	867.0	361.0	50.1	.01	2.1	14.4	375.4
2	891.5	338.9	27.9	.01	1.2	-198.6	426.4
3	940.4	339.2	-18.1	.06	.6	-64.7	591.7

The estimated effect of a shock to income transfers on the expected value of the exchange rate is consistent with analysis within a general equilibrium trade model. In the trade model, an increase in the transfer from one country to another causes the currency of the former country to depreciate relative to the currency of the latter, as described in Chapter II.

Likewise, the estimated impact of an unanticipated appreciation of the U.S. dollar on expected future values of income transfers to the corn-importing region is negative, as would be expected on the basis of the trade model. Appreciation of the U.S. dollar is also estimated to cause the expected value of U.S. oil imports to fall. If so, unanticipated devaluations of the U.S. dollar in the early 1970s played a causal role in inducing later increases in oil prices, a possibility that is not implausible since oil sales are for the most part denominated in dollars.

Interactions among agricultural variables are reported in Table 3.9. An unanticipated increase in corn production causes U.S. corn price to fall contemporaneously. The magnitude of this effect exceeds 50 percent of the magnitude of an orthogonal corn-price innovation. Expected U.S. corn exports and domestic corn consumption rise in the next period. The magnitude of the increase in U.S. consumption exceeds that of an orthogonal consumption innovation, while exports rise just less than by an own-innovation. Exports by competing suppliers drop slightly in response to an unanticipated increase in U.S. corn production.

An unanticipated increase in corn price causes the expected values of U.S. corn consumption and exports to fall. Consumption falls by 50 percent of an orthogonal consumption innovation, while exports fall by one-quarter of an own-innovation. Shocks to corn price are estimated to have little effect on corn production.

Among other effects reported in Table 3.9, an unanticipated increase in importing-region corn production causes U.S. corn price to decline and U.S. corn consumption to rise, but has little net effect on U.S. corn exports. A shock to corn exports by competing suppliers has similar impacts. An unanticipated increase in U.S. beef price causes expected U.S. corn consumption and exports to increase at first, then fall. A shock to beef price also causes expected corn price to rise, which may explain the net fluctuation in consumption and exports. Effects on other sectoral variables of orthogonal innovations in U.S. corn consumption and exports are generally small.

The estimated effects of shocks to agricultural variables on macroeconomic and nonagricultural variables are also quite small, as shown in Table 3.10. One exception is the estimated effect of shocks to corn-production variables on the expected value of the exchange rate. An unanticipated increase in production in the U.S. or importing-region raises the expected value of the U.S. dollar. The magnitude of these effects is less than 25 percent of a direct orthogonal innovation in the exchange rate.

Estimated effects of shocks to macroeconomic and nonagricultural variables on agricultural variables are shown in Table 3.11. An unanticipated increase in the value of U.S. oil imports depresses expected U.S. corn consumption. Predicted exports of U.S. corn fall contemporaneously then rise. This latter result is consistent with the notion that revenue earned by cartel oil-pricing was utilized partly to purchase additional goods, including U.S. corn, but suggests a lag in this sequence of events. An oil-sector shock also lowers expected corn production in the importing region and exports by competing corn suppliers. Effects on U.S. corn production and U.S. prices of corn and beef are small.

A positive shock to income transfers causes an increase in the expected value of U.S. corn exports, an increase in expected corn price, and a decline in expected U.S. corn consumption and beef price. The magnitude of the contemporaneous effect on expected exports is equal to that of an orthogonal shock to exports directly. Unanticipated depreciation of the U.S. dollar also results in an increase in expected U.S. corn exports and price, and a decline in expected U.S. corn consumption (the effects of an unanticipated appreciation of the dollar are shown in Table 3.11). The effect on beef price is positive, opposite to that of an increase in income transfers.

The magnitude of the effect of a shock to the exchange rate on expected corn price slightly exceeds that of an orthogonal price innovation, after one period. This impact suggests that U.S. corn price changes more than proportionately in response to an exchange rate shock (i.e., the orthogonal exchange-rate innovation is smaller relative to the sample mean of the exchange-rate variable than is the effect of this shock on price relative to the sample mean of the price variable). The response of export quantity to an unanticipated change in the exchange rate is also more than proportionate. In contrast, the response of expected corn exports to an unanticipated price shock is less than proportionate. An unanticipated appreciation of the U.S. dollar, and to a lesser extent a positive shock to income transfers, results in a decline in the expected level of U.S. corn production, and an increase in expected corn production in the importing-region.

An unanticipate increase in the domestic-factor income of either the U.S. or corn-importing region is estimated to have a positive effect on expected corn consumption within the region. In the case of a shock to U.S. domestic-factor income, expected corn production increases in the U.S. and importing region, and expected corn price falls. In the case of an orthogonal shock to foreign domestic-factor income, production effects are smaller, and expected corn price increases. Impulse response functions suggest explosive dynamic impacts of GNP shocks on GNP itself (Table 3.8) and on several agricultural variables. Again, the estimated GNP effects likely reflect time trends in the data.

Sources of Unantipated Developments in U.S. Corn Exports and Price

Taken together the estimated impulse response functions from the orthogonal VAR model confirm that the world corn market is affected to a considerable degree by shocks associated with macroeconomic and nonagricultural variables, as well as by shocks that are more narrowly sector-specific. To complete the analysis, the net effects of shocks from different sources on U.S. corn exports and price are evaluated for the years 1970-1980. These two variables are crucial indicators of developments in the world corn market, at least from a U.S. perspective.

The effects of shocks to the 12 variables included in the VAR model are divided into five catagories for purposes of the historical analysis. The cumulative effect of shocks to the oil-sector, income transfers through trade and factor-payment accounts, and the exchange rate are considered separately. These effects are compared to the joint cumulative effects of shocks to domestic-factor incomes, and the summed cumulative effects of all agricultural variables. Historically observed values of the export and price variables are decomposed. Hence, effects of shocks to nonsectoral variables are compared to the effects of sectoral shocks that do not exclude unpredicted changes in the export and price variables themselves.

Predicted values of U.S. corn exports, and the cumulative effect on exports of prediction errors from each of the five sources are shown in Table 3.12. Effects attributable to errors in trade-related factors are broadly distributed among the oil-sector, income-transfer and exchange-rate variables. Among these variables, the largest cumulative effects are attributed to the exchange rate, but effects of oil-sector shocks and income-transfer shocks are each largest in magnitude in three years. The effects attributed to specific trade-related variables are exceeded by the net effect of errors in sectoral variables in seven of the 11 years. The joint effects of domestic-factor-income shocks exceed the effects of specific trade-related variables in four years.

A similar decomposition of observed corn prices is shown in Table 3.13. The impacts attributed to errors in the exchange rate are dominant in the case of corn price. Effects of exchange-rate errors exceed those of oil-sector and income-transfer shocks in eight of 11 years. The net effect of shocks to agricultural variables exceeds the

Table 3.12 U.S. corn exports: predicted value, and the cumulative effects of shocks to agricultural variables, the exchange rate, domestic-factor incomes, income transfers, and the value of U.S. oil imports, 12-equation VAR model, 1970-1980

		Cumulative Effects of Errors in				
Year	Predicted Value	Oil Imports	Income Transfers	Exchange Rate	Domestic-Factor Incomes	Agricultural Variables
1970	14966.8	265.49	316.11	-951.61	210.83	-447.74
1971	17660.1	-333.69	-702.08	-1927.98	790.49	-2619.19
1972	20978.1	-501.88	-932.66	-680.23	876.10	2253.80
1973	24710.9	713.63	1687.39	1480.74	2072.90	1095.25
1974	20862.3	-1342.81	-248.56	1975.45	625.58	-926.82
1975	33353.2	1121.55	1237.62	1111.08	444.80	-4099.34
1976	38047.6	595.16	572.06	-140.67	3348.41	1616.50
1977	42820.7	-556.89	-538.49	-110.57	1504.67	-2755.67
1978	47590.3	928.17	-485.21	1785.06	1186.59	-2132.50
1979	52310.5	-507.27	1944.03	2245.52	817.88	-157.71
1980	56953.6	1139.05	239.46	380.18	-1219.17	3513.91

Table 3.13 U.S. corn price: predicted value and the cumulative effects of shocks to agricultural variables, the exchange rate, domestic-factor incomes, income transfers, and the value of U.S. oil imports, 12-equation VAR model, 1970-1980

		Cumulative Effects of Errors In				
Year	Predicted Value	Oil Imports	Income Transfers	Exchange Rate	Domestic-Factor Incomes	Agricultural Variables
1970	75.9753	-.244840	.688691	-4.93606	2.80870	-.350972
1971	81.1437	.810375	-.982777	-10.3205	3.77519	-1.87882
1972	86.4921	.081477	-8.72383	-5.05269	3.44046	-15.1585
1973	90.2104	1.60959	2.28193	8.94627	5.25397	-.667474
1974	91.8206	2.35395	5.02587	17.7541	4.16262	16.9855
1975	91.7786	2.98791	3.49731	14.3495	.322433	6.88027
1976	90.6243	.827837	1.71110	.709425	.184870	6.22036
1977	88.6408	1.84194	-4.75698	-8.06211	-2.87047	2.55290
1978	85.9218	-1.82684	-8.05547	-2.55369	-2.73940	4.22977
1979	82.5426	1.18634	.0640036	4.51311	-4.56255	-6.67667
1980	78.6441	-2.51811	5.82732	1.60961	-4.24828	-1.99997

effect of the exchange rate in only three years, and that of domestic-factor-income shocks exceeds exchange-rate effects in only one year.

The cumulative effects on corn exports and price of prediction errors for the trade-related and agricultural variables are illustrated in Figures 3.1 and 3.2. The unanticipated high value of the dollar lowers exports and price in 1970, 1971, and 1972, and unanticipated devaluations have large positive effects on exports and price in 1973, 1974, and 1975. An unanticated decline in the value of the dollar in 1978 has a relatively greater impact on exports than price, compared to the devaluations in the early 1970s.

Unanticipated developments in the corn market also reflect large cumulative effects arising from agricultural shocks. Exports fall compared to expectations one year after unanticipated declines in U.S. corn production in 1970 and 1974. The decline in production in 1974 also has a large positive effect on contemporaneous corn price. Agricultural shocks in 1977 and 1978 arise from diverse sources, while the unusually large U.S. harvest in 1979 helps explains the unantipated expansion of exports in 1980. Shocks to U.S. corn price that are attributed to sectoral variables are much larger in 1972 than in 1971, despite cumulative effects of sectoral variables on exports of similar magnitude (but opposite sign). Almost 50 percent of the effect of sectoral shocks on corn price in 1972 is attributable to a shock to the price variable itself. In contrast, only a small fraction of the effect of sectoral variables on corn prices from 1973 to 1975 arises from price shocks. The cumulative effect of shocks to sectoral variables on price is quite small in 1980, compared to the effect of sectoral shocks

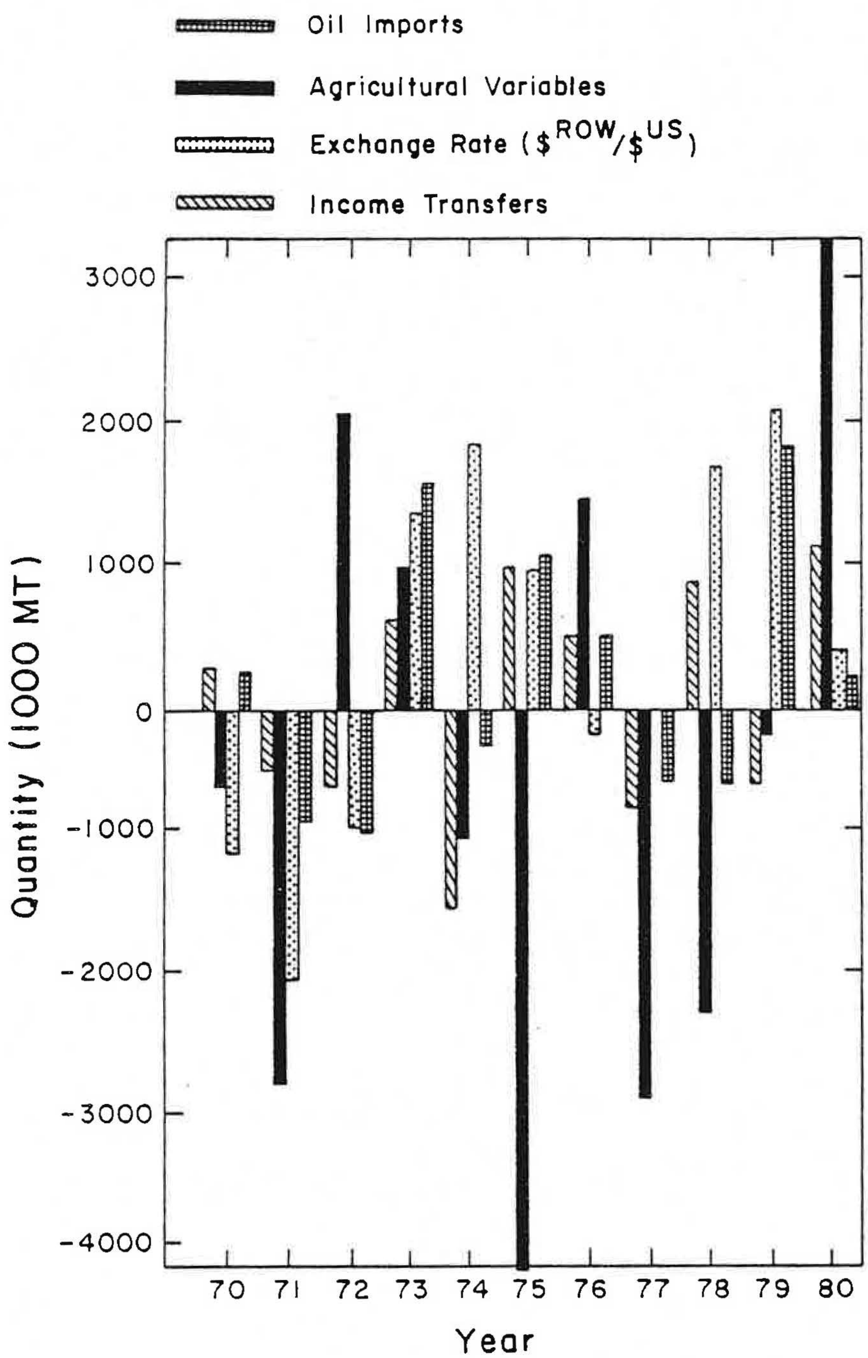

Figure 3.1. Cumulative effect on U.S. corn exports of shocks to agricultural variables, the exchange rate, income transfers, and the value of U.S. oil imports, 12-equation VAR model, 1970-1980

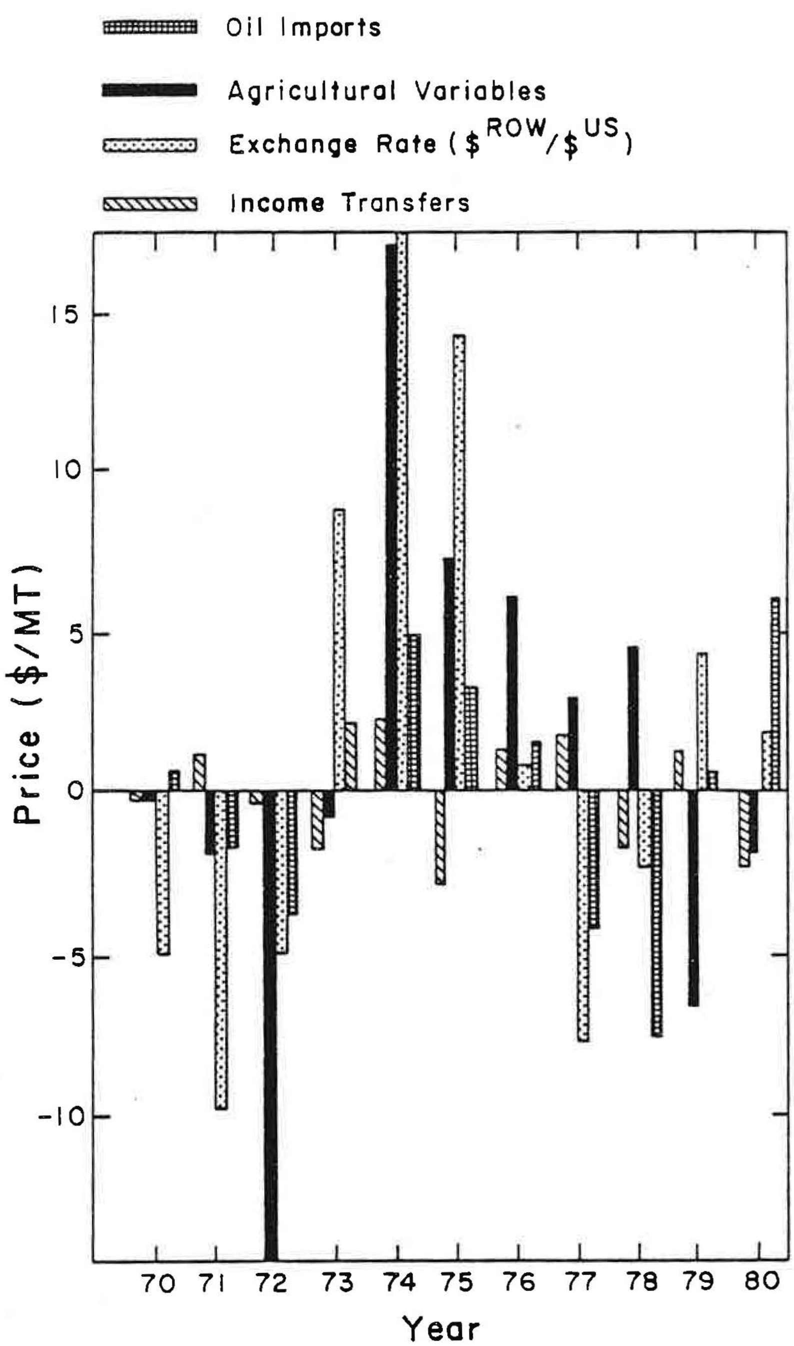

Figure 3.2. Cumulative effect on U.S. corn price of shocks to agricultural variables, the exchange rate, income transfers, and the value of U.S. oil imports, 12-equation VAR model, 1970-1980

on exports. The sectoral effect on exports in 1980 also includes a substantial own-innovation.

The historical pattern of the impacts on corn market developments associated with oil-sector and income transfer variables are less familiar than the pattern associated with the exchange rate and sectoral variables, in part because these variables have not been explicitly considered in previous analyses. The unanticipated increase in the value of U.S. oil imports between 1973 and 1974 has an immediate negative effect on U.S. corn exports, followed by lagged positive effects. Oil prices and imports rose again in 1978 and 1979. As noted previously, the value of U.S. oil imports was unexpectedly low in 1978 and 1980, and unexpectedly high in 1977 and 1979, based on the estimated VAR model. This pattern of forecast errors creates a negative effect of the oil-sector variable on corn exports in 1977 and 1979, and positive effects in 1978 and 1980. Effects of oil-sector shocks on price are estimated to be relatively small.

In terms of income transfers, relatively large cumulative effects on corn exports in 1973 and 1979 reflect large orthogonal shocks with immediate positive impacts. Price impacts tend to emerge more strongly the following year. A decline in anticipated transfers lowers corn exports and price in 1977 and 1978.

Implications of the Analysis

Empirical analysis based on the 12-variable VAR model has interesting implications concerning the effects of macroeconomic factors on agricultral commodity markets and the magnitude of these effects relative to those of sectoral factors. Little evidence of sectoral effects on macroeconomic variables is found.

In broad outline, the results support the assertion that U.S. agriculture will be substantially more unstable when integrated into world markets, as during the 1970s, than when domestic farm programs provide a high degree of insulation, as they did during earlier years. Instability arises from macroeconomic and nonagricultural factors, as well as from sector-specific developments.

The historical analysis confirms Schuh's original contention (1974) that the exchange rate is an important variable that had previously been omitted from analysis of U.S. agriculture. The results presented in Figures 3.1 and 3.2 suggest, however, that some studies focused on the early 1970s (e.g., Fletcher, Just and Schmitz, 1978; Chambers and Just, 1981) may overstate the relative importance of the exchange rate in a longer perspective. Exchange-rate effects on corn price are greater than sectoral effects in 1970, 1971, 1973-75 and 1977, but are smaller in 1976, 1978 and 1979. The effect of exchange-rate shocks on corn exports exceeded net effects arising from shocks to sectoral variables in 1973 and 1974, but are dominated by agricultural shocks of large absolute magnitude in 1972, 1975 and 1977. Sectoral effects are also larger in 1976, and the relatively large exchange-rate effect in 1978 is smaller than the cumulative impact that year of shocks to agricultural variables. The exchange-rate effect on export quantity exceeds the net agricultural effect in 1979, but is dominated by the effects of agricultural shocks in 1980.

Concerning the source of macroeconomic effects on agriculture, oil-sector shocks, income-transfer shocks, and exchange-rate shocks are shown to be closely related by the VAR analysis. Estimated interactions among these variables are consistent with theoretical concepts derived from the general equilibrium trade model. The assertion that distinct effects be attributed to related nonsectoral variables is supported by the VAR model, in which account is taken of interactions among these variables in estimation of specific impacts. Evidence of separate effects of the exchange rate and income transfers supports the reasoning that income effects are central to the impact of macroeconomic factors on agriculture.

Effects on agriculture attributed to the oil-sector variable are smaller than might be expected, particularly with the oil-sector variable first in the orthogonal order. The explanation for this result lies in the extent to which shocks to the exchange rate and income transfers explain subsequently observed values of U.S. oil imports, and the relatively small magnitude of forecast errors for the oil-import variable, compared to actual changes in the value of oil imports.

The dominance of exchange-rate shocks as a source of unexpected corn price obsevations, as opposed to corn export observations, might also be taken as suggestive of a monetary overshooting phenomena affecting both variables. Such a result is not derived in the context of the general equilibrium trade model, but exchange-rate overshooting in response to monetary policy has been suggested by Dornbusch (1976). Only one commodity is considered in the Dornbusch model, and its price is assumed to respond to monetary shocks by partial adjustments over time. Such a model could be extended to incorporate commodity-price overshooting by positing several goods with different rates of price adjustment. Lawrence and Lawrence (1981) have suggested a preliminary model of this type, and such a concept implicitly underlies the views on macroeconomic impacts on agriculture put forth by McCalla (1982). Empirical evaluation of this assertion in a VAR context would require the inclusion of macroeconomic policy variables not included in the 12-variable model reported herein. The relatively large contemporaneous correlations among errors in annual data suggests that such analysis proceed on the basis of a shorter time interval.

In the interim, perhaps it is most appropriate in assessing the relative influence of macroeconomic versus sectoral factors on agriculture, to treat the effects attributed jointly to the exchange rate, income transfers, and oil-sector developments as partially reflecting the impacts of a larger set of macroeconomic variables. The larger set would also include, for example, interest rates and measures of monetary and fiscal policies. Comparing the summed effects of shocks arising within the sector to the separate effects of any one macroeconomic variable may understate the total impact of the nonsectoral factors. Year by year, the effects attributed to the exchange rate, income transfers, and the oil sector tend to be in the same direction. Associating the transfer and oil-import effects would underscore the role of income transfers, relative to the role of the exchange rate. Conversely, associating the income-transfer and exchange-rate effects would underscore the role of macroeconomic policies, relative to shocks to real sectors. In either case, the magnitude of nonsectoral impacts is enhanced relative to sectoral factors.

SUMMARY

In this chapter, the relative effects on the world corn market of shocks to macroeconomic and nonagricultural, as opposed to more strictly sector-specific factors, have been evaluated for the period 1970-1980. Inferences drawn were based on estimated parameters of a 12-variable vector autoregressive model. Characteristics of a VAR model are that it provides a framework for dynamic analysis of economic time-series without imposition of a priori restrictions on interactions among variables, and that it focuses analysis on the effects of unanticipated shocks to each variable in the model.

That developments in the world corn market are influenced by shocks to income transfers, to the value of the dollar, and, to a lesser extent, to the oil-sector, as well as by shocks to agricultural variables, has been shown. Shocks to income transfers, the exchange rate, and the oil sector are also shown to be closely related during the 1970s. Estimated effects of the transfer and oil-sector shocks support the assertion that income effects are central to the impact of macroeconomic factors on agriculture, while dominance of exchange-rate shocks as a source of unanticipated price developments is suggestive of the impact of nonneutral monetary phenomena.

CLOSING REMARKS

The question considered in this dissertation has been the role of currency exchange rates, and more generally of other macroeconomic factors, in markets for agricultural commodities. Specifically, the effects of the value of the U.S. dollar, of income transfers through trade and factor-payment accounts, and of cartel behaviour in the oil sector on the world corn market have been evaluated, relative to the effects of agricultural variables, for the period 1970-1980.

The first objective of this study was to critically review partial equilibrium analysis of exchange-rate effects on goods markets. A two country general equilibrium trade model was developed. The crucial concepts to emerge were that of income transfers via the trade balance inducing shifts in equilibrium prices, with the primary effect that the price of the nontraded good relative to traded goods rises in the deficit country and falls in the surplus country; and that of realignment of currency values facilitating these price adjustments when exchange rates are flexible. Given these general-equilibrium considerations, partial equilibrium analysis of exchange-rate effects was shown to be justified only under narrow assumptions.

The second objective of this study was to consider empirical evidence concerning the effects of the exchange rate on agricultural commodity markets. Previous studies of these effects have suffered from one or more serious deficiencies: partial equilibrium constraints that cannot be justified were imposed on exchange-rate impacts, the exchange rate was the only macroeconomic variable considered, or the structure of the model did not facilitate a comparison of the effects of macroeconomic versus sectoral factors.

To provide a more coherent analysis of the magnitude of macroeconomic and nonagricultural, as opposed to sector-specific, influences on agriculture, parameters of a 12-variable vector autoregressive model were estimated. Sources of unanticipated developments in the world corn market were identified. That macroeconomic as well as sectoral factors effect developments in agricultural commodity markets was shown. Additional analysis would further clarify the extent to which the observed macroeconomic impacts are attributable to monetary policies, fiscal policies, or nonpolicy real shocks.

Relative to previous analyses, two results developed herein stand to enhance our basis for understanding the effects of the exchange rate and other macroeconomic factors on agricultural commodity markets. First, it has been demonstrated that the partial equilibrium constraints often applied to exchange-rate effects on agriculture simply need not hold. Future discussion of these effects ought to be in the context of additional macroeconomic modeling. Second, it has been shown that the specific impacts of a number of closely related macroeconomic and nonagricultural variables, as well as the effects of agricultural factors, should be explicitly considered in empirical models of agricultural markets.

If these points seem obvious now, enough said.

APPENDIX A

COMPARATIVE STATIC PROPERTIES OF THE GENERAL EQUILIBRIUM TRADE MODEL

Equilibrium conditions (14) provide a basis for considering the comparative static properties of the general equilibrium trade model. Three comparative-static results are of particular interest. First, there are the effects of an exogenous income transfer (i.e., the transfer parameter, t) on relative prices and the welfare of each country. Second, there are the effects of an exogenous income transfer on the exchange rate and other nominal variables, under alternative monetary regimes. Third, there are the impacts of alternative monetary and exchange-rate policies on prices and the trade balance.

The effects of an exogenous increase in the income transfer can be determined without reference to nominal variables. Totally differentiate the equilibrium conditions (14) to find

$$\text{(A1)} \quad \begin{bmatrix} \partial(Z_2^1 + Z_2^2)/\partial p_2^1 & \partial Z_2^1/\partial p_3^1 & \partial Z_2^2/\partial p_3^2 \\ \partial Z_3^1/\partial p_2^1 & \partial Z_3^1/\partial p_3^1 & 0 \\ \partial Z_3^2/\partial p_2^1 & 0 & \partial Z_3^2/\partial p_3^2 \end{bmatrix} \begin{bmatrix} dp_2^1 \\ dp_3^1 \\ dp_3^2 \end{bmatrix} = - \begin{bmatrix} \partial(Z_2^1 + Z_2^1)/\partial t \\ \partial Z_3^1/\partial t \\ \partial Z_3^2/\partial t \end{bmatrix}$$

where the matrix of price derivatives of the excess-demand functions is the Jacobian matrix (J) of the market equilibrium conditions. It will be assumed throughout that the initial equilibrium is stable so that J is a Hicksian matrix (i.e., its principal minors are alternatively negative and positive--in particular the determinant of J, denoted $|J|$, is negative).

Following Chipman (1974), define the Slutsky substitution terms, income effects, production transformation terms, and primary burden of the transfer by

$$\text{a)}\quad \hat{s}^k_{ij} = \partial h^k_i/\partial p^k_j + h^k_j(\partial h^k_i/\partial I^k)$$

$$\text{(A2)}\quad \text{b)}\quad m^k_i = \partial h^k_i/\partial I^k \qquad (i, j = 1, 2, 3, \quad k = 1, 2)$$

$$\text{c)}\quad t^k_{ij} = \partial Y^k_i/\partial p^k_j$$

$$\text{d)}\quad \beta = (p^1_1 v_1 + p^1_2)$$

Treating $\hat{s}^k_{ij}$ and m^k_i as functions of p^k, t, and ℓ^k, and using (8), (10), and (12)

$$\text{a)}\quad \partial Z^1_i/\partial p^1_j = s^1_{ij} - t^1_{ij} - m^1_i(X^1_j + v_j t - Y^1_j)$$

$$\text{(A3)}\quad \text{b)}\quad \partial Z^2_i/\partial p^2_j = s^2_{ij} - t^2_{ij} - m^2_i(X^2_j - Y^2_j - v_j t)$$

$$\text{c)}\quad \partial Z^k_i/\partial t = (-1)^k \beta m^k_i \qquad (i, j = 1, 2, 3, \quad k = 1, 2)$$

where $v_j = 0$ for $j = 1, 2$. Now let

$$\text{(A4)}\qquad b^1_2 = Z^1_2 + t \qquad b^2_2 = Z^2_2 - t$$

and define the total substitution term

$$\text{(A5)}\qquad s^k_{ij} = \hat{s}^k_{ij} - t^k_{ij} \qquad (i, j = 1, 2, 3, \quad k = 1, 2)$$

The market equilibrium condition (14a) implies $b^1_2 = -b^2_2$. Using this result, (A3), and (A5), expression (A1) may be rewritten as

$$\text{(A6)}\quad \begin{bmatrix} s^1_{22}+s^2_{22}-(m^1_2-m^2_2)b^1_2 & s^1_{23} & s^2_{23} \\ s^1_{32}-m^1_3 b^1_2 & s^1_{33} & 0 \\ s^2_{32}+m^2_3 b^1_2 & 0 & s^2_{33} \end{bmatrix} \begin{bmatrix} dp^1_2/dt \\ dp^1_3/dt \\ dp^2_3/dt \end{bmatrix} = \beta \begin{bmatrix} m^1_2 - m^2_2 \\ m^1_3 \\ -m^2_3 \end{bmatrix}$$

Using Cramer's rule, and the fact that $\sum_{j=1}^{3} s_{ij}p^k_j = 0$, one finds

$$dp^1_2/dt = \frac{\beta s^1_{33}s^2_{33}}{|J|}\left\{ \frac{\begin{vmatrix} m^1_2 & s^1_{23} \\ m^1_3 & s^1_{33} \end{vmatrix}}{s^1_{33}} - \frac{\begin{vmatrix} m^2_2 & s^2_{23} \\ m^2_3 & s^2_{33} \end{vmatrix}}{s^2_{33}} \right\}$$

$$\text{(A7)}\quad dp^k_3/dt = \frac{-(-1)^k \beta s^i_{33}}{|J|}\left\{ m^k_3 \frac{\begin{vmatrix} s^i_{22} & s^i_{23} \\ s^i_{32} & s^i_{33} \end{vmatrix}}{s^i_{33}} + s^k_{32}\frac{\begin{vmatrix} m^i_2 & s^i_{23} \\ m^i_3 & s^i_{33} \end{vmatrix}}{s^i_{33}} - \begin{vmatrix} m^k_2 & s^k_{22} \\ m^k_3 & s^k_{32} \end{vmatrix} \right\}$$

$(i \neq k;\ i, k = 1, 2)$

$$dp^k_3/dt - p^k_3/p^1_2(dp^1_2/dt) =$$

$$\frac{-(-1)^k \beta s^i_{33}}{|J|}\left\{ m^k_3 \frac{\begin{vmatrix} s^i_{22} & s^i_{23} \\ s^i_{32} & s^i_{33} \end{vmatrix}}{s^i_{33}} - \frac{p^1_1 s^k_{31}}{p^1_2}\frac{\begin{vmatrix} m^i_2 & s^i_{23} \\ m^i_3 & s^i_{33} \end{vmatrix}}{s^i_{33}} + \frac{p^1_1}{p^1_2}\begin{vmatrix} m^k_2 & s^k_{21} \\ m^k_3 & s^k_{31} \end{vmatrix} \right\}$$

$(i \neq k;\ i, k = 1, 2)$

From (A7), it has been shown (Chipman, 1974) that if the nontraded good is strongly superior (i.e., $m_3^k > 0$; $k = 1, 2$) and weakly totally substitutable for both traded goods (i.e., $s_{i3}^k \geq 0$ for $i = 1, 2$; $k = 1, 2$), then a transfer will lower the price of the nontraded good relative to at least one traded good in the surplus country, and raise the price of the nontraded good relative to at least one traded good in the deficit country. To establish the result for the surplus country (a similar proof applies to the deficit country), consider the three possible cases: $dp_2^1/dt = 0$ (no change in the terms of trade between traded goods), $dp_2^1/dt < 0$ (a deterioration in the price of good two relative to the price of good one), and $dp_2^1 > 0$ (an improvement in the price of good two relative to the price of good one). For the first two cases

$$\text{(A8)} \quad \frac{\begin{vmatrix} m_2^1 & s_{23}^1 \\ m_3^1 & s_{33}^1 \end{vmatrix}}{s_{33}^1} \geq \frac{\begin{vmatrix} m_2^2 & s_{23}^2 \\ m_3^2 & s_{33}^2 \end{vmatrix}}{s_{33}^2}$$

and hence

$$\text{(A9)} \quad dp_3^1/dt \leq \frac{\beta s_{33}^2 m_3^1}{|J|} \left\{ \frac{\begin{vmatrix} s_{22}^2 & s_{23}^2 \\ s_{32}^2 & s_{33}^2 \end{vmatrix}}{s_{33}^2} + \frac{\begin{vmatrix} s_{22}^1 & s_{23}^1 \\ s_{32}^1 & s_{33}^1 \end{vmatrix}}{s_{33}^1} \right\} \leq 0$$

so p_3^1 falls relative to both p_1^1 and p_2^1 (if the terms of trade do not change between traded goods), and relative to at least p_1^1 (if the price of good two declines relative to good one).

For the case of $dp_2^1/dt > 0$, the inequality in (A8) is reversed and holds strictly: it can then be shown that $dp_3^k/dt - p_3^k/p_2^1(dp_2^1/dt)$ is less than the middle expression in (A9), so p_3^1 falls at least relative to p_2^1.

To consider the effects of the transfer on welfare within a country, express aggregate utility as

$$\text{(A10)} \quad U^k(t) = U^k\{X_1^k(p^k(t), \ell^k, t),\ X_2^k(p^k, \ell^k, t),\ X_3^k(p^k, \ell^k, t)\} \qquad (k = 1, 2)$$

and differentiate, making use of the equilibrium condition $\partial U^k/\partial x_i^k = \lambda^k p_i^k$ (where λ^k is the marginal utility of income), and the fact that $\sum_{i=1}^{3} p_i^k m_i^k = 1$, to find

$$\text{(A11)} \quad dU^1/dt = -\lambda^1\{\beta + b_2^1 dp_2^1/dt\} \qquad dU^2/dt = \lambda^2\{\beta + b_2^1 dp_2^1/dt\}$$

If country one exports good one, and $dp_2^1/dt < 0$, part of the primary burden of the transfer, β, is alleviated by an improvement in the country's terms of trade. To see that welfare must nevertheless fall in the surplus country (and rise in the deficit country), substitute for dp_2^1/dt from (A7) and solve for

$$\text{(A12)} \quad \frac{d\lambda^1}{\lambda^1 \beta dt} = -\left\{\frac{s_{33}^1 \begin{vmatrix} s_{22}^2 & s_{23}^2 \\ s_{32}^2 & s_{33}^2 \end{vmatrix} + s_{33}^2 \begin{vmatrix} s_{22}^1 & s_{23}^1 \\ s_{32}^1 & s_{33}^1 \end{vmatrix}}{|J|}\right\} \leq 0$$

Monetary regimes must be introduced explicitly to evaluate the effects of a transfer on nominal prices and the exchange rate. Two fundamental results--the invariance of outcomes when deflated prices are considered, and the ineffectiveness of monetary policy when exchange rates are flexible--are direct consequences of the manner in which money is introduced into the model, as described in Chapter II. In the case of no change in the terms of trade between traded goods, it follows directly from the preceding relative price theorem that the real value of the deficit country's currency must appreciate. With stable price levels, the nominal price of the nontraded good can only fall relative to the prices of traded goods in the surplus country, and rise relative to the prices of traded goods in the deficit country, if traded good prices rise in the former and fall in the latter. This can only occur if the nominal exchange rate appreciates for the deficit country. With stable price levels, nominal appreciation of the currency is equivilant to real appreciation.

More generally, specific monetary comparative-static outcomes are intractable when a transfer affects the terms of trade among traded goods. To illustrate, the exchange rate serves to shift the prices of traded goods uniformly relative to nontraded goods. From the relative price theorem, one would anticpate apppreciation of the currency of the deficit country, as is the case in the example given in Appendix B. However, one might construct unusual cases in which price shifts among traded and nontraded goods did not induce such an outcome.

Likewise, under a fixed exchange rate regime, the effects of monetary and exchange rate policies are unambiguous when the transfer leaves relative prices among traded goods unchanged. Chipman (1980) has shown that a monetary expansion by one country, while the second country stabilizes its money supply, will raise the price level in both countries, with the magnitude of the increase greater in the country expanding its money supply. A capital inflow into the former is also induced (i.e., the result will be an induced deficit in the balance of trade). Similarly, if both countries stabilize their money supplies, an appreciation of a country's currency will result in a fall in its price level and a capital inflow. The price level will rise in the other country, and it will experience a capital outflow. Again, in the event that relative prices of the two traded goods are affected by the transfer, unusual cases might be considered in which these result do not hold.

APPENDIX B

FAILURE OF PARTIAL EQUILIBRIUM CONSTRAINTS ON THE EXCHANGE-RATE ELASTICITY OF PRICE

The purpose of this appendix is to provide an example in which the partial equilibrium constraint (4a) on the exchange-rate elasticity of price does not hold when applied to a deflated price and the real exchange rate. The example is based on Cobb-Douglas preferences and consumer demand functions (22). It is assumed that there is no production and that countries receive equal endowments of one traded good and their nontraded good. In particular, suppose

(B1) $$y_1^1 = y_2^2 = y_3^1 = y_3^2 > 0 \qquad y_2^1 = y_1^2 = 0$$

Using the condition of homogeneity of degree zero of excess-demand functions in prices and income

(B2) $$Z_2^2(p_1^2, p_2^2, p_3^2, t, \ell^2) = Z_2^2(p_1^1, p_2^1, ep_3^2, t, \ell^2)$$

and equilibrium conditions (14) can be expressed as functions of prices denominated in the currency of the first country $(p_1^1, p_2^1, p_3^1, ep_3^2)$. Equilibrium conditions for the example are

(B3)
$$\begin{aligned}
&a)\quad \theta_2^1 I^1/p_2^1 + \theta_2^2 eI^2/p_2^1 = y_2^2\\
&b)\quad \theta_3^1 I^1/p_3^1 = y_3^1\\
&c)\quad \theta_3^2 eI^2/ep_3^2 = y_3^2
\end{aligned}$$

where

$$\text{(B4)} \quad \begin{aligned} &a) \quad I^1 = p_1^1(y_1^1 - t) + p_3^1 y_3^1 \\ &b) \quad eI^2 = p_1^1 t + p_2^1 y_2^2 + ep_3^2 y_3^2 \end{aligned}$$

with the parameter t representing the magnitude of the transfer through the trade balance.

Substituting (B4) into (B3) and solving for the equilibrium prices yields, for given p_1^1,

$$a) \quad p_2^1 = \frac{((1-\theta_3^2)\theta_2^1/(1-\theta_3^1))(y_1^1 - t) + \theta_2^2 t}{\theta_1^2 y_2^2} p_1^1 \equiv \gamma_2^1(t)p_1^1$$

$$\text{(B5)} \quad b) \quad p_3^1 = (\theta_3^1(y_1^1 - t)/(1-\theta_3^1)y_3^1)p_1^1 \equiv \gamma_3^1(t)p_1^1$$

$$c) \quad ep_3^2 = (\theta_3^2(t + \gamma_2^1(t)y_2^2)/(1-\theta_3^2)y_3^2)p_1^1 \equiv \gamma_3^2(t)p_1^1$$

The effect of a change in the parameter t on equilibrium exchange rate and prices is determined from (B5), if rules governing behaviour of the monetary authorities are known. The issue is whether the percentage change in a deflated price, say $d(p_1^1/P^1)/dt$ (assuming $p_1^1 = 1$ initially), may exceed the percentage change in the real exchange rate ($d(eP^2/P^1)/dt$, assuming e = 1 initially). In the event that both monetary authorities stabilize Laspeyeres price indices (18), changes in nominal and deflated prices are equivalent, as are changes in the nominal and real exchange rate. In this case, what is to be shown is that dp_1^1/dt may exceed de/dt. For simplicity, assume t = 0 initially.

Using (B5), (18), and $(\bar{\alpha}_1^1 + \bar{\alpha}_2^1\gamma_2^1(\bar{t}) + \bar{\alpha}_3^1\gamma_3^1(\bar{t})) = 1$, a stable price level in country one (i.e. $dP^1/dt = 0$) implies

(B6) $$dp_1^1/dt = -(\bar{\alpha}_2^1(d\gamma_2^1/dt) + \bar{\alpha}_3^1(d\gamma_3^1/dt))$$

Similarly, a stable price level in country two (i.e. $dP^2/dt = 0$) implies

(B7) $$de/dt = dp_1^1/dt + \bar{\alpha}_2^2(d\gamma_2^1/dt) + \bar{\alpha}_3^2(d\gamma_3^2/dt)$$

Combining (B6) and (B7)

(B8) $$dp_1^1/dt - de/dt = -(\bar{\alpha}_2^2(d\gamma_2^1/dt) + \bar{\alpha}_3^2(d\gamma_3^2/dt))$$

Taking derivatives of $\gamma_2^1(t)$ and $\gamma_3^2(t)$ from (B5) and using $\bar{\alpha}_i^k = \theta_i^k/\gamma_i^k(\bar{t})$ for Cobb-Douglas preferences, under our assumptions on y_i^k's

(B9) $$y_1^1((1-\theta_3^2)\theta_2^1)(dp_1^1/dt - de/dt) = (1-\theta_3^2)\theta_2^1(\theta_2^2 + \theta_3^2)$$
$$- ((1-\theta_3^1)\theta_2^2(\theta_2^2 + \theta_3^2) + (1-\theta_3^1)\theta_1^2\theta_3^2)$$

Consider the special case of

(B10) $$\theta_1^1 = \theta_2^2 \qquad \theta_1^2 = \theta_2^1 \qquad \theta_3^1 = \theta_3^2$$

for which (B9) reduces to

(B11) $$y_1^1\theta_2^1(dp_1^1/dt - de/dt) = (\theta_1^2 - \theta_2^2 - \theta_3^2)\theta_2^2$$

In this case,

(B12) $$(dp_1^1/dt - de/dt) > 0 \text{ iff } \theta_1^2 > \theta_2^2 + \theta_3^2$$

Solving (B6) explicitly under (B10) yields

$$\text{(B13)} \qquad y_1^1 dp_1^1/dt = (\theta_2^1 + \theta_3^1 - \theta_2^2)$$

Similarly, using (B10) and (B13) in (B7) yields

$$\text{(B14)} \qquad y_1^1 de/dt = (\theta_2^1 + \theta_3^1) + \theta_2^2(\theta_2^2(\theta_2^2 + \theta_3^2)/\theta_2^1)$$

Thus when $\theta_1^2 > \theta_2^2 + \theta_3^2$, an increase in country one's trade surplus results in an increase in the deflated price of the first traded good that is proportionately greater than the real depreciation of the currency. This outcome is independent of whether the trade balance is taken as exogenous or as the outcome of monetary and exchange-rate policies.

APPENDIX C.

MULTI-MARKET PARTIAL EQUILIBRIUM MODELS OF EXCHANGE-RATE EFFECTS

Investigation of the validity of elasticity constraints derived from a one-market partial equilibrium model has resulted in extension of this model to account for effects of a change in the exchange rate on more than one price. These extensions have failed to clarify the role of the exchange rate in goods markets, and have retained crucial limitations of the one-market analysis.

Perhaps the most widely cited of such extensions was reported in a paper by Chambers and Just that appeared in the May, 1979 issue of the American Journal of Agricultural Economics. Chambers and Just consider an n-good economy in their presentation. The method of analysis followed is otherwise similar to that applied in the one-market case. Excess-supply and excess-demand functions of the form (1) are differentiated with respect to the exchange rate. All prices are allowed to change, but income is held constant. On this basis, an expression for the elasticity of the price of the i-th good with respect to the exchange rate is derived as[1]

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[1]This is equation (11) in the 1979 paper by Chambers and Just. The equations shown here use notation consistent with presentation of the one-market model in Chapter II of this study. In the original paper by Chambers and Just an asterisk denoted a vector rather than the foreign country.

(C1) $$\tilde{E}_{p_i} = E_{p_i} + (E_{p_i}/z^*_{ii})(\sum_{j \neq i}(z^*_{ij}(1 + \tilde{E}_{p_j}) - \varepsilon_{ij}\tilde{E}_{p_j}))$$

where E_{p_i} is the elasticity of price of the i-th good with respect to a change in the exchange rate derived in the one-market model, and z^*_{ij} and ε_{ij} are, respectively, elasticities of foreign excess-demand and domestic excess-supply for the i-th good with respect to the j-th price.

Treating excess-supply functions as homogeneous of degree zero in prices and excess-demand functions as homogeneous of degree zero in prices and income, Chambers and Just rewrite (C1), using (4), as

(C2) $$\tilde{E}_{p_i} = E_{p_i} - \frac{\sum_{j \neq i}((z^*_{ij} - \varepsilon_{ij})\tilde{E}_{p_j}) - (\omega^*_i + z^*_{ii})}{z^*_{ii} - \varepsilon_{ii}}$$

where ω^*_i is the elasticity of excess demand for the i-th good with respect to income in the foreign country.

Observing that (C1) and (C2) imply that $\tilde{E}_{p_i}$ (the price elasticity of the i-th good with respect to the exchange rate in the n-market model) may differ from E_{p_i}, Chambers and Just assert that there is no a priori reason to restrict $\tilde{E}_{p_i}$ to the closed interval {0, -1}. Acknowledging that (C1) and (C2) are difficult to evaluate, however, the special case of cross-price elasticities of foreign excess-demand all equal to zero is considered. In this case, (C2) reduces to

(C3) $$\tilde{E}_{p_i} = E_{p_i} + (1/(z^*_{ii} - \varepsilon_{ii}))(\sum_{j \neq i}\varepsilon_{ij}\tilde{E}_{p_j})$$

On the basis of (C3), Chambers and Just remark that if a devaluation is "inflationary" for supply substitutes, E_{p_i} may underestimate the magnitude of the effect of a change in the exchange rate on the price of the i-th good.

The interpretation provided by Chambers and Just merits two comments in comparison with the role of the exchange rate in the general equilibrium trade model. First, with respect to the issue of traded and nontraded goods, Chambers and Just assume that all goods are traded. They assert that this is no more than a simplifying assumption, with no effect on the qualitative results of their analysis.

This assertion is quite misleading. Technically, the assertion that equations (C1)-(C3) account for changes in all prices is correct. It is also correct that distinguishing between the n-goods on the basis of whether or not they are traded does not change the general form of these equations.[2]

However, to do so is hardly a distinction without substance. The unique role of the exchange rate in the trade model is to uniformly shift prices of traded goods relative to prices of nontraded goods. Chambers and Just do not interpret their equations to reflect such a role. Yet, a distinction between traded and nontraded goods could easily alter their qualitative results. While not being very precise, in equation (C3) for instance, if the i-th good (assumed to be traded) were a close substitute in supply with nontraded goods, rather than traded goods, and the prices of these substitutes fell as a result of a devaluation, then E_{P_i} would overestimate the effect of a change in the

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[2]In a reply to comments on their article, Chambers and Just (1980) present an expression equivalent to (C1) for the case of traded and nontraded goods. They repeat their claim that introduction of nontraded goods does not significantly change their qualitative results.

exchange rate on the price of the i-th good.[3] Further, a uniform shift in equilibrium deflated prices of traded goods relative to deflated prices of nontraded goods (which might be considered one case of a devaluation being "inflationary" for supply substitutes) has been shown in Chapter II to be sufficient to ensure that percentage changes in specific traded-good prices do not exceed the percentage change in the exchange rate. Hence, the interpretation of (C3) is vague with respect to the validity of bounds on the exchange-rate elasticity of price.[4]

The second aspect of the analysis by Chambers and Just that merits comment concerns the distinction between nominal and real variables and the role of the trade balance. The multi-market model that is presented is apparently formulated in nominal terms, but monetary regimes are not explicitly considered. Changes in the exchange rate are taken as exogenous, and no relationship is developed between these changes and income transfers. Implications for the price adjustment process of assuming nominal incomes are constant while all prices are flexible are not considered by Chambers and Just. As a consequence, consistency of their multi-market analysis of exchange-

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[3]A decline in the nominal prices of nontraded goods is more likely under the assumption that monetary authorities stabilize price levels than under the assumption that they stabilize nominal incomes. Under the former assumption some nominal prices must fall when others rise, while in the latter case all nominal prices may rise.

[4]Using the same method of analysis as Chambers and Just, it has been shown by Bredahl, McCamley, Collins, and Meyers (1979) that the exchange-rate elasticity of price is less than unity in absolute value if income elasticities are all positive for excess-demand functions and negative for excess-supply functions (i.e., all goods are superior in both countries), all own-price elasticities are negative for excess-demand functions and positive for excess-supply functions, and all cross-price elasticities are positive for excess-demand functions and negative for excess-supply functions.

rate effects and the role of the exchange rate in the general equilibrium trade model depends on the assertion that both monetary authorities stabilize nominal incomes, as is the case for simpler partial equilibrium models. Application of the elasticity expressions derived from the multi-market partial equilibrium model to deflated prices and real exchange rates cannot be sustained on the basis of the general equilibrium approach.[5]

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[5] In an n-good economy, income effects cannot be zero in each of the n-markets. Hence, the assumption that income does not affect a particular market, by which partial equilibrium analysis can sometimes be justified, cannot be applied to the n-good partial equilibrium model. An interesting case in point is provided by the example (23)-(24), given in Chapter II, in which all income effects arise in the markets for nontraded goods. In this case, a one-market partial equilibrium analysis applied to the traded good is consistant with the general equilibrium trade model if monetary authorities are assumed to stabilize the nominal prices of the nontraded goods, but not if they are assumed to stabilize nominal incomes. If a three-good partial equilibrium model is applied (one traded good and one nontraded good in each country), cross-price effects, but not income effects, can be accounted for in all markets. Analysis of all markets in the framework of a three-good partial equilibrium model is consistent with the trade model if monetary authorities are assumed to stabilize nominal incomes, but not if they are assumed to stabilize the prices of nontraded goods.

APPENDIX D

A POSSIBLE STRUCTURAL MODEL OF THE WORLD CORN MARKET

As one way to understand the set of variables choosen as a basis for an empirical analysis of the world corn market, a standard simultaneous equation model might be specified. One such model would include four equations: an equation for demand for U.S. corn by an aggregate rest-of-world importing region

$$(S.1) \quad z_c^{ROW} = Z_c^{ROW} (p_c^{US}, e, GNP^{ROW}, T^{ROW}, OIL^{US}, y_c^{ROW}, s_c^*)$$

a domestic U.S. consumption equation

$$(S.2) \quad x_{cc}^{US} = X_{cc}^{US} (p_c^{US}, p_b^{US}, GNP^{US}, T^{ROW}, OIL^{US})$$

an equation for domestic demand for end-of-period stocks

$$(S.3) \quad x_{cs}^{US} = X_{cs}^{US} (p_c^{US}, p_b^{US}, (x_{cs}^{US})_{-1}, y_c^{US})$$

and a market-clearing identity

$$(S.4) \quad (x_{cs}^{US})_{-1} + y_c^{US} - x_{cc}^{US} - z_c^{ROW} = x_{cs}^{US}$$

As a system of equations, the model (S.1)-(S.4) treats corn exports to the aggregate importing region, corn consumption in the United States, end-of-period U.S. corn stocks, and corn price in dollars as endogenous. All other variables are treated as exogenous.

To interpret the empirical specification (S.1)-(S.4), recall that excess demand for the i-the good by the k-th country could be expressed in the trade model as

$$(D1) \quad Z_1^k (p^k, t, \ell^k) = h_i^k (p^k, \pi^k (p^k, \ell^i) + D^k) - Y_i^k (p^k, \ell^k)$$

One view of equation (S.1), for example, is that it approximates (D1) with several pragmatic proxies. In place of all prices, only one relative price--the real corn price--is included. The exchange rate in (S.1) serves to convert a given U.S. price to a real price in foreign currency, and as a broad measure of relative prices of traded to nontraded goods. The GNP variable may be viewed as a proxy for the income obtained by domestic production (i.e., $\pi^k(p^k, \ell^k)$), and a measure of the transfer, D^k, is provided by the net income received by the rest-of-world through trade and factor-payment accounts, T^{ROW}. In the empirical model, production of corn is treated as exogenous, but variable between periods. This is not unlike a fixed consumption-good endowment in the static trade model.

The model (S.1)-(S.4) has two useful characteristics relative to the recent literature wherein the effects of the exchange rate on agriculture have been addressed. First, it provides a basis for direct comparison of the effects of sectoral variables, say an observed increase in U.S. corn production, to the effects of nonsectoral variables, such as a change in the exchange rate. Given the controversy over the relative magnitude of sectoral versus nonsectoral impacts this is an appealing attribute of the model.[1]

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[1]Within the framework of traditional simultaneous equation models, an extension of the model presented above would be to introduce supply

The second useful characteristic of the model (S.1)-(S.4) is that the effects of the exchange rate, income transfers, and oil-sector developments are evaluated in one framework. Estimated coefficients from models in which the exchange rate is the only macroeconomic variable may overstate its affect on agriculture. The specification (S.1)-(S.4) provides a basis for addressing this question, while maintaining a degree of continuity with the recent literature.

Estimated Parameters of the Structural Equations.

Estimates of the parameters of the structural equations (S.1)-(S.4), based on annual data from 1954 to 1980, are reported in Table D.1. Reported coefficients were estimated by two-stage least-squares.

Estimated coefficients of all variables are statistically significant in the importing-region corn demand equation. Coefficient estimates suggest a negative impact of an increase in the dollar price of corn. The elasticity of rest-of-world import demand with respect to U.S. price

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response. Supply functions would then include a variety of exogenous shifters and market impacts of these supply factors could be compared to impacts of other exogenous variables.

Chambers and Just (1981) estimate a quarterly recursive model in which U.S. production is a function of lagged price. Production then enters an inventory-demand equation similar to (S.3) and current-price, exports, domestic consumption, and inventories are determined as by (S.1)-(S.4). In the model posited by Chambers and Just there are few supply shifters, and neither foreign production nor exports by competitors enters the foreign-demand quation for U.S. farm products. Hence, the Chambers and Just model does not lend itself to ready comparison of sectoral versus nonsectoral influences. In contrast, their model is well adapted to illustrating how supply response over time dampens initial reactions of agricultural markets to changes in nonsector variables.

Table D.1 Simultaneous equation model of the world corn market, estimated structural equations

(1) $z_c^{ROW} = \; - \; p_c^{US} \; - \; e \; + \; OIL^{US} \; + \; GNP^{ROW} \; + \; T^{ROW} \; - \; y_c^{ROW} \; + \; s_c^*$

	Constant	p_c^{US}	e	OIL^{US}	GNP^{ROW}	T^{ROW}	y_c^{ROW}	s_c^*
Coefficient	48,747.6	-132.3	-21,122.2	513.3	18.8	273.5	-0.22	1.16
Std. error		(54.1)	(14,111.8)	(93.4)	(7.2)	(109.3)	(0.15)	(0.37)
Elasticity		{-0.62}	{-1.46}	{0.31}	{1.64}	{0.12}	{-1.10}	{-0.43}

$R^2 = .986$; $\bar{R}^2 = .981$

(2) $x_{cc}^{US} = \; - \; p_c^{US} \; + \; OIL^{US} \; + \; GNP^{US} \; + \; T^{ROW} \; + \; p_b^{US}$

	Constant	p_c^{US}	OIL^{US}	GNP^{US}	T^{ROW}	p_b^{US}
Coefficient	21,560.3	-302.5	61.5	48.3	274.4	824.8
Std. error		(81.4)	(135.9)	(6.2)	(204.8)	(314.8)
Elasticity		{-0.29}	{0.008}	{0.63}	{0.02}	{0.39}

$R^2 = .919$; $\bar{R}^2 = .901$

(3) $x_{cs}^{US} = \; - \; p_c^{US} \; + \; p_b^{US} \; + \; (x_{cs}^{US})_{-1} \; + \; y_c^{US}$

	Constant	p_c^{US}	p_b^{US}	$(x_{cs}^{US})_{-1}$	y_c^{US}
Coefficient	37,968.0	- 330.9	558.3	0.26	0.42
Std. error		(99.9)	(381.4)	(0.10)	(0.06)
Elasticity		{-0.27}	{0.23}	{0.25}	{0.44}

$R^2 = .921$; $\bar{R}^2 = .908$

Note: Numbers in parentheses are standard errors: numbers in brackets are elasticities evaluated at sample means.

is estimated to be -0.62, other things equal.[2]

The estimated coefficients also support the assertion that the response of corn imports to the exchange rate may exceed the response to price. The estimated elasticity of aggregate corn import-demand with respect to the real exchange rate is -1.46. Presumably the effect captured in the structural coefficient reflects the impact of relative price shifts associated with the exchange rate, since the equation contains separate variables measuring, albeit imperfectly, the impact on corn imports of U.S. price and rest-of-world domestic-factor and transfer incomes. To the extent that changes in the real exchange rate are accompanied by simultaneous changes in these other variables, as would be expected, the impact of the exchange rate on corn imports would be modified.

The estimated coefficient of the oil-sector variable is highly signficiant in the structural equation for rest-of-world corn import-demand. The elasticity is estimated to be 0.31. This elasticity implies that a 10-percent increase in the value of U.S. oil imports results in additional rest-of-world demand for corn of $51 million, all else equal. By way of comparison, based on the proportion of corn exports to total U.S. exports over the sample period, by direct computation a 10-percent increase in the value of U.S. oil imports would raise corn exports by around $20 million, if it is assumed that two-thirds of the increased value of oil imports is offset by expansion of U.S. exports, spread uniformly among goods.

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[2]All elasticities are evaluated at sample means.

The estimated parameters of the structural import-demand equation also suggest that domestic-factor income and income transfers received through the trade and factor-payment accounts have a positive effect on the aggregate level of corn imports from the United States. The elasticity of import-demand with respect to rest-of-world domestic-factor income is estimated as 1.64. A one-percent increase in transfer income received by the importing region is estimated to increase imports of U.S. corn by 0.12 percent. The estimated effect on foreign demand of a one <u>unit</u> increase in transfer income exceeds that of a unit increase in domestic-factor income, though it is not immediately apparent from the reported elasticites. This results from the small proportion of total income that is accounted for by income transfers.

In terms of sectoral factors, estimated coefficients of the rest-of-world import-demand equation suggest that foreign demand for U.S. corn is reduced by increased production within the importing region and by increased corn shipments by competing corn exporters. The estimated elasticities are -1.10 and -0.43 respectively. The elasticity of import-demand with respect to own-production of -1.10 implies that a unit increase in local supply reduces imports of U.S. corn by 0.22 units. A unit increase in shipments by competing corn exporters is estimated to cause a decline in U.S. corn exports of 1.15 units. Apparently substitution between the U.S. and competing exporters as a source of imported grain is higher than substitution between local production and total imports.

With respect to the U.S. domestic-consumption equation, estimated coefficients of the corn-price, domestic-factor-income, and livestock-price variables are statistically significant, as shown in equation (2), Table D.1. Estimated elasticities are -0.29, 0.63, and 0.39, respectively. The signs of the coefficients on variables measuring income transfers to the rest-of-world and the value of U.S. oil imports are positive, which is contrary to expectations. The standard errors of these coefficient estimates are large, and the estimated coefficients are not statistically significant.

In the structural equation for end-of-period demand for U.S. corn stocks (equation (3), Table D.1), all estimated coefficients are statistically significant. Based on these coefficients, an increase in current-period corn price reduces stock demand, while higher lagged ending-stocks, current beef price, and current production have a positive effect on the level of end-of-period stocks.

Estimated Parameters of the Reduced-form Equations.

Reduced-form equations for the variables treated as endogenous in the model (S.1)-(S.4) are reported in Table D.2. Reported coefficients are estimated directly by OLS. Briefly, with respect to sectoral factors, coefficient estimates from the reduced-form equation for aggregate imports of U.S. corn suggest negative effects of increased production in the importing region and competitors' grain shipments. Production in the United States and the level of U.S. carryover stocks are estimated to have positive effect on the quantity of U.S. corn imported by the rest-of-world. The estimated elasticities are -0.98 -0.41, 0.45, and 0.62, respectively.

Importing-region domestic-factor income, income transfers to the importing region through trade and factor-payment accounts, and the

Table D.2. Simultaneous equation model of the world corn market, estimated reduced-form equations

		Constant	y_c^{US}	y_c^{ROW}	$(x_{cc}^{US})_{-1}$	s_c^*	P_b^{US}	OIL^{US}	T^{ROW}	e	GNP^{US}	GNP^{ROW}
z_c^{ROW}	=	2,186.7	0.075	-0.20	0.11	-1.11	32.2	380.8	188.4	-10,900.0	0.23	17.8
			(0.041)	(0.12)	(0.04)	(0.31)	(133.6)	(117.0)	(92.1)	(14,374.5)	(15.28)	(8.8)
			(0.45)	(-0.98)	(0.62)	(-0.41)	(0.07)	(0.23)	(0.08)	(-0.75)	(0.01)	(1.56)
									R^2 = .991;	$\bar{R}^2$ = .986		
P_c^{US}	=	304.8	-0.0005	0.0008	-0.0005	0.0010	1.32	0.828	0.532	-80.2	-0.47	0.038
			(0.0001)	(0.0004)	(0.0001)	(0.0011	(0.46)	(0.404)	(0.318)	(49.6)	(0.053)	(0.030)
			(-0.72)	(-0.86)	(-0.59)	(0.08)	(0.66)	(0.11)	(0.05)	(-1.18)	(-0.65)	(0.72)
									R^2 = .913;	$\bar{R}^2$ = .861		
x_{cc}^{US}	=	-49,229.5	-0.05	-0.07	0.36	0.51	451.6	-207.8	-29.4	25,818.1	23.2	19.9
			(0.73)	0.20)	(0.07)	(0.54)	(233.1)	(205.0)	(161.3)	(25,176.6)	(26.7)	(15.4)
			(-0.06)	(-0.07)	(0.40)	(0.04)	(0.21)	(-0.03)	(-0.03)	(0.36)	(0.03)	(0.35)
									R^2 = .979;	$\bar{R}^2$ = .966		
x_{cs}^{US}	=	52,422.7	0.97	0.29	0.52	0.61	-559.9	-136.7	-171.7	-14,778.9	-24.9	-137.9
			(0.09)	(0.25)	(0.09)	(0.67)	(290.4)	(255.4)	(200.9)	(31,371.2)	(33.3)	(19.3)
			(1.03)	(0.25)	(0.50)	(0.04)	(-0.23)	(-0.02)	(-0.01)	(-0.18)	(-0.28)	(-0.58)
									R^2 = .979;	$\bar{R}^2$ = .967		

Note: First numbers in parentheses are standard errors; numbers below these are elasticities evaluated at sample means.

value of U.S. oil imports are estimated to have positive effects on foreign imports of U.S. corn. Estimated coefficients for these three variables are statistically significant. The elasticity of corn imports with respect to rest-of-world domestic-factor income is estimated to exceed unity. The exchange-rate coefficient is not statistically significant in the reduced-form corn-imports equation.

In the reduced-form equation for U.S. corn price, the sectoral explanatory variables that have statistically significant estimated coefficients are corn production in the U.S. and the importing region, lagged U.S. end-of-period stocks, and U.S. beef price. An increase in U.S. or foreign production, or U.S. stocks is estimated to reduce corn price, while an increase in beef price is estimated to raise corn price. Among macroeconomic variables, estimated coefficients of the value-of-oil-imports, income-transfer, and exchange-rate variables are statistically significant. Estimated elasticities are 0.11, 0.05 and -1.18, respectively. The elasticity of corn price with respect to the exchange rate suggests that changes in the value of the U.S. dollar effect corn price more than proportionately.

In the reduced-form equations for both domestic U.S. corn consumption and end-of-period stocks, the estimated coefficient of the lagged stocks variable is positive and statistically significant. In the end-of-period stocks equation, the estimated coefficient of the U.S. corn-production variable is also positive and statistically significant. The net effect of higher beef price is estimated to be positive in the consumption equation and negative in the stocks equation. Both coefficients are significant.

The estimated coefficients of the value-of-U.S.-oil-imports variable are negative in both the U.S.-consumption and end-of-period stocks equations, as are the coefficients of the variable measuring income transfers to the corn-importing region. None of the estimated coefficients are statistically significant; nor is the estimated coefficient of the exchange-rate variable significant in either of these equations. Multicollinearity also creates some difficulty identifying the effects of specific domestic-factor incomes. The estimated coefficients of both U.S. and foreign domestic-factor-income variables are positive in the U.S. consumption equation and negative in the end-of-period stocks equation, but only one of these coefficients is statistically significant.

Implications of the Analysis

Analysis on the basis of the structural model broadly confirms the importance to agriculture of both sectoral and macroeconomic factors that is suggested by the VAR model in Chapter III, while providing a certain continuity with previous studies. Estimated parameters support the conclusion that there are substantial exchange-rate impacts on agriculture. As before, the statistically significant effects attributed to variables measuring income transfers and the value of U.S. oil imports imply that traditional econometric models including only an exchange-rate variable to reflect the influence of macroeconomic forces may overstate the exchange-rate effect per se. Indeed, the structural model suggests a somewhat larger role for the oil-sector than is suggested by the VAR analysis. If the oil-sector variable is omitted from the model (S.1)-(S.4), the estimated impact of the exchange rate on U.S. corn exports and price is much larger than reported herein.

Limitations of the Analysis

In contrast to the VAR approach, analysis in the framework of a standard econometric model proceeds on the basis of restrictions on interactions among variables imposed a priori so that a particular "structural" model, such as (S.1)-(S.4), is presented. In general, the standard econometric approach offers the advantage, given limited historical data, that imposed restrictions facilitate inclusion in some part of the model of many more relevant variables than may practically be included in a symmetric, unrestricted VAR. Theoretical arguments or past empirical evidence may suggest the relevance of such a specification in some cases.

From the perspective of an unrestricted VAR, nevertheless, several crucial attributes of the standard approach require narrow justification. Consideration of these limitations underscores the merit of an evaluation of macroeconomic versus sectoral influences on the world corn market in a VAR framework, as presented in Chapter III. In particular, these considerations suggest that estimated coefficients of specific variables treated as exogenous in a model such as (S.1)-(S.4) be interpreted with some caution.

To illustrate, in the standard model the division of variables into a group considered exogenous and a group considered endogenous presupposes that shocks to endogenous variables do not affect exogenous variables. To justify such an assumption, the autoregressive representation of an unrestricted VAR model would have to be of the form

$$
(D2) \qquad \begin{bmatrix} A_{22}(L) & A_{12}(L) \\ 0 & A_{22}(L) \end{bmatrix} \begin{bmatrix} y_t \\ x_t \end{bmatrix} = \begin{bmatrix} u_t \\ v_t \end{bmatrix}
$$

where y_t is a (k x 1) vector of variables treated as endogenous in the standard model, x_t is an ((m-k) x 1) vector of variables treated as exogenous, u_t and v_t are vectors of one-step-ahead forecast errors for the y_t and x_t variables, and $A_{ij}(L)$ are matrices of autoregressive parameters. In the case of the world corn market, a specific classification of variables as endogenous versus exogenous may be untenable, either with respect to the division among sectoral variables, or with respect to the absence of any impact of sectoral variables on the macroeconomy. For example, though macroeconomic variables are often treated as exogenous in empirical agricultural models, it has also been asserted that associations among macroeconomic and agricultural variables are due primarily to the effect of sectoral shocks on macroeconomic factors (e.g., Fischer, 1981).

Changes in exogenous variables are also treated as mutually independent in a standard econometric model. This is the basis on which an interim multiplier traces the effects of an exogenous change on endogenous variables, and on which reduced-form equations decompose historical movements in predicted values into components attributed to each specific exogenous variable. In a VAR framework, the exogenous variables from (D2) are independent only under an additional assumption such as

a) $A_{22}(L) = diag\{a_{ii}(L)\}$

(D3)

b) $cov\ \upsilon_t = diag\{\sigma_{ii}\}$

Quite apart from the issue that endogenous variables do not affect exogenous variables, the asymmetric treatment of endogenous versus exogenous variables in a standard model is highlighted by (D3). Endogenous variables are treated as simultaneously determined, so presumably contemporaneous correlations in innovations are quite large among these variables. In contrast, it is implicitly assumed in the standard model that contemporanous correlations among errors in exogenous variables are small. Such treatment of exogenous variables may be quite misleading. The general equilibrium trade model considered in Chapter II provides a basis for suspecting this to be the case for the exchange rate and income transfers.

Further, interim multipliers of a standard econometric model trace the effects of a given change in an exogenous variable on the assumption that future values of the exogenous variable are not affected by the initial shock.[3] Yet, changes in expected future values of a variable may often be attributed to a current shock. Effects of these changes are accounted for in the impulse response functions from a VAR model.

In addition, analysis in a VAR framework places focus on the effects of unanticipated shocks, by proceeding on the basis of the

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[3]This may be verified by review of the derivation of interim multipliers. For example, see Theil, 1971, pp.464-65.

moving average rather than the autoregressive representation of a vector stochastic process. This approach is consistent with the notion that current behavior of economic agents in dynamic settings is conditioned on their expectations about the future, and that current values of observed economic variables reflect these expections. Though this concept cannot be reflected well in a static model, it is the effects of unanticipated shocks on the expected future paths of variables that is of interest in such a setting. The magnitude of these effects is estimated on the basis of historical data in a VAR analysis.

In contrast, little distinction between expected developments and unanticipated shocks is provided in the evaluation of effects of exogenous variables on endogenous variables in a standard econometric model. Treatment of exogenous variables as nonstochastic precludes such a distinction. Even if exogenous variables are viewed in a less deterministic fashion, the effects of unanticipated shocks can not be isolated unless the initial model is appended to include some model of the determination of the exogenous variables.

Finally, analysis based on reduced-form equations of a standard econometric model focuses exclusively on the effects of exogenous variables on endogenous variables. Unlike the symmetric treatment provided by the impulse response functions from a VAR model, usual reduced-form analysis provides no basis for evaluating the effects of shocks to endogenous variables on other endogenous variables. Comparison of the relative impacts affecting an endogenous variable is thus restricted to comparisons only among exogenous factors.[16] Perhaps this asymmetry in interprutation of the model is not surprising given the dichotomy imposed between endogenous and exogenous variables. However, if the magnitude of the effects of shocks to variables treated as endogenous, relative to the effects of shocks to variables treated as exogenous, is relevant--as is the case in standard models developed to evaluate macroeconomic versus sectoral impacts on agriculture--such an asymmetry constrains the utility of an analysis.

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[16]Expressions for the ratio of changes in endogenous variables can be derived from the reduced-form equations of a standard econometric model. These ratios might be interpreted to measure the change in one endogenous variable associated with a change in another endogenous variable. However, these ratios depend directly on the changes in exogenous variables that are posited to occur.

APPENDIX E

DATA SOURCES

The variables selected as a basis for analysis of factors affecting the world corn market were constructed as described in the text, based on the following series:

Nominal U.S. Corn Price:	"Average Cash Price of Corn, No. 2 Yellow at Chicago," compiled by Eonomic Research Service, USDA and reported in Commodity Yearbook, Commodity Research Bureau Inc., Jersey City, New Jersey (various issues).
Nominal U.S. Beef Price:	"Average Wholesale Price of Beef Steers at Omaha, Choice, 900-1100 lbs.," Commodity Yearbook, op. cit., (various issues).
U.S. Corn Exports:	"0440045 Yellow Corn, Except Seed, Unmilled, Not Donated for Relief," U.S. Exports, Schedule E., Commodity by Country, U.S. Department of Commerce, Annual Summary, 1953-1980.
U.S. Corn Consumption:	"United States Corn Quarterly Supply and Disappearance," compiled by Economic Research Service, USDA and reported in Commodity Yearbook, op. cit., (various issues).
U.S. End-of-Period Corn Stocks:	Ibid., (various issues).
U.S. Corn Production:	Ibid., (various issues).
Foreign Corn Production:	"Maize," Production Yearbook, Food and Agricultural

Organization of the United Nations, Rome, Italy, 1953-1981.

Shipments by Competing Exporters: "Maize," Trade Yearbook, Food and Agricultural Organization of the United Nations, Rome, Italy, 1953-1981.

Nominal Exchange Rates: "Exchange Rates," series rf (period average), by country, International Financial Statistics Yearbook, International Monetary Fund, Washington, D.C., 1982.

National Accounts: "National Accounts," Series 90c, 98c 99b and 90e or 98e, by country, International Financial Statistics Yearbook, op. cit.

U.S. Oil Imports: "Petroleum Imports," Series 71a, United States, International Financial Statistics Yearbook, op. cit.

Consumer Price Level: "Consumer Prices," Series 64, by country International Financial Statistics Yearbook, op. cit.

Values of the data series are shown for the period 1969-1980 in Tables 3.3, 3.4, and 3.5. Complete series for the period 1954-1980 are available upon request.

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