



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

The Exchange Rate and U.S. Agricultural Exports

Clark Edwards

Abstract

An export slump is one of the major problems plaguing U S agriculture. Many of the world economic forces that had turned against U S farmers in the early eighties have now changed. The exchange rate is one of these forces. This article presents a simulation of the disparate impacts of depreciation on importers and competing exporters, and the implications for specifying price transmission equations in international trade models. Protective policies, such as tariffs and quotas, reduce the elasticity of exports with respect to a change in price.

Keywords

Exchange rates, exports, imports, agriculture, international, prices, trade, trade barriers

The volume of U S farm exports continues below its 1980 peak. This is one of the major problems plaguing agriculture. Lower exports contributed in the eighties to lower incomes, financial stress, and reduced values of land and other farm assets. Agriculture may not recover until farm exports pick up.

The export slump in the eighties followed an unusually rapid export expansion in the seventies. Changes in the world economic situation at the turn of the decade contributed to the slump. Slowed economic growth and reduced availability of foreign exchange reduced imports in many countries. A more expensive dollar and higher prices received by U S farmers added to the cost of importing U S farm products. Agricultural production increases in other countries either reduced demand for imports or increased supplies of competitive exports. High exchange rates were correlated with high domestic interest rates, so farmers were squeezed between reduced revenues and increased costs. High energy costs associated with the world energy situation added further to the squeeze. Subsequent reductions in energy costs were associated with losses of income and of foreign exchange for some importers of farm products. Changes in subsidies, tariffs, quotas,

embargoes, and transportation rates added to the volatility of the decade.

The boom of the seventies was at an unsustainable rate of 8 percent per year. Many worried that the boom would stop because of limits to U S agricultural capacity. But the end came from the demand side instead, when the market collapsed for exports of U S farm products.

Many of the world economic forces that had turned against U S farmers by the early eighties have since changed, although they may be less favorable than they were during the early seventies. Reduced exchange rates and lower prices received by farmers relative to world levels suggest that conditions are now right for exports to begin to pick up. If they do, it will take U S agriculture a few years to absorb the resources idled during the export slump and to work off the accumulated surpluses. If they don't, U S agriculture can anticipate deepening financial troubles.

This article focuses on only one of several factors affecting the level of farm exports: price transmission. The key to price transmission is the exchange rate, but the mechanism is modified by institutional arrangements such as subsidies and tariffs. Relatively lower exchange rates were associated with the export boom of the seventies, and relatively higher ex-

The author is a senior economist with the National Economics Division, ERS.

change rates were associated with reduced exports in the eighties. The depreciation of the dollar in 1985 and 1986 could help expand exports.

The theory of equilibrium among three countries trading a single commodity is considered in the next section of this article. Currency realignments among competing exporters and importers have important, but disparate, economic effects on the various sources of supply and demand. The exchange rate theory is then used as a framework for evaluating some literature on exchange rates and agricultural exports. Both the theoretical and empirical approaches tend to agree that exchange rates are potentially important in explaining the variation in exports, but they tend to differ as to the magnitude of the change in exports with respect to a change in exchange rates. Finally, some implications are developed for specifying price transmission relationships in existing agricultural models and for reconciling some divergent views of the elasticity of response. The reconciliation entails allowances for tariffs, subsidies, and other institutional arrangements affecting price transmission.

Trade Equilibrium Among Two Exporters and One Importer

Consider a three-country world in which each country produces, consumes, and trades a homogeneous agricultural product under perfect competition. Such a model is as small as one can devise and still simulate the impacts of exogenous changes in the exchange rates of an exporting country on its own exports and also on production, consumption, and trade of an importer and a competing exporter. Variables in the model are the quantity produced, the quantity consumed, and the price in each country—nine variables in all.

There are three demand equations, one for each country. For simplicity, let them be linear:

$$p_j = \alpha_j - \beta_j qd_j \quad \text{for } j = 1 \text{ to } 3$$

And there are three linear supply equations:

$$p_j = \mu_j + \sigma_j qs_j \quad \text{for } j = 1 \text{ to } 3$$

where p , qd , and qs are the prices, quantities demanded, and quantities supplied, α , β , μ , and σ are parameters for the demand and supply equations, and j is an index for countries.

Trade among countries requires two transactions, one related to the exchange among goods and the other to the exchange among currencies. In this

model, the terms of trade among goods are endogenous and the terms among currencies are exogenous. Let the symbol r_j represent the exogenous exchange rate between the first and the j^{th} country. Then two of the price relationships are

$$p_1 = r_j p_j \quad \text{for } j = 2 \text{ to } 3$$

An increase in r_j reflects a depreciation in the currency of country 1. In empirical work it is important whether the exchange rate measures foreign currency per unit of domestic currency or domestic currency per unit of foreign currency. For the purposes of a hypothetical simulation, this ambiguity is not important. These two price transmission equations imply a third redundant equation:

$$p_2 = (r_3 - r_2) p_3$$

This simplest form of the price transmission equations is used in the theoretical simulation. The review of literature to follow shows that modifications reflecting institutional arrangements such as tariffs and transportation are important. Such modifications will be discussed later.

The final equation assures that the market clears. Many trade models require that the sum of the exports by the exporting countries equals the sum of the imports by the importing countries. This restriction has the same effect as requiring that the sum of demands in all countries equals the sum of supplies. The latter formulation was chosen because it is easier to track things if some of the shocks to the model cause one of the countries to switch from, for example, an exporter to an importer. In conjunction with the other equations, the final equation assures that market-clearing prices are found:

$$\sum qd_j = \sum qs_j \quad \text{for } j = 1 \text{ to } 3$$

The model presented here and the hypothetical data used to implement it help organize ideas, evaluate the literature, and suggest specifications for more detailed and empirical models. This model brings out salient relationships between exports and exchange rates with a minimum of conceptual framework. It omits facets of exchange that are important in real-world trade while highlighting the disparate impacts of exchange rate fluctuations on the various sources of demand and supply.

Taking exchange rates as exogenous in a one-commodity world overlooks important problems facing world trade since exchange rates began to float in the early seventies. Orden, for example, explains exchange rates by income transfers among countries resulting from trade surpluses and deficits in a

multicommodity framework (17)¹ Other real-world relationships not considered here include monetary matters and the distinction between shortrun and longrun responses. See Chambers (4), for example, for a broader perspective than that taken here, including endogenous changes in exchange rates and the relationship to agriculture of monetary phenomena other than exchange rates. A more complete model specification and careful statistical estimation of the structure are beyond the purpose of this article, although the analysis and review suggest how such model building and estimation might be done.

Sensitivity to Exchange Rates

The small and linear system presented here is relatively easy to solve. Consider a reduction of the model to two equations and two unknowns. Let the unknowns be the quantity supplied in country 1 and the price in country 1. One of the equations is the original supply function for country 1

$$p_1 = \mu_1 + \sigma_1 q_{s1}$$

The other equation is found by the substitution of the other seven demand and supply functions into the market-clearing equation. The resulting relation, solved for q_{s1} as a function of p_1 , captures the net demand for the quantity produced in country 1

$$q_{s1} = \left[\frac{\alpha_1}{\beta_1} + \left(\frac{\alpha_2}{\beta_2} + \frac{\mu_2}{\sigma_2} \right) + \left(\frac{\alpha_3}{\beta_3} + \frac{\mu_3}{\sigma_3} \right) \right] - \left[\frac{1}{\beta_1} + \left(\frac{1}{\beta_2} + \frac{1}{\sigma_2} \right) \left(\frac{1}{r_2} \right) + \left(\frac{1}{\beta_3} + \frac{1}{\sigma_3} \right) \left(\frac{1}{r_3} \right) \right] p_1$$

This linear and downward sloping equation contains the parameters of the other seven demand and supply functions. Econometricians frequently use the term "demand function" to denote quantity as a function of price and use the term "inverse demand function" to denote price as a function of quantity. The qualifier "inverse" is dropped in this article, although both forms of the function appear. However, understanding the distinction is important in interpreting the various relations discussed because an increase in the slope of a demand curve, for example, is a decrease in the slope of the inverse demand curve.

An increase in the demand in a foreign country or a decrease in the supply increases the demand for the

product of country 1. Devaluation of the currency of country 1 also increases demand. The individual exchange rates enter the demand equation as a weighted harmonic mean, where the weights are functions of the slopes of the various demand and supply curves, the flatter the slope, the heavier the weight. This weighting scheme is different from that usually encountered in an index of exchange rates.

A change in the demand for the production of country 1 with respect to a change in an exchange rate is described by the partial derivatives

$$\frac{\delta q_{s1}}{\delta r_2} = - \left[\frac{1}{\beta_2} + \frac{1}{\sigma_2} \right] \frac{p_1}{r_2^2}$$

and

$$\frac{\delta q_{s1}}{\delta r_3} = - \left[\frac{1}{\beta_3} + \frac{1}{\sigma_3} \right] \frac{p_1}{r_3^2}$$

As an exchange rate increases (r_j increases), the currency of country 1 depreciates and the quantity demanded increases, the increase is a function of the price, exchange rate, and the slopes of these supply and demand curves in the foreign country. These derivatives are incorporated into the definitions of elasticity of the quantity demanded of country 1 with respect to either exchange rate. For example, the exchange rate elasticity of demand with respect to country 2 is

$$\text{elasticity} = - \left[\frac{1}{\beta_2} + \frac{1}{\sigma_2} \right] \frac{p_2}{q_1}$$

A complete symbolic solution of the nine equation model should be instructive and not too difficult. Yet it is sometimes easier to get a feel for the interaction among equations—that is, for how a change in one exogenous parameter affects all the endogenous variables simultaneously—by means of a simulation. The partial elasticities just discussed do not give the flavor which total elasticities do by reflecting feedbacks from other relationships in the system.

The nine-equation, three-country trade model was calibrated to produce the base scenario listed in the first column of table 1. Prices in all three countries equal unity, demands equal 100 units of the homogenous commodity, and supplies are such that countries 1 and 2 each export 10 units to country 3.

The parameters to produce the base scenario were chosen to incorporate the following structural properties: the price elasticities of demand at the initial equilibrium are 0.5 in each of the three coun-

¹Italicized numbers in parentheses refer to items in the References at the end of this article.

tries and the price elasticities of supply are 1.0. The parameters are

$$\left. \begin{array}{l} \alpha_j = 3.0000 \\ \beta_j = 0.0200 \\ \mu_j = 0.0000 \\ \sigma_1 = 0.0091 \\ \sigma_2 = 0.0091 \\ \sigma_3 = 0.0125 \end{array} \right\} \text{ for } j = 1, 2, 3$$

The chart shows the trade balance among the three countries. The chart is not drawn to scale. The chart and the logic underlying the model are taken from Kost (13), also see (1). Panels A, C, and E show the domestic supplies and demands, panels B and D show price transmission. The solid price line traces equilibrium production, consumption, exports, and imports when all three prices are equal and all exchange rates are unity, as in the base scenario, column 1, table 1. The dotted price line traces trade equilibrium under devaluation by country 1 against the other two countries, as in column 4, table 1.

Devaluation need not apply against all other currencies simultaneously. A country's currency may devalue against one country while holding constant with others. Consider three cases: a devaluation by

country 1, an exporter, first against the other exporter, second, against the importer, and finally, against both concurrently.

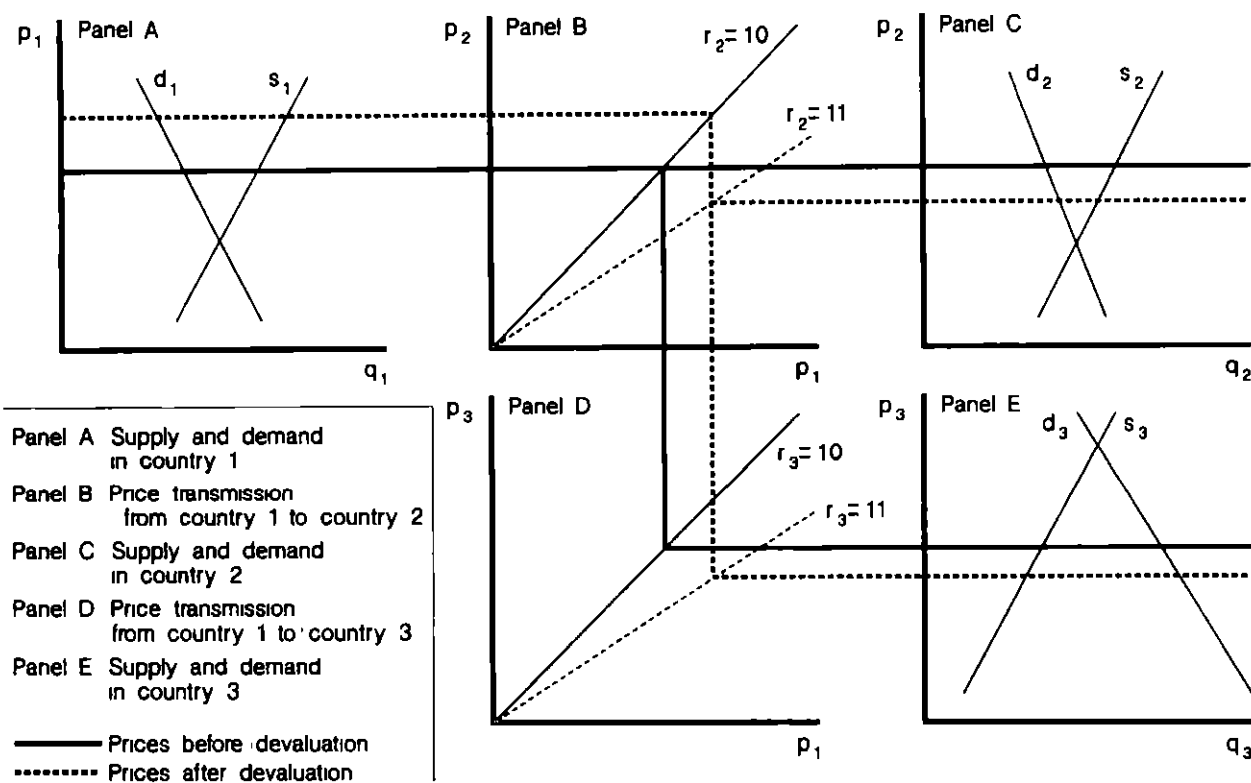
The effects of a 10-percent devaluation by country 1 against the other exporter (country 2) are reported in column 2 of table 1. This situation would result if the United States devalued against other exporters of farm products while the values of the currencies of importers were tied to the dollar. The exchange rate r_2 was set at 1.1, but r_3 remained at 1.0. The devaluation lowers prices in country 2, the other exporting country. This situation is not explicit in the chart, but it can be followed there. Note where the solid price line from panel A projects to the 45-degree line in panel B. Drop straight down to the dashed line in panel B, where p_2 is 90 percent of p_1 . From this intersection, project p_2 to panel C to see how the devaluation lowers the price in country 2, reduces production, and increases consumption. Their exports are reduced. Reduced world production boosts world prices, which stimulates production in countries 1 and 3 and decreases consumption there. Prices in country 2 are subsequently boosted also, so the equilibrium decrease in that country is less than the initial drop. Suppliers in the country against which the devaluation took place are worse off, but consumers in that country are better off as they are paying less to consume more. Suppliers in the country that devalued are better off, and so are suppliers in the importing country. Exports of country 1 increase 53 percent, implying a total elasticity

Table 1—Supply and demand responses to exogenous changes in the exchange rates, three-country model

Economic variable ¹	Base scenario	$r_2 = 1.1$ $r_3 = 1.0$	$r_2 = 1.0$ $r_3 = 1.1$	$r_2 = 1.1$ $r_3 = 1.1$
<i>Units</i>				
Country 1				
p_1	1.00	1.0334	1.0270	1.0622
q_{d1}	100.00	98.3299	98.6515	96.8884
q_{s1}	110.00	113.6743	112.9668	116.8455
Exports	10.00	15.3445	14.3154	19.9571
Country 2				
p_2	1.00	.9395	1.0270	.9657
q_{d2}	100.00	103.0271	98.6515	101.7167
q_{s2}	110.00	103.3403	112.9668	106.2232
Exports	10.00	3.132	14.3154	4.5064
Country 3				
p_3	1.00	1.0334	.9336	.9657
q_{d3}	100.00	98.3299	103.3195	101.7167
q_{s3}	80.00	82.6722	74.6888	77.2532
Exports	-20.00	-15.6576	-28.6307	-24.4635

¹ p = price, q_d = quantity demanded, q_s = quantity supplied, and exports = $q_s - q_d$

Effect of a Devaluation by an Exporting Country on an Importer and a Competing Exporter



of about 5. Consumers are worse off in countries 1 and 3 because they are paying higher prices to consume less. World consumption declines slightly in this example.

The effects of a 10-percent devaluation by country 1 against the importer (country 3) are reported in column 3 of table 1. This situation would result if the currencies of competing exporters, such as Canada, fell about in line with the dollar as the dollar depreciated relative to the currencies of importers, such as Japan. The exchange rate r_3 was set at 1.1, but r_2 remained at 1.0. The devaluation lowers prices in the importing country (country 3). Note where the solid price line from panel A projects downward from the 45-degree line in panel B to the 45-degree line in panel D. Continue straight down to the dashed line which represents a 10-percent devaluation against country 3. From this intersection, project p_3 to panel E (this projection is not shown in the chart) to see how the devaluation initially lowers the price, reduces production, and increases consumption in country 3, so imports are increased. The expansion in world consumption boosts world prices. The price increase stimulates production in the two exporting countries and decreases consumption there. Exports of country 1 increase 43

percent. Prices in country 3 are subsequently boosted also, so the equilibrium decrease is less than the initial drop. Suppliers in the importing country are worse off because they are selling less at lower prices, but consumers there are better off because they are paying less to consume more. Suppliers in the country that devalued are better off, and so are the suppliers in the other exporting country. Consumers are worse off in both exporting countries because they are paying more to consume less. Total world consumption increases slightly in this example.

The effects of a 10-percent devaluation by country 1 against both other countries are reported in column 4 of table 1. Uniform devaluation is often assumed in theory, but the review of literature later in this article indicates that it may seldom obtain in practice. The dashed line traces out production, consumption, and trade in equilibrium after the uniform devaluation. The devaluation against both countries improves the position of farmers in the devaluing country, but worsens the position of consumers there. Lower prices in the other countries help consumers there, but hurt farmers. The importing country increases its imports and shifts its

source of imports toward the devaluing country. The other exporter loses some of its markets. The devaluing country about doubles its exports, partly because of increased imports by the deficit food producer and partly because it captures some of the market of the other surplus food producer.

An exogenous change in an exchange rate changes one pair of relative prices. Subsequent demand and supply response induces changes in other relative prices. If one could predict the equilibrium prices that would result from a depreciation, then one could predict from the various supply and demand elasticities what the changes in production, consumption, and trade would be. The more elastic the supply in the devaluing country, the less will be the changes in other relative prices subsequent to the devaluation and, therefore, the easier it is to predict equilibrium prices.

In the example, the three price elasticities of demand underlying table 1 are 0.5, and the three price elasticities of supply are 1.0. Therefore, the initial effect of a 10-percent devaluation is a 10-percent reduction in supply in the affected country and a 5-percent increase in demand. Of course, the trick to using this information is to know what the system equilibrium price effects will be. For the general case, one needs a model, such as we have here, that predicts the equilibrium prices and quantities. The devaluation against the other exporter added 5.3 units to exports, and the devaluation against the importer added 4.3 units. These separate effects almost add up to the 10.0 units added by the uniform devaluation. Had the price elasticity of supply in country 1 been greater (it is 1.0 in the example), the price response to changing world production and consumption would have been less, and the separate effects would have come even closer to adding up to the total effects. On the other hand, a more inelastic supply in the devaluing country would have increased the ensuing price response and created a larger difference between the separate and total effects.

So, except in special cases, knowing that one can predict final quantities if one knows final prices is not very useful. The important and practical exception is: If the devaluing country is a residual supplier into world markets (that is, if that country's export supply function is perfectly elastic), then the resulting changes of a devaluation on consumption, production, and trade can be estimated from a knowledge of supply and demand elasticities in the affected countries.

Trade Equilibrium When One Country is a Residual Supplier

The United States has been characterized as a residual supplier of grains in world trade. One way to describe a residual supplier is that the country stands ready to export an indefinitely large quantity in response to a small increase in the world price, that is, the country has a perfectly elastic export supply function. Another way to characterize the same phenomenon is that all other countries trade at the world price, and then the residual supplier fills in the gap between total exports and total imports at the world price. We can model country 1 as a residual supplier by making an extreme assumption that p_1 equals 1.0 and by dropping country 1's supply function from the model. In this eight-equation version of the model, country 1's price is exogenous and country 1's supply is determined as a residual in the balance equation that sets world production equal to world consumption. The base scenario in column 1 of table 2 is the same as the base scenario in table 1. The parameters remain as before (see page 4).

The effects of a 10-percent devaluation by the residual supplier against the other exporting country, country 2, are reported in column 2 of table 2. The price received by farmers in the other exporting country drops in accordance with the price transmission equation, it remains at the new, lower level as supply and demand adjust to the exogenous change in relative prices. Supply decreases in accordance with the price elasticity of supply, and demand increases in accordance with the price elasticity of demand. Exports drop, in fact, in this example, country 2 switched from an exporting country to an importing country. No changes take place in the importing country (country 3) because its price does not change. The residual supplier expands shipments to replace those lost by the other exporter, this is export supply substitution with a vengeance. Suppliers in the devaluing country gain through increased sales at the same price. Consumers in the country against which the devaluation was taken gain through increased consumption at a lower price, but suppliers there lose from reduced sales at a lower price. There are no welfare changes for consumers in countries 1 and 3 or for farmers in country 3. Total world consumption is increased.

The effects of a 10-percent devaluation by the residual supplier against the importing country (country 3) are in column 3 of table 2. Country 3's price drops, production decreases, consumption increases, and the difference is met by the residual

supplier Farmers in the devaluing country gain, as do consumers in the importing country Farmers in the importing country sell less at lower prices Consumers in the devaluing country and both consumers and farmers in the other exporting country have no changes in welfare Total world consumption is increased

The effects of a 10-percent devaluation by the residual supplier against both the importing and exporting countries are in column 4 of table 2 The increase in exports associated with devaluing against the other exporter plus the increase associated with devaluing against the importer add precisely to the increase in exports for the uniform devaluation This result would not hold precisely, but might hold approximately if the price of the residual supplier were permitted to vary a little

If the devaluing country is a residual supplier and if the price transmission equations are known, one can calculate from the appropriate elasticities of demand and supply the consequences of a depreciating currency on production, consumption, and trade separately for each affected country and then sum the results

The theoretical discussion indicates the equity and efficiency implications of fluctuating exchange rates Price and exchange rate elasticities of demand for exports can be high even though domestic demands in individual countries are inelastic The model reveals the complicated structure of an equa-

tion which expresses net demands for a commodity in terms of foreign demands, supplies, and exchange rates The discussion now turns to selected literature on the role of exchange rates and price transmission in agricultural exports

The Responsiveness to Depreciation: Price Transmission

The dollar began to float relative to other currencies in 1971 and 1973, after an extended period of fixed exchange rates The fluctuation in exchange rates was accompanied by changes in prices and exports Schuh noted that analyses of trade had, through the early seventies, neglected exchange rates (18) Under the assumption that the net export demand for farm products is highly elastic, Schuh concluded that the depreciation of the dollar in 1971 and in 1973-74 contributed importantly to the increase in prices received by farmers and to the increase in exports

Theoretical models of competitive trade equilibrium tend to suggest that exports are elastic with respect to depreciation, as Schuh assumed In the example (tables 1 and 2), a 10-percent devaluation increased exports 50-150 percent Bredahl and Gallagher concluded that "the percentage change in quantity traded due to an exchange rate change may be quite large" (1) Some empirical work supports these large responses Chambers and Just found that a 10-percent depreciation resulted in shipments of 91 percent more corn, 34 percent more wheat,

Table 2—Supply and demand responses when the devaluing country is a residual supplier

Economic variable ¹	Base scenario	$r_2 = 1.1$ $r_3 = 1.0$	$r_2 = 1.0$ $r_3 = 1.1$	$r_2 = 1.1$ $r_3 = 1.1$
<i>Units</i>				
Country 1				
p_1	1.00	1.0000	1.0000	1.0000
q_{d1}	100.00	100.0000	100.0000	100.0000
q_{s1}	110.00	124.5455	121.8182	136.3636
Exports	10.00	24.5455	21.8182	36.3636
Country 2				
p_2	1.00	.9091	1.0000	.9091
q_{d2}	100.00	104.5455	100.0000	104.5455
q_{s2}	110.00	100.0000	110.0000	100.0000
Exports	10.00	-4.5455	10.0000	-4.5455
Country 3				
p_3	1.00	1.0000	.9091	.9091
q_{d3}	100.00	100.0000	104.5455	104.5455
q_{s3}	80.00	80.0000	72.7273	72.7273
Exports	-20.00	-20.0000	-31.8182	-31.8182

¹p = price, qd = quantity demanded, qs = quantity supplied, and exports = qs - qd

and 8 percent more soybeans while reducing domestic use by 21, 2, and 4 percent, respectively (5)

Other empirical work suggests that the impact of exchange rate fluctuation is small. Greenshields found that changes in exchange rates between the Japanese yen and the currencies of Japan's major suppliers of wheat, corn, sorghum, and soybeans had little effect on U.S. grain and soybean exports to Japan (10). Greenshields' assumptions differ from Schuh's. Schuh assumed a perfectly elastic export demand and an inelastic export supply, Greenshields assumed a perfectly elastic export supply, as assumed in table 2. Schuh's assumption puts most of the impact of depreciation on price, Greenshields' puts most of it on quantity. Even so, Greenshields found little difference between the actual quantities exchanged after the depreciation and what one might have expected had exchange rates not changed. He attributed the trade stability to protective institutional arrangements such as determinations by the Japanese of how much will be imported each year.

Vellianitis-Fidas did a cross-sectional analysis for 1971-73 and a time series analysis for 1954-69, when the U.S. dollar was relatively stable, but important depreciations and appreciations occasionally occurred (19). The studies exhibited no relationships not explained by extenuating circumstances, "the change in the exchange rate of the United States, a major supplier of agricultural commodities on the world market, did not significantly affect agricultural trade" (19). Johnson, Grennes, and Thursby found that the dollar depreciation in 1973-74 was less important than price-insulating policies by other major importers and exporters in explaining price movements (12). Jabara found that response to exchange rates was inelastic, but noted that aggregated models mislead, wheat-producing countries had a different response than nonproducing countries had (11).

Numerous studies indicate that, although the impacts of depreciation are less than indicated by theoretical, competitive, trade equilibrium models such as described here, the effects can be substantial. The simplified models of trade apparently omit real-world factors that tend to damp price transmission. The limits to using price to explain quantity is common in the empirical literature of economics, whereas theoretical models continue to emphasize the price-quantity relation. Among the omitted factors are trade restrictions (3) and price insulation (2, 15). Collins, Meyers, and Bredahl find both substantive and procedural explanations (7). Among their substantive explanations, they find that the impact of depreciation varies with the crop exam-

ined, the year observed, the country involved, the economic structure (represented by the various demand and supply elasticities), relative rates of inflation, and government policies in importing and exporting countries. Among their procedural explanations, Collins, Meyers, and Bredahl find that estimates of impact vary with whether the price used in analysis is real or nominal, with what opportunity costs are explicitly recognized, and even with the definition of "exchange rate effect." Meyers examined alternate ways to specify exchange rate models and showed that different specifications result in different estimates (15).

Longmire and Morey used trade-weighted, inflation-adjusted prices and exchange rates by commodity to assess the effects of a change in the price of a dollar on agricultural exports (14). They estimated that a 20-percent depreciation (appreciation) would raise (lower) exports of wheat, corn, and soybeans by about 16 percent.

The commodity export demand equations used in the Economic Research Service's forecasting model called FAPSIM adjust prices using the Special Drawing Rights (SDR) exchange rate. The price elasticities of export demand for wheat and corn are 0.5 and 0.4, respectively. That is, a 20-percent depreciation would increase corn exports by 10-percent and wheat exports by 8 percent.

Linear Price Transmission

Price transmission among countries was modeled as

$$p_1 = r_j p_j$$

When r_j is 1.0, prices are the same in both countries. When country 1 devalues 10 percent, r_j is 1.1 and p_1 is 10 percent above p_j . The review of literature suggests a need to modify this equation. Tariffs, subsidies, variable import levies, quotas, licenses, transportation regulations, high marketing margins, commodity-specific exchange rates, pegged exchange rates, and other policies affecting the price transmission equation complicate the simple model used here. For example, if protection is implemented between countries 1 and 2, but not between countries 1 and 3, price transmission between countries 2 and 3 changes. A devaluation by country 1 and a revaluation by country 2 are not symmetrical because of the differential effects on country 3 (see 2).

Coyle, Chambers, and Schmitz reviewed recent theoretical and empirical research on the economic

gains from international trade, particularly agricultural trade (8) They found that the traditional arguments concerning the equity and efficiency of free trade are easily violated under a variety of circumstances Some of their findings can be reflected by transformations of the price transmission equations Consider linear transformations first, and then nonlinear ones

Suppose that country 1 subsidizes exports A subsidy would drive the price down in country j , just as a devaluation would A tariff by country 1 on its own exports would raise the price to others, just as an appreciation would Tariffs and subsidies are like multiple exchange rates, except that they are usually by commodity and exchange rates are usually by country The review of literature indicates that commodity detail may be as important as regional detail, but the model used here assumes only a single commodity Let s be 1 plus the subsidy rate minus the tariff rate When there is no tariff or subsidy, $s = 1$ and there is no action A subsidy of 10 percent increases s to 1.1, and a tariff of 10 percent decreases it to 0.9 The modified price transmission equation is

$$p_1 = r_j s_j p_j$$

If a subsidy or tariff were imposed by volume of trade, say per bushel or per ton, instead of as a percentage of price, then the modification of the price transmission equation is additive instead of multiplicative Let S be positive for a per-unit subsidy and negative for a per-unit tariff or transportation charge Then the price transmission equation which accounts for both additive and multiplicative policy changes is

$$p_1 = S_j + r_j s_j p_j$$

Policies implemented by country 1 that stretch or shrink the price, such as *ad valorem* taxes, or that affect costs per ton or bushel, such as transportation differentials, can be modeled as linear transformations on the price transmission equation The general form of the price transmission equation is

$$p_1 = \pi_j + \phi_j (r_j p_j)$$

where π and ϕ are to be determined by empirical analysis If one can assume that the policy structure is constant during a sample period, one can then use regression analysis to estimate the two parameters (However, one must decide which way causality runs when doing these regressions) The discussion related to tables 1 and 2 assumed $\pi = 0$ and $\phi = 1$ and found a highly elastic response to

depreciation If ϕ is less than unity, or π is less than zero, the price transmission under depreciation will be damp, and the export response will be more inelastic Protective tariffs and high transportation costs damp elasticities

Meyers, Gerber, and Bredahl estimated linear transformations of price transmission to account for price insulation by the importing country (16) They found the elasticity between the Japanese and U S price to be 0.99 for soybeans, 0.85 for corn, and 0.77 for soybean meal For wheat and rice, where price insulation inhibited transmission, they concluded that the elasticity was zero

Meyers discusses appropriate ways to specify the exchange rate in estimating a transmission equation, he recommends converting all values—including demand shifters such as income per capita—to real, base year, base country values (15)

The choice of which exchange rate to use in empirical work is important Dutton and Grennes examined alternative measures of effective exchange rates appropriate for agricultural trade analysis (9) They found that the proper measurement of the exchange rate variable may be as important as accurate measurement of parameters in a model For example, the Special Drawing Right (SDR) can be misleading because the dollar is an important part of the SDR basket of currencies and because the SDR uses a different weighting scheme than some of the other indicators Dutton and Grennes found it surprising how much different indexes, "all purporting to measure the same thing, differ among themselves" (9, p. 25)

Nonlinear Price Transmission

Some policies affect price transformations in a nonlinear way Examples are price support programs, income tax laws, imperfect competition, and nontariff barriers Collins estimated equations for the transmission of corn, wheat, and soybean prices at U S gulf ports to 47 countries (6) The equation was of the form

$$p_j = a r_j^b p_1^c$$

Where a , b , and c are parameters estimated by regression analysis, and p_1 is the U S gulf port price These parameters were each assumed equal to unity in tables 1 and 2 Non-unity values imply imperfections in price transmission Note that Collins' equation puts the j^{th} country's price on the left side For the purposes of pure theory and when the three regression parameters are set equal to

unity, this switch makes no difference, other than that Collins' exchange rate (r) is the reciprocal of the one used here. The switch is important in reflecting assumptions about the direction of causality in the regression analysis. Moreover, non-unity values for the elasticities of transmission, b and c , can cause differences in interpretation when the equation is switched. If c is estimated as close to zero and then the Collins equation is solved for p_1 , the elasticity associated with p_1 , $1 - c$, will approach infinity. If the Cobb-Douglas functional form is used to estimate price transmission, it is important which direction of causality is assumed when the elasticities differ significantly from unity. This is not a problem with linear price transmission equations.

Collins' findings are summarized in table 3. The modal exchange rate elasticity is unity for each of the crops examined. However, 36 percent of the wheat exchange rate elasticities are between 0 and 1, and 36 percent of the corn exchange rate elasticities are close to zero. The modal price elasticity is significantly less than unity and greater than zero for each crop. There is a greater degree of imperfection in the price transmission than in the exchange rate transmission.

Collins' findings support the suggestion of other empirical research that the responses to changes in exchange rates need not be nearly as elastic as implied in the theoretical model examined in this article. Price and exchange rate transmission varies by crop and by country. The rates depend on factors such as tariffs, subsidies, transportation costs, embargoes, quotas, marketing margins, relative rates of inflation, and other institutional arrangements and market imperfections.

Implications

This review raises empirical questions that the model presented here cannot answer. Even so, the

Table 3—Price and exchange rate transmission elasticities

Elasticity	Wheat		Corn		Soybeans	
	Price	Rate	Price	Rate	Price	Rate
<i>Number of countries</i>						
Not significantly different from 1	5	17	10	17	3	8
Between 0 and 1	22	11	18	4	6	2
Not significantly different from 0	3	2	5	12	1	0

empirical difficulties of incorporating appropriate price transmission relationships into existing and complex models of U S agriculture are not insurmountable. One could, for example, add a net trade module to an existing domestic model, where the trade module reflects supplies, demands, and price transmission in sufficient commodity and regional detail. Or one could concentrate on specification of the export equations in an existing model. Recall that the nine-equation model was solved for the demand for the production of country 1 as a function of price and of the various parameters of the model. Careful examination of the subscripts of that equation reveals that demand for the total production of country 1 is the sum of domestic demand and the two net foreign demands.

To focus on the demand for exports, consider instead a three-equation version of the model which includes the supply and demand curves for country 1 and net demand for the exports of country 1. The literature review suggested that proportional tariffs and subsidies (s) and per-unit tariffs and subsidies (S) will modify the price transmission equations and will thereby affect the demand for exports. When s and S are included, the demand relation associated with net exports of country 1 is

$$qs_1 - qd_1 = \left[\left(\frac{\alpha_2}{\beta_2} + \frac{\mu_2}{\sigma_2} \right) + \left(\frac{\alpha_3}{\beta_3} + \frac{\mu_3}{\sigma_3} \right) \right] + \left[\left(\frac{1}{\beta_2} + \frac{1}{\sigma_2} \right) \left(\frac{S_2}{s_2 r_2} \right) + \left(\frac{1}{\beta_3} + \frac{1}{\sigma_3} \right) \left(\frac{S_3}{s_3 r_3} \right) \right] - \left[\left(\frac{1}{\beta_2} + \frac{1}{\sigma_2} \right) \left(\frac{1}{s_2 r_2} \right) + \left(\frac{1}{\beta_3} + \frac{1}{\sigma_3} \right) \left(\frac{1}{s_3 r_3} \right) \right] p_1$$

The weights in the harmonic mean of the exchange rates in the constant term differ from the weights in the slope. The consequences of proportional and per-unit tariffs and subsidies will be examined subsequently. When they are absent, $S = 0$ and $s = 1$, and the demand relation associated with net exports of country 1 simplifies to

$$qs_1 - qd_1 = \left[\left(\frac{\alpha_2}{\beta_2} + \frac{\mu_2}{\sigma_2} \right) + \left(\frac{\alpha_3}{\beta_3} + \frac{\mu_3}{\sigma_3} \right) \right] - \left[\left(\frac{1}{\beta_2} + \frac{1}{\sigma_2} \right) \left(\frac{1}{r_2} \right) + \left(\frac{1}{\beta_3} + \frac{1}{\sigma_3} \right) \left(\frac{1}{r_3} \right) \right] p_1$$

Substituting the numerical parameters used in the example hides some of the useful structural information, but it highlights the way the exchange rates enter the relation as a weighted harmonic mean of the individual exchange rates

$$qs_1 - qd_1 = 300 - \left[\frac{160}{r_2} + \frac{130}{r_3} \right] p_1$$

Reconsideration of proportional and per-unit tariffs and subsidies expands the above equation to

$$qs_1 - qd_1 = 300 + \left[\frac{160 S_2}{s_2 r_2} + \frac{130 S_3}{s_3 r_3} \right] - \left[\frac{160}{s_2 r_2} + \frac{130}{s_3 r_3} \right] p_1$$

When per-unit tariffs and subsidies (S) are absent, proportional tariffs and subsidies (s) enter the equation exactly as exchange rates do. That is, a 10-percent tariff has exactly the same consequence as a 10-percent appreciation, and a 10-percent subsidy has exactly the same effect as a 10-percent devaluation.

The presence of per-unit tariffs and subsidies affects the constant term. When the per-unit measure is present, the proportional measure affects the constant as well as the slope. The general consequences of S on trade are similar to those of s or r: a per-unit subsidy, a proportional subsidy, or a devaluation increases the demand for exports and increases the elasticity of demand. The demand shift raises prices to farmers in the exporting country and decreases prices to consumers in the importing country. That is, farmers in the exporting country and consumers in the importing country gain from the policy, whereas farmers in the importing country and consumers in the exporting country lose.

Tariffs make the demand for net exports more inelastic, and subsidies make it more elastic. In the simulation, the policy levels required to make a noticeable change were not great. A 10-percent tariff against both countries cut the price elasticity of demand for net exports about in half. It may be that the presence of tariffs, subsidies, transportation costs, and other barriers to trade, which can be interpreted as changes in the coefficients of the equations used here, can explain much of the discrepancy over empirically and theoretically determined export elasticities. Tariffs and subsidies may be selective by commodity, whereas exchange rates are usually selective by country. That is, one can specify a combination of proportional tariffs and subsidies and exchange rates that achieve any desired distribution of commodities by region.

As a further simplification, consider a single exchange rate reflecting prices in country 1 against a weighted average of prices in other countries, such as the Special Drawing Right (SDR). To illustrate, let the two exchange rates be equal ($r = r_1 = r_2$). Leave out tariffs and subsidies. The export demand relation reduces to

$$qs_1 - qd_1 = 300 - \left[\frac{290}{r} \right] p_1$$

Or, to generalize

$$\text{Export demand} = \Phi + \theta (p_1 - r)$$

Where Φ and θ are functions of the parameters used in the example. This is the form most likely to be found in existing domestic agricultural models that recognize international trade. The major limitation to using this form of the export demand equation is that the structure underlying Φ and θ is changeable, the data required to identify the structure are not readily available.

The price transmission equations and the net export demand equation discussed here provide clues for correcting specification errors. If the demand for exports were to be estimated for a period during which exchange rates were constant, as they were prior to 1971, then the rates need not be explicit and may be subsumed in the θ coefficient. But with the volatility observed in exchange rates for more than a decade, these rates require explicit attention in models designed to explain and forecast agricultural exports. The review of empirical work suggests that Φ and θ should be considered as functions of other things as well, such as transportation differentials, tariffs and subsidies, price insulation, relative rates of inflation, and the volatility introduced by the interventions and policy reversals of various governments. The review of theory suggests the use of a harmonic mean of exchange rates weighted by the slopes of the relevant demand and supply curves. Price and the exchange rate enter the export demand equation multiplicatively with a shared coefficient (θ) and not additively with separate coefficients. When it is assumed to be additive, empirical estimates of the elasticity of exports with respect to exchange rates may be relatively high (5).

Both theoretical and empirical considerations suggest that the depreciation of the U.S. dollar, which accompanied the decrease in prices received by farmers during the past 2 years, and the prospects for further depreciation over the life of the Food Security Act of 1985, could lift export levels of U.S. farm products substantially above those forecast by models that rely on price effects alone. This discussion has pointed to factors to consider when incorporating price transmission relationships into agricultural models. Furthermore, it has shown that export demand depends on more than relative prices and exchange rates.

References

- (1) Bredahl, Maury E, and Paul Gallagher "Comment on Effects of an Exchange Rate Change on Agricultural Trade," *Agricultural Economics Research*, Vol 29, No 2, Apr 1977, pp 45-48
- (2) Bredahl, Maury E, William H Meyers, and Keith J Collins "The Elasticity of Foreign Demand for U S Agricultural Products The Importance of the Price Transmission Elasticity," *American Journal of Agricultural Economics*, Vol 61, No 1, Feb 1979, pp 58-63
- (3) Bredahl, Maury E, and Abner W Womack "Currency Adjustments under Trade Restrictions," *Agricultural Economics Research*, Vol 30, No 1, Jan 1978, pp 53-55
- (4) Chambers, Robert G "Agricultural and Financial Market Interdependence in the Short Run," *American Journal of Agricultural Economics*, Vol 66, No 1, Feb 1984, pp 12-24
- (5) _____, and Richard E Just "A Critique of Exchange Rate Treatment in Agricultural Trade Models," *American Journal of Agricultural Economics*, Vol 63, No 1, Feb 1981, pp 32-46
- (6) Collins, H Christine "Price and Exchange Rate Transmission," *Agricultural Economics Research*, Vol 32, No 4, Oct 1980, pp 50-55
- (7) Collins, Keith J, William H Meyers, and Maury E Bredahl "Multiple Exchange Rate Changes and U S Agricultural Commodity Prices," *American Journal of Agricultural Economics*, Vol 62, No 4, Nov 1980, pp 656-65
- (8) Coyle, Barry, Robert G Chambers, and Andrew Schmitz *Economic Gains From Agricultural Trade A Review and Bibliography* BLA-48 U S Dept of Agr, Econ Res Serv, July 1986
- (9) Dutton, John, and Thomas Grennes *Measurement of Effective Exchange Rates Appropriate for Agricultural Trade* Economics Research Report No 51 North Carolina State Univ - Raleigh, Nov 1985
- (10) Greenshields, Bruce L *Changes in Exchange Rates Impact on U S Grain and Soybean Exports to Japan* FAER-364 U S Dept of Agr, Econ Res Serv, July 1974
- (11) Jabara, Cathy J "Cross-Sectional Analysis of Wheat Import Demand among Middle-Income Developing Countries," *Agricultural Economics Research*, Vol 34, No 3, July 1982, pp 34-37
- (12) Johnson, Paul R, Thomas Grennes, and Marie Thursby "Devaluation, Foreign Exchange Controls and Domestic Wheat Prices," *American Journal of Agricultural Economics*, Vol 59, No 4, Nov 1977, pp 619-27
- (13) Kost, William E "Effects of an Exchange Rate Change on Agricultural Trade," *Agricultural Economics Research*, Vol 28, No 3, July 1976, pp 99-106
- (14) Longmire, Jim, and Art Morey *Strong Dollar Dampens Demand for U S Farm Exports*, FAER-193 U S Dept of Agr, Econ Res Serv, Dec 1983
- (15) Meyers, William H "Exchange Rates in International Commodity Models The Common Currency Question," *Agricultural Economics Research*, Vol 31, No 4, Oct, 1979, pp 40-43
- (16) _____, Elizabeth J Gerber, and Maury E Bredahl "The Effect of Price-Insulating Policies on Exchange Rate Analysis," *Agricultural Economics Research*, Vol 32, No 1, Jan 1980, pp 25-30
- (17) Orden, David "The Exchange Rate and Agricultural Prices A Comment on Some Neglected Income Effects," *American Journal of Agricultural Economics*, Vol 68, No 4, Nov 1986
- (18) Schuh, G Edward "The Exchange Rate and U S Agriculture," *American Journal of Agricultural Economics*, Vol 56, No 1, Feb 1974, pp 1-13
- (19) Vellianitis-Fidas, Amalia "The Impact of Devaluation on U S Agricultural Exports," *Agricultural Economics Research*, Vol 28, No 3, July 1976, pp 107-16