June 1980

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Feed Grain Imports and Feed Grain Prices in Importing Countries

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SUMMARY

The effects of several variables on the feed grain sector of six importing countries were investigated in this study. The six countries were Greece, Israel, Japan, Portugal, Spain, and the United Kingdom. A simultaneous model with six equations was used to explain the domestic price of feed grains in the importing country and the quantity of feed grains imported by the country. Other endogenous variables in the model were the price of livestock, the production of livestock products, the demand for livestock products, and the size of the livestock inventory in the importing country. The simultaneous model for each importing country allows the government of the importing country to control the domestic price of feed grains through the government's manipulation of trade barriers for feed grains. Because of the existence of trade barriers, the domestic price of feed grains is allowed to differ from the cost of importing feed grains. The cost of importing feed grains incorporates ocean transportation costs and the exchange rate of the importing country.

The simultaneous models for Japan, Spain, and the United Kingdom were on a quarterly basis. The simultaneous models for Greece, Israel, and Portugal were on a yearly basis because of a lack of data. The observation period for Greece, Israel, Portugal, and Spain was from 1958 through 1976. The observation period for Japan was from 1960 through 1976, and the observation period for the United Kingdom was from 1958 through 1974.

Results of this study confirm previous findings concerning the effects of a nation's livestock sector upon feed grain imports. But this study finds that the livestock sector is not an exogenous determinant of feed grain prices and imports; feed grain markets affect the livestock sectors. The cost of importing feed grains was found to have a significant effect on domestic prices and, therefore, on imports. But five of the six countries follow policies that insulate domestic feed grain prices from fluctuations in world feed grain prices. Feed grain imports are responsive to the domestic price of feed grains for four of the countries studied.

A second model for each importing country was used to study imports of U.S. feed grains by the country. This model was different for each country, but the general form of this model was that imports of a particular feed grain from the United States were explained by the total quantity of the feed grain imported by the country, the quantity of the feed grain available for export by the United States, and the quantity of the feed grains available for export by other exporters. The model involved a single equation for each of the countries studied.

The results show that the total quantity of feed grains imported by a country from all sources is the main variable that influences the quantity of feed grain imports from the United States. For the three largest importers of feed grains, Japan, Spain, and the United Kingdom, imports of U.S. feed grains varied depending on availability of feed grains from competitors.
Feed Grain Imports and Feed Grain Prices in Importing Countries

by Michael R. Reed and George W. Ladd

From 1958/59 to 1973/74, world trade in feed grains increased from 20.8 million metric tons to 76.0 million metric tons, a 265% increase (Food and Agriculture Organization of the United Nations, 1958d through 1976d). International trade in feed grains also has become more important to the United States. In recent years, the United States has consistently suffered a deficit in the balance of trade. Agricultural exports are important in strengthening the position of the dollar on overseas markets. The U.S. trade balance in agricultural products has been positive in most years since 1958 and has increased dramatically since 1970. United States feed grain producers have found themselves more reliant on foreign markets for feed grains in recent years, too. In 1958/59, only 6% of the corn produced in the United States was exported, but in 1973/74, nearly 25% of the corn produced in the United States was exported (FAO, 1958c through 1976c and 1958d through 1976d).

This large increase in the volume of trade in feed grains, along with shocks such as the Russian wheat deal and the depletion of grain stocks in the 1972-1974 period, has stimulated research in the area of international grain trade.

REVIEW OF LITERATURE

Research on international trade in agricultural economics has focused on individual commodities with the objective of explaining the U.S. export pattern. Jones and Morrison (1976), Mitchell (1976), and Ryan and Houck (1976) estimated import demands for U.S. soybeans and soybean products. They used a world price model; that is, they assumed the price of imported soybeans was the same for all countries studied. This price was the U.S. price of soybeans. They ignored transportation costs and trade barriers and were not specific on their treatment of exchange rates.

Jones and Morrison (1976) explained imports of soybean meal and soybean equivalents for some eastern European countries by using a two-equation recursive model. The first equation explained the livestock inventory by using population lagged 1 year and a per-capita product index lagged 1 year as predetermined variables. The second equation explained imports of soybean meal plus meal equivalents of soybeans as a function of the U.S. wholesale price of soybean meal, protein meal as a percentage of concentrates, the importing country's production of soybean meal, time, and the estimated size of the livestock inventory (from the first equation). The size of the livestock inventory explained most of the variation in soybean meal imports. The coefficient of the price of soybean meal was significantly different from zero in only one of the three equations reported. The estimation technique was ordinary least squares on each equation.

Mitchell (1976) studied net imports of wheat, feed grains, and soybeans by various regions of the world. The independent variables for these equations were the importing country's domestic supply, time, and the U.S. export price adjusted for the 1971 and 1973 dollar devaluations. The results for wheat and feed grains showed that net imports were not responsive to price. None of the coefficients on the U.S. export price was significantly different from zero in equations for wheat or feed grains. Three separate equations explained soybean imports of each region. The three were for soybean meal, soybean oil, and soybeans. The coefficient of U.S. export price of soybeans was significantly different from zero for some of the regions.

Ryan and Houck (1976) studied U.S. exports of soybeans and soybean meal to various countries. The independent variables for the soybean equations were the U.S. wholesale price of soybeans divided by the U.S. price of soybean meal, foreign production of oilseeds, and an income index for the European Economic Community (EEC) and Japan. The results, as measured by \( R^2 \), were quite good. The coefficients of price variables were significantly different from

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1Project 2196 of the Iowa Agriculture and Home Economics Experiment Station. The authors gratefully acknowledge the help of Marshall H. Cohen, Christine Collins, William T. Coyle, Michael R. Kurtzig, and James Lopes of the Economic Research Service; and Robert D. Knapp, Leon Mears, Wilferd L. Phillipson, Robert J. Wicks, and Dudley G. Williams of the Foreign Agricultural Service in the search for data. Their assistance made this study possible.

21958/59 stands for the year beginning on July 1, 1958, and ending on June 30, 1959. This notation will be used throughout the report.

3Barley, corn, oats, rye, and sorghum are feed grains.

4The Food and Agriculture Organization is hereafter cited as FAO.
zero over most of the time periods studied. The coefficient of the income index consistently had the highest t-value. The independent variables for the soybean meal equations were the price of fish meal at European ports, the number of hogs in the six countries of the EEC (EC6), the number of poultry in the EC6, exports of soybean meal from Brazil, and either the U.S. price of soybean meal and the U.S. price of soybeans or the ratio of the two prices. The coefficients for the price variables were not significant in most equations for soybean meal.

Abbott (1979) used separate equations to explain net imports of wheat and feed grains by 33 countries. Abbott tried to account for the existence of trade barriers by allowing the domestic price in the importing country to partly respond to changes in the world price. The prices in the model were cif\(^5\) prices so that transportation costs were incorporated, but exchange rates and tariffs were omitted. The independent variables were domestic price, domestic income, time, domestic production, aid in kind received of the commodity, the foreign exchange position of the importing country, the domestic stock of animals, and the domestic population. The coefficient for the price variable was significantly different from zero in only 5 of 33 equations for both wheat and feed grains.

A reason that price coefficients tend to be significant for soybeans and soybean products and not significant for wheat and feed grains may be trade barriers. There are fewer trade barriers for soybeans and soybean products than for wheat and feed grains. So the U.S. price of soybeans measures the importing country's price of soybeans more accurately than the U.S. price of feed grains measures the importing country's price of feed grains. Jones and Morrison's study (1976) probably was hampered by the fact that eastern Europe is characterized by central planners, and the role of price probably is diminished. If trade barriers are considered, the coefficient for the domestic price of feed grains could be significant.

Johnson (1971) and others have used a market share analysis to explain international trade in some commodities. The market share analysis allows a commodity produced in one country to be an imperfect substitute for the same commodity produced in another country. In that case, imports of a particular commodity should be distinguished by origin. Johnson sees the fact that countries import the same commodity from different countries as a rationale for this view. The emphasis of the market share approach is on estimating the elasticity of substitution between different import-supplying countries.

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\(^5\) cif prices include cost, insurance, and freight. This price covers the cost of the commodity up to the port of entry.

**NEEDED EXTENSIONS**

Three important aspects of international trade have not yet been properly handled in any one study. These aspects are: 1) ocean shipping costs, 2) exchange rates, and 3) trade barriers. Some studies consider one or two of these three, but no study has considered all three.

**Ocean Shipping Costs**

Ocean shipping costs have not been constant and have not experienced a sustained trend. For example, the average shipping cost (per long ton) from U.S. gulf ports to Tilbury, United Kingdom, was $8.78 in 1966/67, $3.30 in 1971/72, $16.52 in 1973/74, and $6.78 in 1975/76 (International Wheat Council, 1973/74). Ocean shipping costs have an effect on the cost of imported feed grains to the importing country. During the 1966-74 period, ocean shipping costs averaged 11.5% of the cost of imported U.S. corn at entry into the United Kingdom (this excludes any import duties). A large proportion of previous studies found that the quantity of feed grain imports by a country was not responsive to the price incorporated in the model. The exclusion of the cost of ocean shipping from the feed grain price could be a reason for those results.

**Foreign Exchange Rates**

A buyer in the United Kingdom who wishes to buy feed grains is concerned with the pound price of feed grains. An American seller is concerned with the dollar price of feed grains. If the American and the Englishman wish to make a transaction, someone must change currencies. Assume that the buyer must exchange his country's currency for the currency of the seller. Then the Englishman must exchange his pounds for dollars, and the exchange rate between the pound and the dollar is a part of the cost of U.S. feed grains the Englishman purchases. If the dollar price remains the same, the cost of U.S. feed grains to the Englishman can still change if the exchange rate changes. Therefore, the exchange rate must be incorporated into the international trade model.

Ryan and Houck (1976) and Jones and Morrison (1976) did not incorporate exchange rates in their studies. The prices they used were all dollar prices. Because the values of currencies change periodically, even under a system of fixed exchange rates, these studies omitted an important factor. For instance, the United States devalued the dollar in 1971 and 1973 when the world monetary system was under a regime of fixed exchange rates. These devaluations made U.S. feed grains less expensive in terms of foreign currencies.

Deppler (1974) used intercept dummy variables to capture the effects of changes in exchange rates
on the total value of imports and exports for various countries. The dummy variables were used to allow the intercept for the aggregate import demand and export supply functions to change when the exchange rate changed. But a devaluation will do more than simply change the intercepts of these two functions. It will also change the price elasticities and slopes. Consider the United Kingdom demand for imports from the United States. Assume that total U.K. imports from the United States are a function of the price (in dollars) for these imports.

Let $P$ and $Q$ represent price (in dollars) and physical volume of these imports, and let the line labeled $D_1$ in Figure 1 represent the U.K. demand function for imports from the United States. The price in pounds that the U.K. importers must pay per unit of imports equals $P$ divided by the number of dollars required to buy one U.K. pound. Denote this exchange rate by $k$. Suppose the dollar-price of imports is $P_1$. Then total volume of imports is $Q_1$.

If the United States devalues the dollar in terms of the British pound by 20 percent, it takes 20 percent more dollars to buy 1 British pound, and it takes about 17 percent fewer pounds to buy 1 dollar ($1/1.20$ is approximately 0.83). The 20-percent devaluation causes a 17-percent decrease in the price (in pounds) of imports. Thus, the volume of imports $Q_1$ can be purchased for 17 percent fewer pounds than before the devaluation. The number of pounds that were required to buy $P_1$ dollars before the devaluation will now buy $1.2P_1$ dollars. Thus, the dollar price for volume $Q_2$ is now $1.2P_1$. The new demand curve passes through the point $A$.

Now suppose that the price of imports in dollars before devaluation was $P_2$. Then imports were $Q_2$. After devaluation, the import demand function at volume $Q_2$ passes through the price $1.2P_2$. Thus, the devaluation affects the slope and the intercept of the import demand function, and the new import demand function is represented by the line labeled $D_2$. By using intercept dummy variables to capture the exchange rate change, one would get an estimated demand function like $D_3$. What should be done is to divide the dollar price by the exchange rate denominated in dollars per pound to obtain the pound price. Some of the agricultural studies state that they have "adjusted" for the exchange rate in their model. The adjustment, however, should not be handled with intercept dummy variables only.

### Trade Barriers

Some studies use the U.S. price as the importing country's price, others take into consideration ocean shipping costs and exchange rates in the cost of importing the commodity. But no study that we have seen explicitly accounts for tariffs or quotas. One reason may be the lack of reliable published data on trade barriers for most countries. Hillman (1978) recognized the discriminatory nature of nontariff barriers to trade in agricultural products. He also outlined the difficulties in quantifying nontariff barriers. Grain import policies of many countries are reported by FAO (1958b through 1976b) each year. But the government of the reporting country is in charge of submitting the information, and the information is incomplete for most countries. A large proportion of the reporting countries issues import licenses to importers of grains. Unfortunately, the publication does not give the prices of the licenses, the numbers issued, or other information needed for a complete picture of the country's true policies. Import licenses could be a disguised quota.

Abbott (1979) tried to incorporate import policies by allowing the importing country's domestic price to partly adjust to the cost of importing the commodity. But he had no specific rationale for this specification. Abbott recognized that tariffs and quotas have effects on imports but did not consider their effects on the difference between the domestic price and the cost of importing.

### OBJECTIVES

The aim of this study was to investigate factors that have been overlooked in previous work on international trade in agricultural commodities and to
discover their influence on trade in feed grains. These factors are trade barriers, ocean shipping costs, and exchange rates. The specific objectives of the study are:

1) to obtain demand equations for feed grains by certain feed grain importing countries of the world,
2) to investigate factors that influence the domestic price of feed grains in these importing countries, and
3) to determine the variables affecting foreign sales of U.S. feed grains.

Other factors in the importing country are investigated, but they are considered only to make the analysis for feed grains more accurate.

A COUNTRY’S TOTAL IMPORTS OF FEED GRAINS

Import Demand

In a world with no trade barriers or transportation costs, the equilibrium dollar price of a good will be the same in every country because of arbitrage if there is perfect competition. If the dollar price is higher in some countries, an individual could buy the good in a country where the dollar price was low and sell the good in a country with a high dollar price, thus earning positive profits. Therefore, the supply of the good in the countries with the high dollar price will increase because of arbitrage. This will tend to decrease the dollar price in those high-priced countries. The supply of the good in the countries with a low dollar price will decrease because of arbitrage. This will tend to increase the dollar price in those low-priced countries. Arbitrage will be profitable until there is no difference in the dollar price between countries.

In a world with no trade barriers, perfect competition in the markets, but positive transportation costs, there can be different dollar prices for the same good at different locations. But the difference in the dollar price between two countries will be no greater than the cost of transporting the good between the two countries. Suppose that the dollar cost of imported feed grains into a particular importing country is $P_1$. If feed grains are not distinguishable by their country of production, then the domestic price of feed grains in the importing country, $P_D$, will equal the dollar cost of imported feed grains divided by an exchange rate, $k$, denominated in dollars per unit of the importing country's currency, $P_D = P_1/k$.

If the importing country does not import a large share of the feed grains that are traded internationally, the country will be able to import any amount of feed grains it wants at a cost of $P_1$, or $P_1/k$ in its own currency units. This is the small-country assumption of international trade. Any price lower than $P_1$ paid by the importing country will result in no feed grains being supplied from exporting countries because exporting countries can receive higher prices elsewhere. No dollar price above $P_1$ will last because the importing country will be able to find some exporter who will be willing to supply feed grains at a price of $P_1$. So the cost of imported feed grains is exogenous to the importing country and fixed at $P_1$.

Figure 2 shows the domestic feed grain market. The domestic price of feed grains is measured along the vertical axis. The quantity of feed grains is measured along the horizontal axis. $S_{DF}$ is the domestic supply function for feed grains. $D_F$ is the domestic demand function for feed grains. If there were no international trade in feed grains, the domestic price of feed grains would be $P_N$, where domestic supply equals domestic demand. Assuming that feed grain inventories of the importing country remain constant, domestic production of feed grains would equal domestic consumption. In Figure 2, this amount is $Q_1$.

![Figure 2. The domestic feed grain market with no trade.](image-url)

Assume that the country depicted imports feed grains, so the cost of imported feed grains must be lower than $P_N$. The import price has been labeled $P_1/k$. The import supply curve for feed grains is perfectly elastic at that price. So the actual supply-demand situation for feed grains is depicted in Figure 3.

The demand curve is the same as in Figure 2, but the supply curve, $S_F$, is the portion of the domestic supply curve below $P_1/k$, and at $P_1/k$, the supply curve is perfectly elastic, reflecting the import supply curve. One can think of $S_F$ as the lower envelope of the domestic supply and import supply curves.
The domestic supply and demand curves do not determine the domestic price of feed grains in the importing country. The domestic price of feed grains is determined by the outside world. The domestic supply and demand curves determine the demand for imports. In Figure 3, \( Q_d \) is domestic supply, \( Q_c \) is domestic consumption, and \( Q_d - Q_c \) is the quantity of imports.

Under the assumptions (a) of perfect competition in the domestic and international feed grain market, (b) that foreign-produced feed grains are a perfect substitute for domestically produced feed grains, and (c) that the importing country's imports are a small fraction of total world trade, the import demand for feed grains is an excess demand. Therefore, the demand for imported feed grains should be a function of the same variables that affect domestic supply and demand.

Figure 4 shows the import demand function, \( I_F \). It is derived by subtracting \( S_{DF} \) from \( D_F \) at each domestic price. In this figure, imports equal \( Q_3 - Q_2 \). \( P_D \) is the domestic price of feed grains at which there are no imports of feed grains. It is the same as \( P_N \) in Figure 2. There are domestic prices that are high enough to cause the country depicted to be an exporter of feed grains, but the quantities exported at these prices have not been shown.

Supply

The domestic supply function for feed grains is derived from the assumption of profit maximization by producers. This equation will be specified as a function of present and past values of the domestic price of feed grains and the lagged price of inputs for feed grain production. Lagged values of the domestic price influence supply because planting decisions must be made 6-12 months before harvest. If the functional form of the domestic supply curve is linear:

\[
S_{DF} = a_0 + a_1 P_D + a_2 P_{D-1} + a_3 P_{P-1}
\]

The subscript t-1 denotes a variable lagged one period. Absence of a time subscript denotes the current value of a variable. \( P_D \) and \( P_{D-1} \) are current domestic feed grain price and domestic feed grain price lagged one time period. \( P_{P-1} \) is the price of inputs for feed grain production in period t-1. The lagged price variables can be viewed as representative lagged prices because longer lags may be included. From profit maximization, one would expect that \( a_1 \) and \( a_2 \) would be greater than zero and that \( a_3 \) would be less than zero. As the domestic price of feed grains increases, the quantity of feed grains supplied is expected to increase. As the price of inputs for feed grains production increases, the quantity of feed grains supplied is expected to decrease.

Demand

The domestic demand function for feed grains is derived from the assumptions of utility maximization by consumers and profit maximization by producers of products that use feed grains as an input. The quantity of feed grains demanded is a function of the domestic price of feed grains, real domestic per-capita income, and the size of the domestic livestock industry. If the functional form of the demand function is linear:
Excess demand

Note that the domestic price of feed grains has two effects on imports. The first effect is the supply effect, and the second is the demand effect. Both the supply and demand effects tend to decrease import demand, so their combined effect is negative.

Import demand

Equation (3) has been derived under the assumption of perfect competition in the markets for feed grains. But there may not be perfect markets in the importing country. The government of the importing country usually has some control over how the market operates. If the government is concerned with the trade balance of the country, it may follow policies to improve the balance of trade. There are two ways to improve a country's balance of trade. One is to increase the value of exports, and the other is to decrease the value of imports. The value of exports is largely determined by other countries, but the value of imports can be influenced by the government. A common way of holding down or decreasing the value of imports of a certain commodity is by imposing foreign exchange restrictions.

It is quite common for a government to control a large percentage of the stocks of feed grains. Because of a lack of foreign exchange, a government may dictate that only X units of the country’s currency may be exchanged for the purchase of imported feed grains. The rest of the feed grains needed for domestic consumption would come from government inventories of feed grains. These foreign exchange restrictions affect neither domestic supply nor domestic demand, but they do affect imports. A measure of the amount of foreign exchange, FE, was therefore added as an independent variable to the excess import demand function to obtain

\[ I_F = c_0 + c_1 P_D + c_2 P_{Dt-1} + c_3 (Y/N) + c_4 L + c_5 F_E \]
the work of Rausser and Freebairn (1974) on "policy preference functions." They discuss specification and estimation of policy preference functions and apply their procedure to a policy preference function for U.S. beef import policy. In another context, Rausser and Stonehouse (1978) make a strong case for treating governmental policies as endogenous. Their concern is with policies affecting supplies of farm products.

**Arguments for trade barriers**

There are many arguments for trade barriers. One is the infant-industry argument. This claim asserts that some industries may be more efficient in large-scale operations, but that the industry must be allowed to develop. If competition is keen from foreign industries, the domestic industry will not be able to develop and enjoy the benefits of large scale. If the government imposes a tariff or quota on imports from foreign countries, the domestic industry will be able to develop and reach optimal size. The future benefits from the development of the domestic industry will exceed the start-up costs.

Another argument is that trade barriers will allow domestic production to increase, owing to the higher domestic price for the product. This will increase employment in the domestic industry. Also, if the good is important for national security, the reliance on foreign sources of supply will diminish when domestic production increases. The importing country will become more self-sufficient and independent.

Another argument rises from the problems some countries have with crowded cities. If farm income is increased, more people will choose to live in rural areas. This will lessen the pressures on the crowded cities. A tariff or quota on agricultural products will raise the price of farm products to domestic producers and, therefore, increase farm output and employment. So protective trade policies are a means of combating some urban problems and encouraging a rural way of life for more people. Nevertheless many countries need to keep food prices in the city low. This is often accomplished by subsidizing food in the large cities to soothe the urban masses. The money needed for the subsidies could be obtained from the trade barriers.

Trade barriers can be used to improve a country's balance of payments. Imports of a good will fall if a tariff or quota is imposed, but the price that the foreign importer receives will not change under the small-country assumption. Therefore, the quantity of the good imported will decrease, the outflow of currency from the importing country will decrease, and the balance of payments will improve.

When import duties are collected or quota licenses are sold, the government of the importing country receives revenue. For some countries, money from trade barriers is a major source of government revenue.

Trade barrier revenues are easy to collect and are more indirect than other methods of taxation, so there is less opposition to trade barriers than to other methods of taxation. When personal income taxes increase, people know the tax has increased because they pay directly to the government. If a tariff on a good increases, the people will still pay the tax through a higher price for the product, but they may not know the reason that the price of the good increased. They do not pay for a tariff directly. Import barriers can serve as an invisible tax.

Another argument for trade barriers is the "optimum tariff" argument. This argument is relevant for countries whose importing decisions can influence the price that foreign suppliers receive for the commodity. A country that has some market power can impose a tariff that will lower the cost of importing the good by reducing world demand. This argument is irrelevant for any country that satisfies the small-country assumption.

**Government's utility function**

By imposing trade barriers on feed grain imports, the government of the importing country has some degree of control over the domestic price of feed grains. If the tariff on imported corn increases, at least a part of this duty will be passed on to the people who purchase the corn in the importing country. Indeed, if the governmental policies are the only restriction in the feed grain market, the government of the importing country can actually control the domestic price of feed grains. The government knows that, if the tariff increases by $5 per metric ton, the domestic price will increase by $5 per metric ton.

If the government can control the domestic price of feed grains, then how does it decide what the price should be? One possible explanation is that the government maximizes the value of a utility function. The variables in the utility function stem from the arguments for trade barriers presented in the previous section. With respect to the feed grain industry, the arguments that seem most likely to concern the government are to increase farm employment, to increase national security or self-sufficiency, to improve the balance of payments situation, and to increase government revenues.

The infant-industry argument was eliminated because operations that produce feed grains are relatively small throughout the world. The economies-of-scale in production probably are small or nonexistent. Even if there are substantial economies-of-scale in production of feed grains, it doesn't seem that foreign governments are encouraging producers to capture their benefits. The other argument that was eliminated was the idea of an optimum tariff. This is because it was assumed that the importing country modeled could not influence the cost of imported feed grains; therefore, the country's optimal tariff is zero.
One way to increase farm employment and keep people out of the city is to increase farm income. Then more people will move to or stay on farms. So with respect to the feed grain industry, the government's utility function would be positively influenced by the value of domestic sales of feed grains.

A good measure for degree of self-sufficiency in feed grains is the total amount of feed grains imported. The balance of payments situation in the feed grain market would be represented by the value of feed grain imports. As the quantity and value of feed grain imports decrease, the government's utility function should increase.

The amount of revenue the government receives from trade barriers will be the difference between the domestic price of feed grains and the cost of imported feed grains, multiplied by the quantity of feed grains imported. If these government revenues increase, the government's utility also should increase.

The utility function for the government of the importing country has four variables that have been mentioned thus far: value of domestic feed grain sales, the quantity of feed grain imports, the value of feed grain imports, and the revenue the government receives from trade barriers for feed grains. If these four variables were the only variables in the government's utility function, the country would always have some trade barriers to feed grains. The trade barrier would allow domestic feed grain production to increase, the quantity and value of feed grain imports to fall, and the government revenues to increase. All these changes would result in a higher level of utility for the government. But not all importing countries have trade barriers, according to FAO (1958b through 1976b). So some other variable must be in the government's utility function that would cause trade barriers to have a negative influence on utility. That variable could be the amount of consumer surplus derived from the domestic feed grain market.

Consumer surplus for a particular commodity measures the benefits that accrue to buyers of that commodity. Consumer surplus is positive if a buyer purchases a good at a price lower than the value the good has for him. If the price of the good increases, consumer surplus will decrease. Therefore, as the domestic price of feed grains increases, consumer surplus derived from the domestic feed grain market will decrease. So if trade barriers on imported feed grains are imposed, the domestic price of feed grains will increase, and consumer surplus will fall. Because the government represents the people of the country, an increase in consumer surplus increases the government's utility. Inclusion of consumer surplus as a variable in the utility function takes into consideration the changes in consumer welfare that occur because of trade barriers. The greater the weight that consumer surplus has in the government's utility function, the less restrictive trade barriers will be. Therefore, the government's utility function used in this study is:

\[
U = f(P_D \cdot S_F, I_F, (P/k) \cdot I_F, TT, CS)
\]

where

\[
U \quad \text{is the government's utility from the domestic feed grain market in period } t.
\]

\[
P_D \cdot S_F \quad \text{is domestic farm income from feed grain sales in period } t.
\]

\[
I_F \quad \text{is the quantity of feed grains imported in period } t.
\]

\[
(P/k) \cdot I_F \quad \text{is the value of feed grains imported in period } t.
\]

\[
TT \quad \text{is the government's revenue from feed grain trade barriers in period } t.
\]

\[
CS \quad \text{is consumer surplus from the domestic feed grain market in period } t.
\]

If the function \( f \) is linear:

\[
U = d_1 P_D \cdot S_F + d_2 I_F + d_3 (P/k) \cdot I_F + d_4 TT + d_5 CS
\]

\[
d_1, d_2, d_3, d_4, d_5 > 0 \quad d_5 < 0
\]

Because the government's instrument for maximizing its utility is the domestic price of feed grains, the utility function is differentiated with respect to \( P_D \), set equal to zero, and then solved for the government's utility maximizing value of \( P_D \). The result is (see Reed, 1979, pp. 43-48 for detail on derivation):

\[
P_D = \gamma_0 + (\gamma_1)P_{D,t-1} + (\gamma_2) (Y/N) + (\gamma_3) L
+ (\gamma_4) I_F + (\gamma_5) (P/k) + (\gamma_6) P_{D,t-1}
\]

where \( \gamma_1, \gamma_4 < 0, \gamma_2, \gamma_3, \gamma_5, \gamma_6 > 0 \)

\[
\Delta = 2a_1 d_1 + c_1 d_4 - b_1 d_3 > 0
\]

The sign of \( \Delta \) is indeterminate. But if the utility weights for the value of domestic feed grain sales, government revenue from feed grain trade barriers, and consumer surplus derived from the domestic feed grain market in eq. (6) are equal, then

\[
d_1 = d_2 = d_4 = d \quad \text{and}
\]

\[
\Delta = 2a_1 d + c_1 d - b_1 d, \text{but } c_1 = b_1 - a_1, \text{ so}
\]

\[
\Delta = a_1 > 0
\]

If \( \Delta \) is positive, then

\[
P_D = e_0 + e_1 P_{D,t-1} + e_2 (Y/N) + e_3 L + e_4 I_F + e_5 (P/k) + e_6 P_{D,t-1}
\]

\[
e_1, e_4 < 0 \quad e_2, e_3, e_5, e_6 > 0
\]

In this case, if variation in \( (Y/N) \) or \( L \) caused the
domestic demand for feed grains to increase, the domestic price of feed grains also would increase. If variation in $P_{dt}$ or $P_{st}$ caused the domestic supply of feed grains to increase, the domestic price of feed grains would decrease. If the cost of imported feed grains increased, the domestic price of feed grains also would increase. If $\Delta$ were positive, the domestic price of feed grains would tend to move in more plausible directions, given changes in the predetermined variables. By the term "plausible direction," it is meant that the domestic price movement is in the direction that usually is expected by economists. If variables change such that domestic demand increases, the domestic price also should increase. It seems unlikely that, as the cost of imported feed grains increases, the domestic price of feed grains should decrease (which would be the case if $\Delta < 0$).

But in the general case, because $\Delta = (2d_1 - d_3)_{a_1} + (d_1 - d_2)_{b_1}$, the larger the utility weights for the value of domestic feed grain sales and for the government revenue derived from feed grain trade barriers relative to the utility weight for consumer surplus obtained from the domestic feed grain market, the larger $\Delta$ will be.

The second-order condition for utility maximization is not sufficient to determine the sign of $\Delta$ unambiguously.

The econometric model for the importing country has two equations, eqs. (4) and (7), and is simultaneous: $I_t$ and $P_t$ are endogenous variables. The world market determines the price of feed grains at the importing country's border, then the government imposes the utility maximizing barrier on imported feed grains.

Livestock Industry

The model specifies that the size of the domestic livestock inventory helps to determine imports of feed grains and domestic price of feed grains for the importing country. Previous import-demand studies have treated the domestic livestock inventory as exogenous or predetermined. But because feed grains are an input in the production of livestock, the domestic price of feed grains may influence the size of the domestic livestock inventory. To avoid simultaneous equation bias, a simple model was used to explain the domestic livestock industry.

International trade in livestock products is limited because transportation costs are high, and trade barriers are very restrictive in most countries. For these reasons, it was assumed that the livestock industry is closed to foreign supplies. This means that the domestic price of livestock is determined by domestic supply and demand. The domestic livestock industry model involves four equations: production of livestock products, demand for livestock products, livestock inventory equation, and a supply-demand relationship for livestock products. The derivation of the livestock equations is explained in Reed (1979).

Criteria Used in Choosing Countries

The countries chosen for the study had to meet certain criteria. Because the model is derived from the "small-country" assumption, each country's imports of feed grains could have no effect on its cost of imported feed grains. This assumption is a close approximation for every individual country in the world. But the way this model is constructed, all European Economic Community member countries need to be treated as a single country because of their common agricultural policy. EEC countries import approximately one-third of the feed grains traded. So the "small-country" assumption probably is violated for the EEC as a whole. The EEC as a whole is not analyzed. The United Kingdom is studied, but the observation period for the United Kingdom included only 2 years in which it was a member of the EEC.

The countries modeled should have reliable data sources on variables needed for the analysis. Some data needed for the study can be estimated or assumed to be the same as in the United Kingdom or some other country. But data on feed grain prices, livestock prices, livestock production, livestock inventories, and other variables that must be unique for each country need to be available. This limits the analysis to more developed countries that can afford to spend money collecting and publishing data. But most substantial feed grain importers are more developed countries. Finally, the countries must be net importers of feed grains throughout the observation period. The model is constructed to explain imports of feed grains, not exports of feed grains.

Full Model for Each Country

In addition to variables defined previously, the following variables are used:

- $Q_{PL_t}$ = quantity of livestock products produced in period $t$
- $L_t$ = beginning domestic livestock inventory in period $t$
- $P_{L_t}$ = farm price of livestock products in period $t$
- $D_{L_t}$ = demand for livestock products in period $t$

Each estimated equation was linear in the variables. But for convenience, each equation will be written here in general functional form.

Greece

Because of data limitations, the model fitted for Greece had $P_{st}$ deleted from eqs. (4) and (7). Data limitations and sources are discussed for all countries in a later section entitled Data. The equations in the full model fitted for Greece are:
The observation period for Greece was from 1958 through 1976.

Israel

The Israeli data set had the same limitations as the Greek data set. Therefore, the Israeli model was the same as the Greek model. The observation period for Israel also was from 1958 through 1976.

Japan

The main crop that Japan produces is rice. Since 1969, Japan has been a major exporter of rice. In 1971, large stockpiles of rice became a problem for Japan, and the Japanese government subsidized the use of stockpiled rice in animal feeds to encourage disposal of the surplus rice. "Since rice will replace feed grains on a one-to-one basis, the use of surplus rice stocks for feed will reduce the feed grain import potential of a like amount" (U.S. Department of Agriculture, Foreign Agricultural Service, 1972b, p. 4). To capture effects of this policy, the quantity of rice stocks at the beginning of period $t$, $R$, was included in the import demand for feed grains, eq. (4), for Japan. As the quantity of rice stocks at the beginning of period $t$ increases, the import demand for feed grains by Japan is expected to fall. Including the stock of rice in the import demand function for feed grains allows the stock of rice to affect the domestic price of feed grains by the mechanism outlined in a previous section entitled Domestic Price of Feed Grains. Data on $p_s$ are also available for Japan. To obtain the Japanese model from the model for Greece, then, the variable $R$ was added to eqs. (9) and (10); the variable $P_o$ was added to eq. (11), and $P_o$ and $P_{o-1}$ were added to eq. (13).

The observation period for Japan was from 1960 through 1976.

Portugal

The Portuguese data set had the same limitations as the Greek and Israeli data sets. Therefore, the Portuguese model was the same as the Greek and Israeli models. The observation period for Portugal was from 1958 through 1976.

Spain

The Spanish model was the same as the Greek, Israeli, and Portuguese models because of the same data limitations. The observation period was also from 1958 through 1976.

United Kingdom

The United Kingdom joined the European Economic Community in 1972 along with Ireland and Denmark. In 1972, the internal price of feed grains in the United Kingdom was substantially lower than the target prices in the EEC member countries. The membership agreement called for U.K. import levies to equal the levies of other EEC member countries by Jan. 1, 1978. To attain this goal, a transition period began on Feb. 1, 1973. United Kingdom import levies increased slowly during the transition period until the U.K. levies were comparable to those of the other EEC members on Jan. 1, 1978. To handle this situation, a dummy variable, $D$, was inserted in eqs. (4) and (8) for the United Kingdom. The dummy variable was constant during the period that the United Kingdom was not a member of the EEC. The dummy variable was also constant after the United Kingdom was a full member of the EEC, but with a higher value than when the United Kingdom was not a member. For observations in the transition period, the value of the dummy variable increased linearly from the value before membership in the EEC to the value after full membership. For further explanation of the dummy variable, see the later section entitled Data.

Livestock producers in the United Kingdom, as in many other western European countries, feed a substantial amount of wheat to livestock. According to the USDA-FAS (1977, p. 5), "Since wheat can only be fed up to a certain proportion of total grain intake, it is often used only to supplement rather than replace coarse grains in livestock rations." If this is so, then wheat is not a substitute for feed grains in livestock rations, and it is not necessary to incorporate equations for the entire U.K. wheat market into a U.K. feed grains model. To obtain the U.K. model from the model for Greece, the variable $D$ was added to eqs. (9) and (10); the current wheat price $P_w$ was added to eq. (11); and $P_w$ and $P_{w,t-1}$ were added to eq. (13). The observation period for the United Kingdom was 1958 through 1974.

Data

Because feed grains and livestock are not homogeneous commodities, price, quantity of production, and other variables needed for these commodities must be obtained by aggregation.

Feed grain aggregates

For all countries except Japan, feed grain quantities were measured in corn equivalents. The importing country's marginal rate of substitution of each
grain for corn was measured as the ratio of the importing country's average price of corn during the sample period to the country's average price of the feed grain during the sample period. This rate was then multiplied by the quantity of the feed grain to obtain the corn equivalent of the feed grain. Corn equivalents of all feed grains were added to obtain the aggregate quantity of feed grains. For Japan, feed grain quantities were measured in barley equivalents.

**Livestock aggregates**

Aggregate demand, $D^*_t$, was measured in the conventional way: weighting quantity by marginal rate of substitution estimated by a price ratio. For each country except Israel, the ratio of average price for a livestock product over the sample period to the average price of a hog carcass over the sample period was used to estimate the marginal rate of substitution between each livestock product and the carcass of a hog. Then each livestock product was transformed into hog carcass equivalents, using the estimated rates of substitution, and hog carcass equivalents were aggregated to form $D^*_t$. For Israel, marginal rates of substitution between other livestock products and poultry products were used to obtain $D^*_t$.

Because the livestock sector was included in this study to explain the feed grain sector, the relationship between livestock and feed grains is of primary importance. In most countries, poultry consume much more feed grain per pound of body weight than cattle or sheep. In many countries, a 4-pound layer consumes more feed grain than a 900-pound steer. Therefore, to obtain $Q_{eq}$ and $L$, the quantity or number of each livestock or livestock product was weighted by feed grain consumption. The inventory of each type of livestock was adjusted for its feed grain consumption to obtain the livestock inventory in feed grain consuming units. After inventories were transformed into feed grain consuming units, the aggregate livestock inventory, $L$, was obtained by summing the inventory of each type of livestock.

Because the aggregation used to form $Q_{eq}$ was different from the aggregation used to form $D^*_t$, eq. (14) was used instead of the familiar supply-equals-demand identity. To obtain $Q_{eq}$, the quantity of feed grains consumed by the type of livestock that produces the particular livestock product was used to weight the production of each livestock product.

**Sources**

The models presented were constructed to be fitted with quarterly data, but quarterly data were impossible to obtain for many of the variables for Greece, Israel, and Portugal. The models for these three countries, therefore, were changed to a yearly basis. The models for Japan, Spain, and the United Kingdom were on a quarterly basis because quarterly data were available.

**Domestic price of feed grains, $P_d$** Yearly prices of feed grains used to aggregate feed grain imports were found in FAO-ECE (1960/61 through 1975/76) for Greece, Portugal, Spain, and the United Kingdom. Yearly prices of feed grains used to aggregate feed grain imports for Japan were from the Institute of Developing Economics (1969). Yearly unit values for feed grains were used to aggregate feed grain imports for Israel. A unit value is the total value of production divided by the total quantity of production. The data for these unit values for feed grains were found in the Israel Central Bureau of Statistics (1958a through 1976a).

The price of sorghum in Greece, Portugal, and Spain and the price of rye in Israel and Japan could not be found. Missing prices for each country were assumed to be equal to the price of corn for the country.

The yearly price of corn obtained from these sources for Greece, Israel, and Portugal was used as the price of feed grains for the yearly models. The quarterly price of corn for Spain was collected from the Spain Instituto Nacional de Estatistica (1958 through 1976). The quarterly price of corn for the United Kingdom came from the Great Britain Ministry of Agriculture, Fisheries, and Food (1958/59a through 1973/74a). The U.K. price was for corn imported from the United States that has already passed through the port of entry.

The only feed grain price that was available for Japan on a quarterly basis was the government-fixed price of barley. This is not a market price, but a support price. According to the FAO (1958b through 1976b) and the USDA-FDCCD (1972), imports of all feed grains are duty-free for Japan. There has been a quota on barley imports but no other trade barrier on feed grain trade. Therefore, the price of imported feed grains should be close to the domestic price of feed grains because more than 90% of Japan's feed grain imports face no trade barriers. For these reasons, the Japanese models were fitted with the import price of barley as $P_d$.

**Imports of feed grains, $I$** The FAO (1958a through 1976a) published data on quarterly imports of barley, corn, oats, and rye for the United Kingdom. Data on quarterly imports of sorghum by Japan were published in the Japan Ministry of Finance (1958 through 1976).

FAO (1958d through 1976d) reported yearly imports of feed grains for Greece, Israel, and Portugal; imports of oats, rye, and sorghum for Spain; and imports of rye and sorghum for the United Kingdom. These yearly totals were divided by four to obtain quarterly observations. The imports of sorghum were not directly observable from FAO (1958d through 1976d), but sorghum and millet imports were
published, so sorghum and millet were considered feed grains.

Livestock production, Q_{PL}. Observations on the production of beef, pork, mutton, poultry meat, milk, and eggs were needed to form the aggregate livestock production variable. Yearly observations on production of these livestock products for Greece, Israel, and Portugal came from the FAO (1958c through 1976c). Quarterly observations for Japanese livestock production came from the Japan Ministry of Agriculture, Statistics and Information Department (1958 through 1976). Quarterly livestock production figures for Japan were not available before 1960. All livestock production in the United Kingdom by quarters was available through the Great Britain Central Statistical Office (1958 through 1976). Spanish production figures for beef, pork, and mutton by quarters were available from the FAO (1958a through 1976a), and Spanish production data for poultry meat was available from the Spain Instituto Nacional de Estatistica (1958 through 1976).

Spanish production of milk and eggs was reported on a yearly basis only through the FAO (1958c through 1976c). The yearly totals were divided by four to get quarterly observations.

Livestock inventory, L. Data on the size of livestock inventories were available on a quarterly basis for the United Kingdom only. Inventories were published by the Great Britain Ministry of Agriculture, Fisheries, and Food (1958/59b through 1975/76b). For England and Wales, sheep inventories were not given for the first quarter but were included for the other three quarters. For Scotland and Northern Ireland, the other territories that make up the United Kingdom, all livestock inventory figures were given biannually, in June and December. To have quarterly data for Scotland and Northern Ireland, the missing observations for March and September were estimated by averaging the figures for the previous quarter and the following quarter. The same procedure was followed to estimate sheep inventories in England and Wales for the first quarter of each year. Quarterly livestock figures for the United Kingdom ended in 1974.

Observations on the livestock inventories of all other countries were on a yearly basis and were gathered from the FAO (1958c through 1976c). A missing-value procedure, which is outlined later in this section, was used to calculate the missing quarterly inventories of livestock for Japan and Spain.

Price of livestock products, P. Yearly prices of livestock products used to aggregate livestock inventories and livestock production were published by the FAO-ECE (1960/61 through 1975/76) for Greece, Portugal, Spain, and the United Kingdom. The Institute of Developing Economics (1969) reported Japanese livestock product prices on a yearly basis. Yearly unit values of Israel livestock production were calculated from quantity and value of production data published by the Israel Central Bureau of Statistics (1958a through 1976a). The price of sheep was available only for Israel; for other countries, it was assumed that the price of sheep was equal to the price of hogs.

The quarterly price of hogs in Japan was published by the Japan Ministry of Agriculture, Statistics and Information Department (1958 through 1976). The quarterly price of hogs in the United Kingdom was published by the Great Britain Ministry of Agriculture, Fisheries, and Food (1958/59a through 1973/74a). The quarterly price of hogs in Spain was published by the Spain Instituto Nacional de Estatistica (1958 through 1976).

Real domestic per-capita income, (Y/N) Data on disposable income are not available for the countries in the study for every sample year in the study. Real domestic per-capita income of the country was calculated from data published by the International Monetary Fund (1958 through 1976). It was obtained by dividing private consumption expenditures of the country by the consumer price index and population of the country. To obtain quarterly population figures, a time trend was fitted to the yearly population figures. Then the predicted quarterly population figures were used in calculating the real domestic per-capita income of the country. Private consumption in Spain was available only on a yearly basis. Quarterly observations were obtained by interpolating between yearly observations. Spanish private consumption was 1,730 billion pesetas in 1970 and 1,953 billion pesetas in 1971. These figures are annual averages, so they were assumed to be the levels of private consumption as of midyear, July 1. The level of private consumption in the third quarter of 1970 was estimated to be: 1730 + 1.5/12 (1953-1730). This gives the level of private consumption as of mid-quarter, Aug. 15. The level of private consumption in 1970 IV was estimated to be: 1730 + 4.5/12 (1953-1730). In this way, quarterly observations of private consumption in Spain were obtained.

Amount of foreign exchange available, FE The value of exports by the importing country was used as the measure for FE. Observations on the value of exports were published by the International Monetary Fund (1958 through 1976).

Cost of imported feed grains, P_{jk} For all countries except Japan, the cost of imported feed grains to the importing country in dollars, P_{1}, was equal to the price of no. 2 yellow corn free on board (f.o.b.) gulf ports, minus any subsidy paid by the U.S. government to corn exporters, plus ocean transportation costs. The price of no. 2 yellow corn f.o.b. gulf ports was published by the USDA-AMS (1958 through 1976).
U.S. government subsidy payments to corn exporters were gathered from the USDA-ERS-FDCD (1958 through 1962). Ocean transportation costs from the U.S. gulf ports to the United Kingdom were collected from the International Wheat Council (1958 through 1976).

The cost of imported feed grains for Japan was equal to the price of no. 2 barley f.o.b. tracks in Portland, Oregon, minus any government subsidy paid to barley exporters, plus ocean transportation costs. The Portland barley price was used because much of the U.S. barley exported to Japan is shipped from the Pacific Northwest. The price of no. 2 barley f.o.b. tracks in Portland was published by the USDA-AMS (1958 through 1976). U.S. government payments to barley exporters were collected from the USDA-ERS-FDCD (1958 through 1962). Ocean transportation costs from the Pacific ports to Japan were collected from the International Wheat Council (1958 through 1976).

The cost of imported feed grains did not include the cost of unloading the feed grains at the port of the importing country. Also, for Japan, the cost of imported feed grains did not include loading costs at Portland. No data were available on these loading and unloading costs.

Ocean transportation costs were not available for grain shipped to Greece, Israel, Portugal, or Spain, so these ocean transportation costs were estimated from rates to the United Kingdom. It was assumed that ocean transportation costs from the United States to Portugal and Spain were the same as to the United Kingdom and that costs to Greece and Israel were 1.25 and 1.50 times the costs to the United Kingdom, respectively. These factors were decided on by comparing distances from the U.S. gulf to those countries. It is approximately the same distance from the U.S. gulf to Portugal, Spain, or the United Kingdom. The route from the U.S. gulf to Greece is approximately 1.25 times the distance from the gulf to the United Kingdom. The route from the U.S. gulf to Israel is approximately 1.50 times the distance from the gulf to the United Kingdom.

The cost of imported feed grains in dollars was then divided by the exchange rate to obtain (P/k). Exchange rates were published by the International Monetary Fund (1958 through 1976).

The costs of imported feed grains were higher than the domestic prices of feed grains for the entire sample period except for the period around 1973 and 1974. These two years saw rapid increases in the costs of imported feed grains. The domestic prices of feed grains in all countries rose also, but the costs of imported feed grains were above the domestic prices of feed grains for all countries for at least one observation. The domestic prices soon passed the import prices, however.

Price of wheat, $P_k$. The price of wheat, which was used only in the model for the United Kingdom, was collected from the FAO (1958a through 1976a).

Dummy variable for the United Kingdom, $D$. The purpose of the dummy variable for the United Kingdom, $D$, was to capture the fact that the United Kingdom joined the European Economic Community in 1972, and the transition period started in February 1973. The dummy variable had a value of 0.00 for all observations preceding 1973. For the first quarter of 1973, the dummy variable had a value of 0.67. The reason for that value was that the transition period had lasted 0.67 quarter at the end of 1973-I. The dummy variable increased by 1.0 each quarter until the transition period ended in January 1978. So the dummy variable actually measured the number of quarters that the United Kingdom had been in the transition period. The values of the dummy variable through 1973 were:

<table>
<thead>
<tr>
<th>Quarter</th>
<th>$D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972-IV and earlier</td>
<td>0.00</td>
</tr>
<tr>
<td>1973-I</td>
<td>0.67</td>
</tr>
<tr>
<td>1973-II</td>
<td>1.67</td>
</tr>
<tr>
<td>1973-III</td>
<td>2.67</td>
</tr>
<tr>
<td>1973-IV</td>
<td>3.67</td>
</tr>
</tbody>
</table>

Rice stocks, $R$. The quantity of rice stocks, a variable that was used only in the model for Japan, was reported by the Japan Ministry of Agriculture, Statistics and Information Department (1958 through 1976).

Quantity of feed grains fed to livestock. Data on the amount of feed grains fed to each type of livestock were not available for any country. But the amounts of concentrated feed consumed by particular types of livestock were available. Concentrated feed consumed by each type of livestock in the United Kingdom was reported by the Great Britain Central Statistical Office (1958 through 1976). For Japan, concentrated feed consumption was reported by the Japan Ministry of Agriculture and Forestry (1958 through 1976). Concentrated feed consumption was available only in 1970 for Spain. These data were published by the USDA-FAS (1971). It was assumed that these consumption figures for Spain accurately reflected consumption throughout the 1958-1976 period.

Data on concentrated feed consumption for Greece, Israel, and Portugal were not available. Because of the similar livestock structure among these countries and Spain, the factors used to convert hog equivalents into hog and feed grain consuming
equivalents for Greece, Israel, and Portugal were assumed to be the same as the factors for Spain.

**Estimation of missing values of endogenous variables**

The livestock inventory figures for Japan and Spain were available on a yearly basis only. Both inventory figures were during the first quarter of the year (Japan’s inventory was taken in February, and Spain’s was taken in January and February). To obtain inventory observations for the missing quarters, the first-quarter livestock inventories were regressed on all exogenous variables (using the observation from the first quarters only). The coefficients obtained from this regression equation and the second-, third-, and fourth-quarter observations on the exogenous variables were then put into the regression equation to estimate inventories for the respective quarters.

**Results**

This section presents results of the statistical analyses. The estimation procedure used to analyze the total imports models was autoregressive three-stage least squares.7

In the first part of this section, the results are given by equation. The signs of the coefficients are discussed, and some intercountry comparisons are made. The only results reported are the results of the final reduced models, which were obtained by deleting variables from the full models presented previously. The second part of this section discusses the results by country. The experiments undertaken

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**Table 1. Estimated import demand equations from final reduced models.** (Dependent variable is \( I_p \)).

<table>
<thead>
<tr>
<th></th>
<th>Intercept</th>
<th>( P_D )</th>
<th>( P_{t-1} )</th>
<th>( L )</th>
<th>( (Y/N) )</th>
<th>( L )</th>
<th>( L )</th>
<th>( P_{t-1} )</th>
<th>( R )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece</td>
<td>-386</td>
<td>-1.66</td>
<td>-1.66</td>
<td>0.27**</td>
<td>-125**</td>
<td>0.021**</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(406)</td>
<td>(1.56)</td>
<td>(0.08)</td>
<td>(36)</td>
<td>(0.07)</td>
<td>(0.004)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Israel</td>
<td>254**</td>
<td>-2.92**</td>
<td>-2.92**</td>
<td>0.03**</td>
<td>0.29**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(68)</td>
<td>(0.37)</td>
<td>(0.01)</td>
<td>(0.03)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>-1477**</td>
<td>-22.6**</td>
<td>-22.6**</td>
<td>0.26**</td>
<td>-42.6**</td>
<td>5.12**</td>
<td>-0.12**</td>
<td>(1.71)</td>
<td>(0.03)</td>
</tr>
<tr>
<td></td>
<td>(198)</td>
<td>(7.2)</td>
<td>(2.3)</td>
<td>(0.07)</td>
<td>(11.3)</td>
<td>(1.71)</td>
<td></td>
<td>(0.03)</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>-126</td>
<td>-0.24</td>
<td>-0.24</td>
<td>0.14</td>
<td>-63.0</td>
<td>0.032**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(299)</td>
<td>(0.13)</td>
<td>(0.09)</td>
<td>(31.0)</td>
<td>(0.004)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>-347**</td>
<td>-0.25**</td>
<td>-0.25**</td>
<td>0.24**</td>
<td>32.8**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(109)</td>
<td>(0.07)</td>
<td>(0.08)</td>
<td>(5.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.K.</td>
<td>3846**</td>
<td>-27.2**</td>
<td>-27.2**</td>
<td>-0.07**</td>
<td>0.53**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(572)</td>
<td>(8.3)</td>
<td>(0.02)</td>
<td>(0.14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

7For a detailed explanation of autoregressive three-stage least squares, see Reed (1979).

---

Standard deviations are in parentheses.

**Significantly different from zero at the 1% level.
variables and of the autoregressive error coefficients are presented in the Appendix for all equations. In the import demand equations from the final reduced models, 19 slope coefficients are significantly different from zero at the 1% level. Each country except Portugal had at least three coefficients significant at the 1% level. Portugal had only one coefficient significant at the 1% level, but did have two other coefficients significantly different from zero at the 10% level.

Only two of the 19 significant coefficients were of the wrong sign. The lagged domestic price of feed grains had a positive effect on imports for the Spanish model, but the sum of the coefficient for P_D and P_{D-1} is slightly negative.

The livestock inventory in the United Kingdom had a negative influence on U.K. feed grain imports. It may be that the method of aggregating livestock inventories was not appropriate for the United Kingdom. In applying the aggregation procedure for livestock inventories, it was assumed that concentrated feed consumption reflected feed grain consumption. But for the United Kingdom, where a substantial quantity of wheat is fed to livestock, concentrated feed consumption may change through increased feeding of wheat. Therefore, the negative coefficient for the livestock inventory may reflect the inaccurate treatment of wheat in the U.K. model.

The mean price elasticity of import demand varied from a high of -0.40 for Japan to a low of -2.79 for Spain. This elasticity reflects the price effect on the supply and demand for feed grains. So the resultant price elasticities are not extreme.

One expects a high correlation between a price and lagged price. Dropping either P_D or P_{D-1} from this equation usually caused the t-value for the remaining feed grain price variable to increase in absolute size. Only in the Japanese and Spanish equations were the coefficients for both P_D and P_{D-1} significant in the final reduced model.

**Domestic price of feed grains**

The estimated final reduced equations for the domestic price of feed grains are given in Table 2. In the final reduced models, 16 coefficients were significantly different from zero at the 5% level. The equation for the domestic price of feed grains was omitted from the Japanese model because P_D = (P_t/k) in Japan. Because the model for all countries was built on the "small-country" assumption, fitting the equation for the domestic price of feed grains for the Japanese domestic model would have no theoretical support in this study. Japanese domestic factors, such as the livestock inventory or real per-capita income, cannot affect the import price of feed grains.

The expected signs of the variables in eq. (7) for the domestic price of feed grains could not be determined *a priori*. Even though the expected signs of the variables in this equation could not be determined, it is logical to believe that factors that increase the demand for feed grains or decrease the supply of feed grains should increase the domestic price of feed grains. But many of the coefficients in Table 2 do not bear out that logic.

The sign of the coefficient for P_{D-1} was always positive, though a larger value of P_{D-1} should increase feed grain supply and, therefore, decrease the price of feed grains. As stated earlier in this section, one ex-

---

**Table 2. Estimated equations for domestic prices of feed grains from final reduced models.**

(Independent variable is P_D).

<table>
<thead>
<tr>
<th>Country</th>
<th>Intercept</th>
<th>I_F</th>
<th>P_{D-1}</th>
<th>L</th>
<th>(Y/N)</th>
<th>(P_{D-1}/k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece</td>
<td>-51*</td>
<td>0.66**</td>
<td>0.01</td>
<td>-3.78</td>
<td>0.28**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(50)</td>
<td>(0.20)</td>
<td>(4.27)</td>
<td>(0.07)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Israel</td>
<td>59**</td>
<td>0.29**</td>
<td>0.43**</td>
<td>0.02</td>
<td>0.60**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(10)</td>
<td>(0.05)</td>
<td>(0.13)</td>
<td>(0.09)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>-876</td>
<td>0.54</td>
<td>0.31*</td>
<td>0.02</td>
<td>0.19**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(767)</td>
<td>(0.47)</td>
<td>(0.11)</td>
<td>(0.18)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>7676**</td>
<td>-0.41**</td>
<td>1.46**</td>
<td>-0.44**</td>
<td>200**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1676)</td>
<td>(0.10)</td>
<td>(0.10)</td>
<td>(0.16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.K.</td>
<td>-17.5**</td>
<td>0.002*</td>
<td>0.65**</td>
<td>0.20**</td>
<td>0.70**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.2)</td>
<td>(0.001)</td>
<td>(0.07)</td>
<td>(0.03)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*aStandard deviations are in parentheses.

*Significantly different from zero at the 5% level.

**Significantly different from zero at the 1% level.
pects high positive correlation between a price and its lagged value. This may explain the positive coefficients for $P_{Dt-1}$.

The results for Spain are different from the results of other countries studied. The coefficients for $I_p$, $L_1$, and $(P/k)$ are negative for Spain but positive for other countries. The signs of the coefficients for $P_{Dt-1}$, $L_1$, and $(P/k)$ suggest that $\Delta$ may be negative for Spain. Factors that increase the demand for feed grains may bring about government actions that decrease the price of feed grains.

Production of livestock products

The results of estimating the equations for the production of livestock products are presented in Table 3. All coefficients of the domestic livestock inventory are significantly different from zero at the 1% level and are of the correct sign.

Some coefficients of the price variables are of the wrong sign. This could be because some variables have been left out of this simple model of the livestock industry. Inclusion of these additional variables could improve the explanatory power of this equation and the other livestock equations.

Table 4. Estimated equations for the demand for livestock products from final reduced models. (Dependent variable is $b_L$).

<table>
<thead>
<tr>
<th>Intercept</th>
<th>$p_L$</th>
<th>$P_L$</th>
<th>$L$</th>
<th>$P_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece</td>
<td>-141**</td>
<td>0.07**</td>
<td>0.039**</td>
<td>0.89**</td>
</tr>
<tr>
<td>(27)**</td>
<td>(0.01)</td>
<td>(0.003)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Israel</td>
<td>-54**</td>
<td>0.045**</td>
<td>0.009**</td>
<td>0.006**</td>
</tr>
<tr>
<td>(10)</td>
<td>(0.006)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Japan</td>
<td>-122**</td>
<td>-5.51**</td>
<td>-0.06**</td>
<td>0.006**</td>
</tr>
<tr>
<td>(26)</td>
<td>(1.19)</td>
<td>(0.02)</td>
<td>(0.003)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Portugal</td>
<td>34</td>
<td>-0.05**</td>
<td>0.05**</td>
<td>0.047**</td>
</tr>
<tr>
<td>(36)</td>
<td>(0.012)</td>
<td>(0.02)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Spain</td>
<td>39**</td>
<td>0.04**</td>
<td>5.27**</td>
<td>0.013**</td>
</tr>
<tr>
<td>(65)</td>
<td>(0.01)</td>
<td>(0.08)</td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>U.K.</td>
<td>-164**</td>
<td>-0.13**</td>
<td>0.021**</td>
<td>0.004**</td>
</tr>
<tr>
<td>(23)</td>
<td>(0.06)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
</tbody>
</table>

*Standard deviations are in parentheses.
**Significantly different from zero at the 5% level.
***Significantly different from zero at the 1% level.

Livestock inventory

Results for the livestock inventory equation are in Table 5. The livestock inventory equation for Israel does not have any coefficient significant at the 5% level. The Portuguese equation has one significant coefficient, but it is of the wrong sign. This may stem from the fact that the observations for Israel and Portugal were on a yearly rather than a quarterly basis. Quarterly observations on the size of the domestic livestock inventory in Japan and Spain had to be predicted from the exogenous variables. This procedure results in some error in estimated values of $L$, and this may have adversely affected the explanatory power of the livestock inventory equations for Japan and Spain.

The main intent of this study was to investigate the feed grain market in these six importing countries. Some of the livestock equations, especially the livestock inventory equation for some countries, suffered because of this objective. In some alternative models, the results for the livestock inventory equations were better, especially for Israel and Portugal, than the results in Table 5, but the import demand and domestic price of feed grains equations were worse than the equations in Tables 1 and 2. Variable deletions for reduced models were chosen to improve all six equations, but sometimes a variable deletion improved the fit for some equations and worsened the fit for other equations. The weight placed on improving the import demand and domestic price of feed grains equations was higher than the weight placed on improving the livestock equations.
Table 5. Estimated livestock inventory equations from final reduced models. (Dependent variable is L).

<table>
<thead>
<tr>
<th></th>
<th>Intercept</th>
<th>$P_D$</th>
<th>$P_L$</th>
<th>$P_{Dt-1}$</th>
<th>$P_{Lt-1}$</th>
<th>$P_D$</th>
<th>$P_{Ot-1}$</th>
<th>$P_W$</th>
<th>$P_{Wt-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece</td>
<td>2224</td>
<td>-50.9*</td>
<td>6.03**</td>
<td>25.2</td>
<td>2.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2011)</td>
<td>(17.4)</td>
<td>(1.85)</td>
<td>(17.7)</td>
<td>(2.16)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Israel</td>
<td>5025</td>
<td>2.11</td>
<td>3.54</td>
<td>15.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2516)</td>
<td>(16.79)</td>
<td>(3.18)</td>
<td>(20.01)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>91,211**</td>
<td>-4217**</td>
<td>45.0</td>
<td>-1799**</td>
<td>-67.4**</td>
<td>4859**</td>
<td>-2731a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(13,394)</td>
<td>(941)</td>
<td>(25.8)</td>
<td>(666)</td>
<td>(19.6)</td>
<td>(1082)</td>
<td>(1169)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>1546</td>
<td>2.62*</td>
<td>-0.82</td>
<td>0.31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2423)</td>
<td>(1.07)</td>
<td>(1.94)</td>
<td>(0.56)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>17,434**</td>
<td>-1.58*</td>
<td>--</td>
<td>2.34**</td>
<td>123**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(885)</td>
<td>(0.63)</td>
<td>(0.65)</td>
<td>(29)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.K.</td>
<td>21,769**</td>
<td>57.2**</td>
<td>670**</td>
<td>12.7</td>
<td>-582**</td>
<td>-305</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1414)</td>
<td>(19.3)</td>
<td>(195)</td>
<td>(17.1)</td>
<td>(144)</td>
<td>(203)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

aStandard deviations are in parentheses.
*Significantly different from zero at the 5% level.
**Significantly different from zero at the 1% level.

Demand-supply relationship for livestock

Table 6 presents the results of the demand-supply relationship for livestock. The coefficient for $Q_{PL}$ is positive and significantly different from zero at the 1% level for all countries.

Results for each country

The main intent of this section is to outline the experiments or variable eliminations that resulted in the final reduced model. A variable was not always deleted when its coefficient was not significant. Some variables are theoretically important enough that they are left in the final reduced form, though their coefficients may indicate that the variable should not be in. The best example is the price of feed grains in the import demand equation. Either $P_D$ or $P_{Dt-1}$ was kept in the import demand equation for each country, even though the coefficient may have a small absolute t-value. The same treatment was given to L in the import demand and both L and $(P/k)$ in the domestic price of feed grains equation.

After the final reduced models presented in this report were obtained, another model was estimated for each country. It was estimated in an effort to improve the equations for production of livestock products. It differed from the final reduced model only in the presence of a time trend variable in the production equation to account for trends in efficiency in livestock production. For each country, this model was inferior to the final reduced model. Adding the trend variable failed to improve the equations for feed grain imports and prices and resulted in inferior equations for the livestock sector.

Greece. The equations for feed grain imports and domestic price in the full Greek model seemed to be the equations that needed the most improvement. In the full model, the coefficient for $P_D$ in the import demand equation was significant at the 5% level but of the wrong sign. The first experiment was to examine the effects of deleting $P_D$ from the import demand equation. It was hoped that deleting $P_D$ would increase the explanatory power of $P_{Dt-1}$, which had a negative coefficient. The result of eliminating $P_D$ was that the coefficients for L, $(Y/N)$, and FE became significant at the 1% level, while the coefficient for $P_{Dt-1}$ turned nonsignificant.

If a variable elimination, or experiment, was judged successful, the variable was eliminated in in-
vestigating the effects of other variable eliminations. This procedure was followed for all countries. So it was decided to leave \( P \) out of the import demand equation.

The aim of the next experiment was to improve the equation for the domestic price of feed grains. \( I \) was deleted from this equation because the t-value on its coefficient was only 0.26. The result of deleting \( I \) was that the coefficients for \( P \) and \( (P/k) \) in the equation for the domestic price of feed grains were significant at the 1% level. The absolute t-values for other variables in the equation for the price of feed grains also increased, so \( I \) was kept out of the equation for the domestic price of feed grains.

\( P \) was deleted from the equation for the production of livestock products for the fourth computer run because the coefficient for \( P \) was of the correct sign, but its t-value was only -0.38. The result of dropping \( P \) was a slight improvement in the t-values in the equation for the production of livestock products.

Three other experiments were tried, but the results of the fourth computer run were judged the best. One of the experiments involved dropping \( P \) from the livestock inventory equation. This resulted in a smaller absolute t-value for the coefficient on \( L \) in the import demand equation and smaller absolute t-values for all coefficients in the equation for the domestic price of feed grain. Deleting \( P \) from the livestock inventory equation did cause the t-value of \( P \) to become significant at the 10% level though.

Deleting \( L \) from the livestock inventory equation was tried. This changed the sign of the coefficient for \( L \) in the import demand equation and also decreased the absolute t-value of the coefficient for \( P \) in the demand for livestock products. Eliminating \( L \) had little effect on the t-values of coefficients in the livestock inventory equation.

The final experiment involved deleting \( (Y/N) \) from the equation for the domestic price of feed grains. This deletion improved the t-values of the coefficients for other variables in the equation for the price of feed grains but also changed the sign of the coefficient for \( L \) in the import demand equation.

\( I \). The import demand equation in the full model for Israel had no significant coefficients. The first experiment was aimed at improving the import demand equation. \( P \) was deleted from this equation because its coefficient was positive. This did little to the t-values of coefficients in the import demand equation, but did increase the absolute t-values of the coefficients for \( P \) and \( (P/k) \) in the equation for the price of feed grains. Next, dropping \( (Y/N) \) from the import demand equation caused the absolute t-values of the coefficients in this equation to increase. The coefficients for \( L \) and \( FE \) turned significant at the 5% and 10% levels, respectively.

\( P \) was then eliminated from the equation for the production of livestock products because of its low t-value, -0.09. This experiment improved all t-values in the equation for the production of livestock products, turning the coefficient for \( P \) significant at the 1% level. The livestock inventory equation also was improved by the deletion.

\( L \) was then deleted from the equation for the price of feed grains because the coefficient was of the wrong sign. This experiment increased the absolute t-values of the coefficients of \( FE \) in the import demand equation and of \( P \) in the equation for the price of feed grains.

The final reduced model was then obtained by deleting \( P \) from the livestock inventory equation. Even though dropping \( P \) made the livestock inventory equation a bit worse, it increased the absolute t-values of coefficients of \( L \) in the import demand equation and of \( P \) in the equation for the price of feed grains.

Two other experiments were attempted but were judged unsuccessful. Dropping \( P \) and \( P \) from the livestock inventory equation failed to improve any equation while both experiments hurt the import demand equation and the equation for the domestic price of feed grains.

\( Japan \). The only experiment on the Japanese model was to leave \( FE \) out of the import demand equation. The coefficient for \( FE \) was of the incorrect sign in the full model. As a result of this elimination, the coefficients for \( P \) and \( (Y/N) \) in the import demand equation became significant at the 1% level. So the final reduced model for Japan has only one deletable variable, \( FE \).

\( Portugal \). The Portuguese import demand equation from the full model had no significant coefficients. The aim of the first experiment was to improve the import demand equation. \( P \) was dropped from the equation because of its incorrect sign. This deletion helped the t-values of all coefficients in the import demand equation and turned the coefficient for \( FE \) significant at the 1% level.

Because the t-value on the coefficient for \( I \) in the equation for the domestic price of feed grains was -0.01, \( I \) was dropped from that equation. The result was an increase in the absolute t-values on all other coefficients in the equation for the domestic price of feed grains, but there were still no significant coefficients at the 5% level. Next \( (Y/N) \) was dropped from the equation for the domestic price of feed grains. This turned the coefficient for \( P \) in the equation for the price of feed grains significant at the 10% level. The livestock inventory equation also improved, though no coefficients became significant at the 10% level.

After this second deletion, the coefficient for \( P \) in the equation for the production of livestock products had the lowest absolute t-value, -0.27. Therefore, \( P \)
was dropped from that equation. The result helps one to realize the sensitivity of autoregressive three-stage least squares estimates of this system to changes in equation structure. Almost every t-value in the whole system decreased in absolute size. Because of the interconnection of the six equations, changes in the specification of one equation can drastically change all six equations. The domestic price of feed grains, \( P_d \), was left in the equation for the production of livestock products despite its non-significant coefficient.

The final reduced model was obtained by deleting \( P_t \) from the livestock inventory equation. This deletion of \( P_t \) improved the t-values of all coefficients in the import demand equation. The coefficients for \( P_{d_t-1} \) and \( (Y/N) \) in the import demand equation became significantly different from zero at the 10% level. In general, t-values throughout the system were increased in absolute size.

Other experiments were performed after the final reduced model was obtained, but the results were judged less favorable than the final reduced model. \( P_{d_t}, P_{d_t-1}, \) and \( P_{d_t-2} \) were deleted from the livestock inventory equation one at a time, but these deletions hurt other equations, especially the import demand equation, without helping the livestock inventory equation. The final experiment was elimination of \( P_{d_t} \) from the equation for the domestic price of feed grains. This experiment decreased all the absolute t-values in the livestock inventory equation without helping the t-values in any other equation.

Spain. The first experiment performed on the full model for Spain was to delete FE from the import demand equation. The coefficient for FE in the import demand equation was negative, but not significant. The deletion increased the absolute t-values of coefficients throughout the system.

The second experiment was aimed at improving the livestock inventory equation. After the deletion of FE, two coefficients in the livestock inventory equation were not significant at the 5% level. Therefore, \( P_t \) was dropped from the livestock inventory equation. This deletion resulted in significant coefficients for all variables included in that equation.

The final experiment investigated the effects of deleting \( L \) from the import demand equation. The coefficient for \( L \) was negative, but not significant. Because dropping \( L \) from this equation slightly improved the t-values of the coefficients in the import demand equation, \( L \) was left out of the import demand equation.

United Kingdom. The first experiment for the United Kingdom was to delete \( P_t \) from the equation for the production of livestock products. The coefficient for \( P_t \) in that equation was of the incorrect sign and not significant. It was hoped that this deletion would help the t-values for \( P_d \) and \( P_{d_t-1} \) in the import demand equation, but its only effect was to increase the absolute t-values for \( P_t \) and \( L \) in the equation for livestock production.

\( P_{d_t-1} \) was then deleted from the import demand equation. This deletion turned the coefficient for \( L \) in the equation for the domestic price of feed grains significant at the 10% level and increased the absolute values of coefficients of \( P_d \) and \( D \) in the import demand equation though neither coefficient turned significant.

At this point, the t-value of the coefficient of \( P_w \) in the equation for the production of livestock products was -0.05. \( P_w \) was dropped from that equation. This deletion caused the coefficient for \( P_t \) in that same equation to be significant at the 5% level.

The next four experiments, dropping \( (Y/N) \) and \( D \) from the import demand equation, \( D \) from the equation for the domestic price of feed grains, and \( P_d \) from the livestock inventory equation, all helped t-values throughout the six-equation system. Dropping \( D \) as a predetermined variable for the system was the major reason that \( P_t \) turned significant at the 1% level in the import demand equation. Because of the results of these four experiments, all four variables were deleted in the final reduced model.

The culmination of these seven experiments on the system for the United Kingdom was the final reduced model. After one other experiment was tried, deleting \( P_{d_t-1} \) from the livestock inventory equation, it was decided that the seven successful deletions would form the final reduced model.

**IMPORTS OF U.S. FEED GRAINS**

The six countries that have been chosen for the study are discussed in this section. A short explanation of their import pattern is given, and a model to explain imports of U.S. feed grains also is given for each country. The focus is on barley, corn, and sorghum because relatively little rye or oats are traded internationally.

The general equation used to study a country's imports of a U.S. good \( G \) (in this study, the good is always a feed grain of some kind) is:

\[
(15) \quad CUSG = f(CG, USG, COSG)
\]

where \( CUSG \) is the quantity of good \( G \) imported by country \( C \) from the United States in period \( t \), \( CG \) is the total quantity of good \( G \) imported by country \( C \) in period \( t \), \( USG \) is the total quantity of good \( G \) available for export by the United States in period \( t \), and \( COSG \) is the quantity of good \( G \) available for export from other countries that compete with the United States in selling good \( G \) to importing country \( C \).

Because the United States is a supplier of the...
good to the country, if the country's imports increase, some of the increase is expected to come from the United States. As the amount of the good available for export by the United States increases, the amount of the good imported by the country from the United States is also expected to increase. If more of the U.S. good is available for export, the United States is expected to be able to supply more of the good to the importing country. As the amount of the good available for export by countries that compete with the United States increases, the importing country's imports of the U.S. good are expected to fall. More is available through other sources of supply, and it is likely that the importing country will take advantage of this.

For some countries, the United States is the main supplier of a particular feed grain. In this case, the export availability from the United States and its competitors is not important. What is important is the total quantity of the good imported by the country. For other countries, the United States is not a major supplier of a particular feed grain, and the availability of the good from the United States again is not important. The general model is eq. (15). The specific country models are adaptations of the general model.

These models were estimated with annual data. All variables used were collected from the FAO (1958d through 1976d), except the quantity of rice stocks in Japan. The variable used to reflect the export availability of feed grains by a certain feed grain exporter was the total quantity of exports by that country in the same period. The rice stocks at the beginning of the third quarter (July 1) were used as the observation because all the data collected for these models were on a trade-year basis.\(^{10}\) All feed grain quantities were measured in millions of metric tons, not in corn equivalents.

Greece

Greece imported more than 100,000 metric tons of feed grains in every year during the 1958/59-1973/74 period except in 1959/60. The average for the 1958/59-1973/74 period was 307,000 metric tons. Almost 90% of the feed grains imported during that period was corn. The United States supplied 89% of the feed grains imported during that period. In 1966/67 and 1971/72, Greece imported large amounts of corn from exporters other than the United States. In 1966/67 and 1971/72, the United States' share of the feed grains imported by Greece was less than 50%. In 1966/67, 1971/72, and possibly 1962/63, Greece probably imported feed grains from eastern European countries, such as Romania and Yugoslavia; 1966/67 and 1971/72 were years when Romania and Yugoslavia exported feed grains. Most other years, Romania and Yugoslavia imported feed grains. Greece has purchased over 96% of their feed grain imports from the United States if 1966/67, 1971/72, and 1962/63 are excluded.

Greece does import barley from France occasionally, but most barley imports come from the United States. All Greek imports of sorghum come from the United States. Table 7 shows Greek feed grain imports from 1958/59 to 1973/74.

Because Greece purchases such a large percentage of its imported feed grains from the United States, the equation used to study Greek imports of U.S. feed grains is:

\[
(16) \quad \text{GUSF} = g(GF)
\]

where GUSF is the quantity of Greek imports of U.S. feed grains in period t and GF is the quantity of total Greek feed grains imports in period t.

Israel

Israel is a big importer of feed grains. From 1958/59 to 1973/74 Israel averaged 607,000 metric tons of feed grain imports per year. Most of the feed grains imported were corn and sorghum. The United States supplies about 90% of the feed grains imported by Israel. From 1966/67 to the present, Israel has imported most of its barley from Canada. Canadian barley is the only significant competition that the United States faces in the Israeli feed grain import market.

The average Israeli consumed 412 eggs and 65.6 pounds of poultry meat in 1970 (USDA-FAS, 1972a). This is one reason that Israel has a large demand for imported feed grains. Because Israeli production of feed grains has not been increasing as fast as demand, imports have been increasing. Table 8 shows Israel feed grain imports from 1968/59 to 1973/74.

The equation used to explain imports of U.S. feed grains by Israel reflects the fact that Canadian

<table>
<thead>
<tr>
<th>Year</th>
<th>U.S.</th>
<th>U.S. % of total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958/59</td>
<td>100</td>
<td>79</td>
<td>128</td>
</tr>
<tr>
<td>1959/60</td>
<td>64</td>
<td>93</td>
<td>71</td>
</tr>
<tr>
<td>1960/61</td>
<td>162</td>
<td>99</td>
<td>164</td>
</tr>
<tr>
<td>1961/62</td>
<td>127</td>
<td>100</td>
<td>127</td>
</tr>
<tr>
<td>1962/63</td>
<td>154</td>
<td>83</td>
<td>186</td>
</tr>
<tr>
<td>1963/64</td>
<td>242</td>
<td>98</td>
<td>247</td>
</tr>
<tr>
<td>1964/65</td>
<td>298</td>
<td>97</td>
<td>307</td>
</tr>
<tr>
<td>1965/66</td>
<td>346</td>
<td>98</td>
<td>353</td>
</tr>
<tr>
<td>1966/67</td>
<td>137</td>
<td>49</td>
<td>189</td>
</tr>
<tr>
<td>1967/68</td>
<td>188</td>
<td>94</td>
<td>200</td>
</tr>
<tr>
<td>1968/69</td>
<td>290</td>
<td>95</td>
<td>305</td>
</tr>
<tr>
<td>1969/70</td>
<td>373</td>
<td>94</td>
<td>367</td>
</tr>
<tr>
<td>1970/71</td>
<td>191</td>
<td>100</td>
<td>191</td>
</tr>
<tr>
<td>1971/72</td>
<td>206</td>
<td>47</td>
<td>439</td>
</tr>
<tr>
<td>1972/73</td>
<td>431</td>
<td>100</td>
<td>431</td>
</tr>
<tr>
<td>1973/74</td>
<td>1,072</td>
<td>99</td>
<td>1,087</td>
</tr>
</tbody>
</table>

Source: FAO (1958d through 1976d)

10 The trade year begins on July 1 and ends on June 30.
where IUSO is the quantity of U.S. feed grains other than barley available for export in period t. Therefore, IB and IO were summed to form the total quantity of Israeli barley imports in period t, USB and USO were equal. The calculated F was 0.84, and this hypothesis could not be rejected. USB and USO were summed to obtain total U.S. exports of feed grains, USF. Because neither hypothesis was rejected, the equation that results from the tests is:

(20)  \[ \text{IUSF} = \beta_0 + \beta_1 \text{IF} + \beta_2 \text{USF} + \beta_3 \text{CB} \]

Estimates of eq. (20) obtained by the seemingly unrelated regressions (SUR) method will be presented in a later section entitled Seemingly Unrelated Results.

**Japan**

Japan imported more feed grains than did any other country during the 1958/59-1973/74 period. During that period, Japan averaged over 6.7 million metric tons of feed grain imports per year. Table 9 shows Japanese imports of feed grains by source from 1958/59 to 1973/74. Because Japan has little cultivable land relative to its population, little corn and sorghum is produced in Japan; virtually all corn and sorghum consumed in Japan is imported. Japan does produce large quantities of barley but not enough to satisfy domestic demand.

During the 1958/59-1973/74 period, the United States supplied 58% of Japan's feed grain imports. Competition for the Japanese market is rather stiff most of the time. One reason is that Japan is such a big market. Many exporting countries want a share of the Japanese market because Japan is consistently a heavy importer of feed grains. Another reason that competition is stiff is that the Japanese government is trying to diversify feed grain import sources, especially sources of corn and sorghum. By diversifying sources, Japan can reduce its reliance on the United States as a source of supply. Individual Japanese trading companies have started joint ventures in Thailand to provide technical and material assistance for feed grain production (USDA-FAS, 1969). Also, Japan can correct trade imbalances with some countries by diversifying feed grain imports.

Thailand has a trade imbalance with Japan. "Since the trade deficit with Japan accounts for as much as 60% of Thailand's total trade deficit, the

<table>
<thead>
<tr>
<th>Year</th>
<th>U.S.</th>
<th>Argentina</th>
<th>Thailand</th>
<th>Australia</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958/59</td>
<td>736</td>
<td>47</td>
<td>229</td>
<td>7</td>
<td>279</td>
<td>33</td>
</tr>
<tr>
<td>1959/60</td>
<td>258</td>
<td>19</td>
<td>421</td>
<td>224</td>
<td>43</td>
<td>49</td>
</tr>
<tr>
<td>1960/61</td>
<td>812</td>
<td>39</td>
<td>290</td>
<td>408</td>
<td>143</td>
<td>44</td>
</tr>
<tr>
<td>1961/62</td>
<td>1,163</td>
<td>47</td>
<td>182</td>
<td>7</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>1962/63</td>
<td>1,395</td>
<td>44</td>
<td>95</td>
<td>420</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>1963/64</td>
<td>2,511</td>
<td>51</td>
<td>133</td>
<td>7</td>
<td>126</td>
<td>5</td>
</tr>
<tr>
<td>1964/65</td>
<td>3,163</td>
<td>62</td>
<td>314</td>
<td>729</td>
<td>172</td>
<td>24</td>
</tr>
<tr>
<td>1965/66</td>
<td>4,433</td>
<td>76</td>
<td>152</td>
<td>776</td>
<td>32</td>
<td>12</td>
</tr>
<tr>
<td>1966/67</td>
<td>4,593</td>
<td>59</td>
<td>264</td>
<td>858</td>
<td>188</td>
<td>18</td>
</tr>
<tr>
<td>1967/68</td>
<td>4,294</td>
<td>55</td>
<td>97</td>
<td>631</td>
<td>102</td>
<td>10</td>
</tr>
<tr>
<td>1968/69</td>
<td>4,491</td>
<td>52</td>
<td>309</td>
<td>484</td>
<td>211</td>
<td>20</td>
</tr>
<tr>
<td>1969/70</td>
<td>6,460</td>
<td>65</td>
<td>1,612</td>
<td>7</td>
<td>273</td>
<td>19</td>
</tr>
<tr>
<td>1970/71</td>
<td>5,908</td>
<td>57</td>
<td>1,455</td>
<td>853</td>
<td>525</td>
<td>22</td>
</tr>
<tr>
<td>1971/72</td>
<td>3,835</td>
<td>38</td>
<td>1,156</td>
<td>1,002</td>
<td>1,260</td>
<td>35</td>
</tr>
<tr>
<td>1972/73</td>
<td>8,410</td>
<td>69</td>
<td>368</td>
<td>394</td>
<td>1,090</td>
<td>13</td>
</tr>
<tr>
<td>1973/74</td>
<td>10,226</td>
<td>71</td>
<td>643</td>
<td>927</td>
<td>1,277</td>
<td>20</td>
</tr>
</tbody>
</table>

Source: FAO (1958d through 1976d)
Thai government is making a particular effort to correct this part of the trade imbalance" (USDA-ERS-FDCD, 1972, p. 66). The Japanese have agreed to increase purchases of several Thai agricultural commodities, including corn. Since 1966/67, Thailand has had a corn agreement with Japan. The annual agreements usually call for 800,000 to 1,000,000 metric tons of Thai corn to be shipped to Japan during the year. The price used in these agreements usually is based on the price of U.S. no. 2 yellow corn on the Chicago futures market.

Traditional sources of imported corn for Japan are the United States, Thailand, and South Africa. Minor sources of corn for Japan are Argentina, Brazil, and Mexico. The equation that was used to study Japan's demand for U.S. corn is:

\[ (21) \quad JUSC = j_c (JC, USC, JTS, JMS, R) \]

where \( JUSC \) is the quantity of U.S. corn imported by Japan in period \( t \), \( JC \) is the total quantity of Japanese corn imports in period \( t \), \( USC \) is the quantity of U.S. corn available for export in period \( t \), \( JTS \) is the quantity of corn available for export by traditional suppliers to Japan other than the United States in period \( t \), and \( JMS \) is the quantity of corn available for export by minor suppliers to Japan in period \( t \). Because Japan wants to diversify its sources of corn supply, as the availability of corn from these non-U.S. sources increases, Japanese imports of U.S. corn are expected to fall. The quantity of rice stocks in Japan, \( R \), is included because rice may substitute for corn.

Japan obtains virtually all its sorghum from three sources: the United States, Argentina, and Australia. From 1958/59 to 1973/74, the United States supplied over two-thirds of Japan's sorghum imports. Australia has become a major source of Japanese sorghum imports since 1970/71. The equation that was used to study Japanese imports of U.S. sorghum is:

\[ (22) \quad JUSS = j_s (JS, USS, JOSS, R) \]

where \( JUSS \) is the quantity of U.S. sorghum imported by Japan in period \( t \), \( JS \) is the total quantity of Japanese sorghum imports in period \( t \), \( USS \) is the quantity of U.S. sorghum available for export in period \( t \), \( JOSS \) is the quantity of barley available for export by other Japanese sorghum suppliers (Argentina and Australia) in period \( t \).

Most of Japan's barley imports come from Canada, Australia, France, and the United States. Canada has been the largest and most consistent source of barley for Japan since 1958/59. The equation for the Japanese demand of U.S. barley is:

\[ (23) \quad JUSB = j_b (JB, USB, JOSB, R) \]

where \( JUSB \) is the quantity of U.S. barley imported by Japan in period \( t \), \( JB \) is the total quantity of Japanese barley imports in period \( t \), \( USB \) is the quantity of U.S. barley available for export in period \( t \), and \( JOSB \) is the quantity of barley available for export by other countries that export barley to Japan (France, Australia, and Canada) in period \( t \).

Rye and oat imports of Japan are extremely small relative to corn, barley, and sorghum imports. So the equation to explain U.S. rye and oat imports by Japan was a single equation. The Japanese demand for U.S. rye and oats is:

\[ (24) \quad JUSO = j_o (JO, R) \]

where \( JUSO \) is the quantity of U.S. rye and oats imported by Japan in period \( t \), and \( JO \) is the quantity of total rye and oat imports of Japan in period \( t \).

If \( JUSF \) is defined as

\[ JUSF = JUSC + JUSS + JUSB + JUSO \]

and if eqs. (21), (22), (23), and (24) are linear, they can be added to obtain a linear function for \( JUSF \):

\[ (25) \quad JUSF = j (JC, JS, JB, JO, USC, USS, USB, JTS, JMS, JOSS, JOSB, R) \]

where \( JUSF \) is the quantity of U.S. feed grains imported by Japan in period \( t \).

The coefficient of \( R \) in eq. (25) is the sum of the coefficients of \( R \) in eqs. (21) through (24). The United States has a different competitive position in each feed grain. If stockpiled rice tends to be substituted for barley, the quantity of Japanese rice stocks may have little effect on Japanese imports of U.S. feed grains because most of Japan's imported barley is from Canada. But if stockpiled rice tends to be substituted for sorghum or corn, the quantity of Japanese rice stocks may have a great effect on Japanese import of U.S. feed grains.

Equation (25) was estimated by OLS, and four hypotheses were tested. The first was that the coefficients on \( USC \), \( USS \), and \( USB \) were equal. The calculated \( F \) for this hypothesis was 0.43, which is not significant. The hypothesis could not be rejected, and \( USC \), \( USS \), and \( USB \) were added to form \( USF1 \).

The second hypothesis tested was that the coefficients of \( JTS \) and \( JMS \) were equal. The calculated \( F \) for this hypothesis was 0.57, which is not significant. \( JTS \) and \( JMS \) were summed to obtain \( JOCS \), exports of corn by Japanese suppliers other than the United States.

The third hypothesis was that the coefficients for \( JS \), \( JC \), \( JB \), and \( JO \) were equal. The calculated \( F \) was 0.81, which means that the hypothesis could not be rejected. Total Japanese imports of feed grains, \( JF \), were used as a variable instead of the separate variables on imports by type of feed grain.
The final hypothesis tested was that the coefficients for JOS, JOSS, and JOSB were equal. The calculated $F$ was only 0.09. Therefore, JOS, JOSS, and JOSB were added to form JOFS.

The Japanese equation that results from failing to reject the four hypotheses is:

$$ (26) \text{JUSF} = j(JF, USF1, JOFS, R) $$

The SUR estimate of eq. (26) is presented later.

### Portugal

Portugal increased its imports of feed grains from 29,000 metric tons in 1958/59 to 1,084,000 metric tons in 1973/74. That is an increase of 3,638% over 16 years. U.S. exports of feed grains to Portugal have increased from virtually zero in 1958/59 to 526,000 metric tons in 1973/74, as can be seen in Table 10. These astounding increases are two reasons that Portugal was included in this study. It will be interesting to see if the models can account for their occurrence. During the 1958/59-1973/74 period, Portugal imported 358,000 metric tons of feed grains, on average, per year. About 77% of the feed grains imported was com. Portugal has traditionally relied on two of its overseas states, Angola and Mozambique, to supply imported com. Because of Portugal's rapid increase in demand for corn and increased uses of corn in the two overseas states, Portugal has had to go to other sources for its imported corn. The United States has been the main source for these increased corn imports. South Africa and Argentina also supply corn to Portugal.

The Portuguese demand for U.S. corn that was used in the study is:

$$ (27) \text{PUSC} = p_c(\text{PC, CC, POC, USC}) $$

where PUSC is the quantity of U.S. corn imported by Portugal in period $t$, PC is the total amount of corn imported by Portugal in period $t$, CC is the amount of corn available for export by the two overseas colonial states of Portugal (Angola and Mozambique) in period $t$, POC is the quantity of corn available for export by other competitors of the United States (South Africa and Argentina) in period $t$, and USC is the amount of corn available for export by the United States in period $t$. Angola and Mozambique have been distinguished from South Africa and Argentina as suppliers. The reason is that South Africa and Argentina have only recently exported corn to Portugal, and Angola and Mozambique have exported corn to Portugal for a long time.

Portugal usually is self-sufficient in rye and oat production, but small amounts of barley and sorghum are imported. Because imports of other feed grains usually are small, all feed grains other than corn were included in a single equation:

$$ (28) \text{PUSO} = p_o(\text{PO}) $$

where PUSO is the quantity of U.S. feed grains other than corn imported by Portugal in period $t$ and PO is the total quantity of feed grains other than corn imported in period $t$.

Define PUSF = PUSC + PUSO. If eqs. (27) and (28) are linear, their sum also is a linear function.

$$ (29) \text{PUSF} = p(\text{PC, PO, CC, POC, USC}) $$

Equation (29) was estimated by OLS, and two hypotheses were tested. The first was that the coefficients for PC and PO were equal. The calculated $F$ for this hypothesis was 7.15, which is greater than the critical value of 4.84. PC and PO were left in the Portuguese equation separately because their coefficients are significantly different.

The second hypothesis was that coefficients for CC and POC were equal. The calculated $F$ was 0.55, which is not significant at the 5% level. So CC and POC were added to obtain PCS, corn exports of Portuguese corn suppliers other than the United States.

The Portuguese equation that results from the two hypothesis tests is:

$$ (30) \text{PUSF} = p(\text{PC, PO, PCS, USC}) $$

where PCS is the quantity of U.S. corn imported by Portugal in period $t$.

The SUR estimate of eq. (30) will be presented in the later section on Seemingly Unrelated Results.

### Spain

Spain is one of the leading feed grain importers in the world. It is also one of the best markets for U.S. corn. In the period 1958/59-1973/74, Spanish feed grain imports averaged more than 2.1 million metric tons per year. Forty-one percent of that total...
came from the United States. Spanish imports of feed grains have risen dramatically from 1958/59 when 221,000 metric tons were imported to 1973/74 when almost 4.3 million metric tons were imported. This can be seen in Table 11.

Because Spain is such a large market, competition is quite keen. Competition for corn import supplies to Spain, which account for about 81% of Spain’s total feed grain imports, comes from Argentina and France for the most part, but Mexico, Brazil, and South Africa are occasional or minor suppliers. The equation used to study Spanish imports of U.S. corn is:

\[
(31) \quad \text{SUSC} = \theta \cdot (SC, USC, STS, SMS)
\]

where SUSC is the quantity of U.S. corn imported by Spain in period t, SC is the total quantity of U.S. corn imported by Spain in period t, USC is the amount of U.S. corn available for export in period t, STS is the amount of corn available for export by traditional suppliers to Spain (Argentina and France) in period t, and SMS is the amount of corn available for export by minor suppliers to Spain (Brazil, Mexico, and South Africa) in period t.

The United States occasionally supplies sorghum and barley to Spain, but Spain’s chief source of sorghum imports is Argentina, and most of Spain’s imported barley is from France. So the United States is a minor supplier of feed grains other than corn for Spain. Therefore, all feed grains other than corn were included in a single equation for Spain:

\[
(32) \quad \text{SUSO} = \theta \cdot (SO, AS, FB, USNC)
\]

where SUSO is the quantity of U.S. feed grains other than corn imported by Spain in period t, SO is the total quantity of feed grains other than corn imported by Spain in period t, AS is the amount of Argentine sorghum available for export in period t, FB is the amount of French barley available for export in period t, and USNC is the amount of U.S. feed grains other than corn available for export in period t.

Define \(\text{SUSF} = \text{SUSC} + \text{SUSO}\). If eqs. (31) and (32) are linear, their sum also is linear.

\[
(33) \quad \text{SUSF} = s \cdot (SC, USC, STS, SMS, SO, AS, FB, USNC)
\]

Equation (33) was estimated by OLS, and four hypotheses were tested. The first was that the coefficients for SC and SO were equal. The calculated F for this test was only 0.41. SC and SO were summed, therefore, to form SF, total Spanish imports of feed grains. The second hypothesis was that the coefficients for STS and SMS were equal. The calculated F for this test was only 0.14, and STS and SMS were added to form the variable SCS. The third hypothesis was that the coefficients for SCS, AS, and FB were equal. The calculated F for this test was 1.57, which also is not significant. Therefore, SCS, AS, and FB were summed to obtain SFS, feed grain exports of other Spanish feed grain suppliers. The final hypothesis was the only hypothesis rejected for Spain. It was that the coefficients for USC and USNC were equal. The calculated F was 20.53, which is much greater than the critical value of 4.75. So USC and USNC remained in the equation separately.

The Spanish equation that results from failing to reject the first three hypotheses and rejecting the last hypothesis is:

\[
(34) \quad \text{SUSF} = s \cdot (SF, SFS, USC, USNC)
\]

The SUR estimate of eq. (34) is presented later.

### United Kingdom

The United Kingdom was the third leading importer of feed grains during the 1965/59-1973/74 period, behind Japan and Italy. The United Kingdom averaged more than 4.3 million metric tons of feed grain imports annually during that period. This can be seen in Table 12.

Table 12. United Kingdom imports of feed grains, 1958/59 to 1973/74 (in thousands of metric tons).

<table>
<thead>
<tr>
<th>Year</th>
<th>U.S.</th>
<th>Argen­ tina</th>
<th>Aus­ tralia</th>
<th>France</th>
<th>Canada</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958/59</td>
<td>2,399</td>
<td>300</td>
<td>221</td>
<td>37</td>
<td>1,159</td>
<td>35</td>
<td>4,885</td>
</tr>
<tr>
<td>1959/60</td>
<td>2,396</td>
<td>31</td>
<td>434</td>
<td>181</td>
<td>72</td>
<td>690</td>
<td>29</td>
</tr>
<tr>
<td>1960/61</td>
<td>2,193</td>
<td>49</td>
<td>194</td>
<td>214</td>
<td>309</td>
<td>248</td>
<td>21</td>
</tr>
<tr>
<td>1961/62</td>
<td>2,589</td>
<td>50</td>
<td>310</td>
<td>233</td>
<td>171</td>
<td>175</td>
<td>17</td>
</tr>
<tr>
<td>1962/63</td>
<td>2,030</td>
<td>43</td>
<td>430</td>
<td>130</td>
<td>15</td>
<td>157</td>
<td>12</td>
</tr>
<tr>
<td>1963/64</td>
<td>1,899</td>
<td>50</td>
<td>190</td>
<td>109</td>
<td>130</td>
<td>241</td>
<td>36</td>
</tr>
<tr>
<td>1964/65</td>
<td>1,804</td>
<td>46</td>
<td>233</td>
<td>51</td>
<td>30</td>
<td>206</td>
<td>12</td>
</tr>
<tr>
<td>1965/66</td>
<td>2,547</td>
<td>60</td>
<td>97</td>
<td>52</td>
<td>16</td>
<td>127</td>
<td>7</td>
</tr>
<tr>
<td>1966/67</td>
<td>1,954</td>
<td>67</td>
<td>342</td>
<td>42</td>
<td>275</td>
<td>213</td>
<td>21</td>
</tr>
<tr>
<td>1967/68</td>
<td>1,644</td>
<td>40</td>
<td>44</td>
<td>11</td>
<td>106</td>
<td>63</td>
<td>6</td>
</tr>
<tr>
<td>1968/69</td>
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<td>265</td>
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<td>1970/71</td>
<td>1,328</td>
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<td>277</td>
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<td>370</td>
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<td>1971/72</td>
<td>1,290</td>
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<td>255</td>
<td>139</td>
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<td>1972/73</td>
<td>1,600</td>
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<td>322</td>
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<tr>
<td>1973/74</td>
<td>1,258</td>
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<td>219</td>
<td>54</td>
<td>1,465</td>
<td>60</td>
<td>42</td>
</tr>
</tbody>
</table>

Source: FAO (1958d through 1976d)
States supplied 44% of the feed grains imported by the United Kingdom. The United Kingdom imports large amounts of corn and substantial amounts of barley and sorghum.

The United States is the main supplier of corn to the United Kingdom, but South Africa also exports a lot of corn to the United Kingdom, and Argentina and France export small amounts of corn to the United Kingdom. The equation that was used to study the United Kingdom’s imports of U.S. corn is:

\[(35) \text{BUSC} = h_1(\text{BC, USC, BTS, BMS})\]

where BUSC is the quantity of U.S. corn imported by the United Kingdom in period t, BC is the total quantity of corn imported by the United Kingdom in period t, USC is the quantity of U.S. corn available for export in period t, BTS is the quantity of corn available for export by traditional British suppliers (South Africa) in period t, and BMS is the quantity of corn available for export by minor British suppliers (Argentina and France) in period t.

Most sorghum imports of the United Kingdom originate from Argentina and the United States. The United Kingdom has not been a big sorghum importer during the 1958/59-1973/74 period, but imports were rather large in the early years of the period. The equation that was used to study the United Kingdom’s imports of U.S. sorghum is:

\[(36) \text{BUSS} = h_2(\text{BS, USS, AS})\]

where BUSS is the quantity of U.S. sorghum imported by the United Kingdom in period t, BS is the total quantity of sorghum imported by the United Kingdom in period t, USS is the quantity of U.S. sorghum available for export in period t, and AS is the quantity of Argentine sorghum available for export in period t.

The United Kingdom does import a little barley in most years, but the U.S. share of British barley imports is small. The United Kingdom gets most of its barley from Canada. Both Australia and France export more barley to the United Kingdom than does the United States. So barley, oats, and rye were grouped together because U.S. exports of these goods to the United Kingdom are so small. The equation that was used to study British imports of U.S. barley, oats, and rye is:

\[(37) \text{BUSO} = h_3(\text{BO})\]

where BUSO is the quantity of U.S. barley, rye, and oats imported by the United Kingdom in period t, and BO is the total quantity of British barley, rye, and oat imports in period t.

Define \(\text{BUSF} = \text{BUSC} + \text{BUSS} + \text{BUSO}\). If eqs. (35), (36), and (37) are linear, their sum also is linear.

\[(38) \text{BUSF} = b(\text{BC, USC, BTS, BMS, BS, USS, AS, BO})\]

Equation (38) was estimated by OLS, and four hypotheses were tested. The first was that the coefficients for BC, BS, and BO were equal. The calculated F from the hypothesis was 1.22, which is not significant, and BC, BS, and BO were summed to form BF, total British imports of feed grains.

The second hypothesis was that the coefficients for BTS and BMS were equal. The calculated F from this hypothesis was only 0.50. BTS and BMS were added to form BCS, corn exports of British corn suppliers. The third hypothesis was that the coefficients for BCS and AS were equal. The calculated F for this test was only 0.80. BCS and AS were added to form BFS, feed grain exports of British corn suppliers.

The final hypothesis was that the coefficients for USC and USS were equal. The calculated F for this test was 3.58, which is less than the critical value of 4.96. The hypothesis cannot be rejected, and USS and USC were summed to form USF2.

The equation for the United Kingdom obtained by failing to reject the four hypotheses is:

\[(39) \text{BUSF} = b(\text{BF, BFS, USF2})\]

**Seemingly Unrelated Results**

Disturbance (or error) terms in eqs. (16), (20), (26), (30), (34), and (39) may be correlated. For example, when estimated U.S. feed grain exports to the United Kingdom are low, estimated U.S. feed grain exports to Japan may tend to be systematically low (or high). Because disturbance terms among various equations may be correlated, the Aitken generalized least-squares method (also called the seemingly unrelated regressions method) was used to estimate these equations. A stepwise seemingly unrelated regression procedure was used. At each step, the variable with the lowest absolute t-value was deleted. The first variable deleted was USF from the Israeli equation. The other deletions in order were: USC from the Portuguese equation, PO from the Portuguese equation, USF2 from the British equation, CB from the Israeli equation, PFGS from the Portuguese equation, and USNC from the Spanish equation. In the final reduced model, all significant coefficients were of the correct sign. Every coefficient that was significantly different from zero at the 5% level in the final reduced model also was significantly different from zero at the 5% level in the full model. So the variable deletions from the full model to the final reduced model failed to
change any coefficients from nonsignificant to significant. Remaining variables were significant. Estimated equations, with standard errors in parentheses, are:

\[ \text{GUSF} = -29.1 + 0.99 \text{GF} \]  
\[ (26.3) (0.07) \]

\[ \text{IUSF} = 83.0 + 0.69 \text{IF} \]  
\[ (21.4) (0.03) \]

\[ \text{JUSF} = 102.3 + 0.87 \text{JF} + 0.07 \text{USF} \text{I} \]  
\[ (272.3) (0.06) (0.02) \]

\[ + 0.31 \text{JOFS} + 0.14 \text{R} \]  
\[ (0.04) (0.05) \]

\[ \text{PUSF} = -52.4 + 0.71 \text{PC} \]  
\[ (24.8) (0.06) \]

\[ \text{SUSF} = 129.7 + 0.35 \text{SF} + 0.09 \text{USC} - 0.12 \text{SES} \]  
\[ (81.1) (0.05) (0.01) (0.01) \]

\[ \text{BUSF} = 39.6 + 0.58 \text{BF} - 0.08 \text{BFS} \]  
\[ (574.2) (0.08) (0.02) \]

The coefficients for the imports of feed grains by importing country range from 0.35 for Spain to 0.99 for Greece. If Greece increases its imports of feed grains, 99% of the increase comes from the United States, other things equal. If 100 extra tons of U.S. corn are available for exports, as measured by actual U.S. corn exports, 7 tons would go to Japan and 9 tons would go to Spain, other things equal. If 100 extra tons of Argentine corn were available for export, as measured by actual Argentine corn exports, U.S. feed exports to Japan, Spain, and the United Kingdom would fall by 31, 12, and 8 tons, respectively. All coefficients in the equations are significantly different from zero, of the correct sign, and are of reasonable magnitude.

The results from the Japanese model for total imports showed that, as R increased, feed grain imports decreased. The coefficient for R in the Japanese equation for U.S. feed grain imports is significantly greater than zero, indicating that, as R increased, feed grain imports from the United States increased. These results suggest that feed grains in which the United States has a strong competitive position in the Japanese market are complements with, rather than substitutes for, rice.

**CONCLUSIONS**

For five of six countries studied, domestic feed grains price differed systematically from the cost of imported feed grains measured in the importing country’s domestic currency. The cost of imported feed grains, which incorporated ocean transportation costs and exchange rate, was significant in the domestic price of feed grains equation for four countries. The coefficient for the cost of imported feed grains was significantly less than 1 for five countries. These importing countries follow domestic policies that insulate domestic feed grain prices from fluctuations in world feed grain prices. Because imports depend on domestic prices, it follows that the "world price" or cost of importing feed grains is not the most appropriate price to include in import demand equations for feed grains.

The findings of this study on effects of feed grain prices on feed grain imports contrast to the earlier results of Mitchell (1976) and Abbott (1979) who found feed grain imports to be unresponsive to changes in feed grain prices. We hypothesize that the differences are due to different treatments of feed grain prices. (a) This study differentiates domestic price (Pd) from world price or cost of imports (P/k), allows fluctuations in exchange rates to affect cost of imports, and uses Pd in import demand equations. (b) In this study, domestic feed grain prices are endogenous. They are affected by feed grain imports, as well as having an effect upon feed grain imports. (c) Finally, transportation costs affect cost of imported feed grains in this study.

Feed grain markets are affected by developments in foreign exchange markets. Foreign exchange earnings affect feed grain imports of Greece, Israel, Portugal, and the United Kingdom. Variations in exchange rates affect cost of imports, and this cost affects domestic price and volume of imports in Greece, Israel, Spain, and the United Kingdom. In Israel, Spain, and the United Kingdom, feed grain imports and domestic feed grain prices influence each other.

The previous conclusions can be summarized by the statement: Inclusion of foreign trade barriers, foreign exchange rates, and transportation costs improves econometric models of international trade in feed grains.

Results of this study confirm previous findings concerning the effects of a nation’s livestock sector upon feed grain imports. This study also finds that the livestock sector is not an exogenous determinant of feed grain prices and imports. Feed grain markets affect the livestock sectors. In Greece, Japan, and the United Kingdom, livestock inventories affect feed grain imports, and feed grain imports affect livestock inventories. Also, in Japan, feed grain prices affect livestock production; and in the United Kingdom, feed grain imports affect feed grain prices, which affect livestock inventories. In Portugal, livestock inventories affect feed grain prices, and feed grain prices affect livestock inventories. In

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11 \( \hat{\rho} \) for the U.K. equation was significantly different from zero at the 5% level, so the procedure used to correct for autocorrelated errors was applied to the U.K. equation.
Spain, feed grain prices affect feed grain imports and livestock inventory, and livestock inventory affects feed grain prices. Israel was the only country studied in which no statistically significant evidence was found of effects of feed grain prices or imports on the domestic livestock economy.

The main variables affecting Greek and Israeli imports of U.S. feed grains were total Greek and Israeli imports of feed grains. The main determinants of Japanese imports of U.S. feed grains were total Japanese imports of feed grains, availability of U.S. feed grains for export, availability of feed grains from other suppliers of Japan, and Japanese rice stocks. The only variable that had a significant influence on Portuguese imports of U.S. feed grains was total Portuguese imports of corn. Spanish imports of U.S. feed grains were influenced by total Spanish imports of feed grains, availability of feed grains from other suppliers, and availability of corn from the United States. Imports by the United Kingdom of U.S. feed grains were affected by total U.K. imports of feed grains and availability of feed grains from other sources.

LIMITATIONS

The biggest problem encountered in this study was nonexistence of data. The aggregation procedures used to form the quantity of livestock products produced, Q, and the size of the domestic livestock inventory, L, needed data on the consumption of feed grains by each type of livestock. The only figures that were available were consumption of concentrated feed by type of livestock. It was assumed that concentrated feed consumption by a particular type of livestock reflected feed grain consumption by that same type of livestock. But feed grains are not the only ingredients in concentrated feeds. Alfalfa, milling by-products, many types of meal, and other substances are also ingredients in concentrated feed. Changes in the content of concentrated feed would cause changes in the relationship between concentrated feed consumption and feed grain consumption.

Ocean transportation rates were available for the United Kingdom and Japan, and other transportation rates were calculated from the U.K. rates. Transportation rates vary widely because of backhaul rates, size of vessels that carry the grain, and other factors. Unfortunately, there was no way to obtain the actual ocean transportation rates for Greece, Israel, Portugal, and Spain.

Many quarterly observations needed for the quarterly models were unavailable. The size of the domestic livestock inventory for Spain and Japan was estimated from the predetermined variables of the simultaneous system. It is very possible that the true inventory figures would perform better in the model. Other missing quarterly observations were determined by various methods. These missing-value procedures are imperfect substitutes for knowledge of the actual values of the variables.

Another data problem is the accuracy of the figures reported in the publications cited. Sometimes, the FAO figures and the figures reported by various government agencies of a country were not the same for the same variable. In cases where figures did not match, the differences were small, but it raises some doubt about the accuracy of the compilations and how consistent each source is. Unfortunately, it was not possible to obtain all the data needed for the study from one source. Therefore, it may have been more appropriate to use an errors-in-variables model rather than the autoregressive 3SLS model and seemingly unrelated regressions model.

The variable used to measure the amount of foreign exchange available was the value of exports for the country. There are many other variables that could be used to measure FE. One could argue that the stock of foreign exchange holdings should be used as the measure of FE. Another possibility is to use the total outflow of the country’s currency (other than for importation of feed grains) at time t to measure FE. These other measures may have performed better than the value of exports by the country. But for this study, FE was measured by the value of exports. In addition, the FAO (1958b through 1976b) states that the government of the United Kingdom holds no stocks of feed grains. Therefore, the structure whereby FE influences U.K. feed grain imports may be incorrect.

There is a question as to the appropriate way to measure transportation costs. Volume and costs of imports do depend upon transportation costs. But the transportation cost from U.S. ports may not be the most appropriate or representative measure.

Multicollinearity, correlation between right-hand-side variables in an equation, could be a problem with the results. The full model for each country had problems with multicollinearity because of the existence of both current and lagged prices in the same equation. It is possible that serious multicollinearity is present in the final reduced models, too.

Many of the assumptions needed to obtain data in this study would not be needed in a study of western European countries because they have a wealth of information on variables needed for this study. But the European Economic Community (EEC) would need to be treated as a single entity, and this would introduce another dimension. The EEC probably does not satisfy the international trade small-country assumption, which this study uses. The government utility function and the equa-
tion for domestic price of feed grains may, however, accurately portray the EEC variable levy system.

The equations in the models for imports of U.S. feed grains have two underlying assumptions that may not fit the situation in each importing country. It is assumed that trade barriers on imported U.S. feed grains by the country are the same as trade barriers on feed grains from other exporting countries. For instance, trade barriers on U.S. corn are assumed to be the same as trade barriers on Argentine corn in all the countries studied. The equations cannot capture the effects of different trade barriers for different countries of origin. Another assumption behind these equations is that the importing country does not distinguish feed grains by country of origin. Therefore, corn of given characteristics from the United States is a perfect substitute for corn with the same characteristics from any other country.

This study suffered from problems common to many studies in economics. The analysis is partial equilibrium, while the world economy is more likely general equilibrium in nature. The feed grain and livestock sectors of the importing country are modeled, but other sectors that probably affect the feed grain sector are disregarded. Soybeans, wheat, and other crops can be substituted for feed grains on the supply side. Some substitution for feed grains can occur on the demand side, too, but the analysis does not incorporate these possible substitution effects. The price of wheat is incorporated in the livestock sector for the United Kingdom but not in the feed grain sector.

Feeding of concentrates to livestock is not nearly as widespread in Greece, Israel, Portugal, and Spain as in the United States. Alfalfa and hay are major factors in the maintenance of livestock inventories and production of livestock products, so substitution between feed grains and these nonconcentrated feeds is a possibility. The same substitution probably occurs in the United Kingdom and Japan, but to a lesser extent because of their developed livestock industries.

For these reasons, the scope of the model is too narrow, but the scope also can be considered too broad. If individual feed grains were modeled instead of feed grains in general, the cross-price elasticities between feed grains could explain much about the importing pattern of feed grains for a particular country. If individual feed grains are studied separately, the effects of other variables could also be different. It is possible that some feed grains are used primarily in the livestock industry (e.g., corn) while others are used primarily for direct consumption by humans (e.g., barley for brewing beer). So a change in the size of the livestock inventory could have little effect on the demand for barley but a great effect on the demand for corn.

This same idea can be applied to the livestock sector of each country. Allowing for substitution among livestock and livestock products might do much to explain the livestock industry of the countries. But these substitution effects are lost when aggregate variables are used.

REFERENCES


### Table A-1. Estimates of $p$ and coefficients for seasonal dummies in import demand equations from final reduced models. (The dependent variable is $I_p$).

<table>
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<th>$D_3$</th>
<th>$p$</th>
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</thead>
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<td>Greece</td>
<td>-0.13</td>
<td>(0.23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Israel</td>
<td>0.32</td>
<td>(0.22)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>$368^{**}$</td>
<td>1</td>
<td>$-112^*$</td>
<td>0.34**</td>
</tr>
<tr>
<td></td>
<td>(34)</td>
<td>(48)</td>
<td>(52)</td>
<td>(0.11)</td>
</tr>
<tr>
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<td>-0.39</td>
<td></td>
<td></td>
<td></td>
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<td>Spain</td>
<td>$-17$</td>
<td>85**</td>
<td>$-53$</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>(43)</td>
<td>(41)</td>
<td>(45)</td>
<td>(0.13)</td>
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*aStandard deviations are in parentheses
*bSignificantly different from zero at the 5% level
**Significantly different from zero at the 1% level

### Table A-2. Estimates of $p$ and coefficients for seasonal dummies in equations for the domestic prices of feed grains from final reduced models. (The dependent variable is $P_p$).

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<td>Israel</td>
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<tr>
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<td>(0.26)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>$-64^*$</td>
<td>8</td>
<td>$88^{**}$</td>
<td>0.25*</td>
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<tr>
<td></td>
<td>(31)</td>
<td>(32)</td>
<td>(31)</td>
<td>(0.11)</td>
</tr>
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<td>U.K.</td>
<td>0.32*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*aStandard deviations are in parentheses
*bSignificantly different from zero at the 5% level
**Significantly different from zero at the 1% level

### Table A-3. Estimates of $p$ and coefficients for seasonal dummies in equations for the production of livestock products from final reduced models. (The dependent variable is $D_p$).

<table>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.23)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Israel</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.23)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
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<td>14</td>
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<tr>
<td></td>
<td>(11)</td>
<td>(11)</td>
<td>(11)</td>
<td>(0.12)</td>
</tr>
<tr>
<td>Portugal</td>
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<tr>
<td></td>
<td>(0.23)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>22</td>
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<td>$-62^{**}$</td>
<td>0.37**</td>
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<tr>
<td></td>
<td>(12)</td>
<td>(12)</td>
<td>(10)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>U.K.</td>
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<td>$-14.8^{**}$</td>
<td>25.3**</td>
<td>0.18</td>
</tr>
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<td></td>
<td>(3.6)</td>
<td>(3.5)</td>
<td>(3.6)</td>
<td>(0.12)</td>
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*aStandard deviations are in parentheses
**Significantly different from zero at the 5% level

### Table A-4. Estimates of $p$ and coefficients for seasonal dummies in equations for demand for livestock products from final reduced models. (The dependent variable is $D_p$).

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</tr>
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<td></td>
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<tr>
<td>Japan</td>
<td>$-12$</td>
<td>49**</td>
<td>10</td>
<td>0.20</td>
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<tr>
<td></td>
<td>(13)</td>
<td>(13)</td>
<td>(13)</td>
<td>(0.12)</td>
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<td>Spain</td>
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<td>3</td>
<td>$-43^{**}$</td>
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<td></td>
<td>(12)</td>
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<td>U.K.</td>
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*aStandard deviations are in parentheses
*bSignificantly different from zero at the 5% level
**Significantly different from zero at the 1% level

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998
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<td></td>
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<td>-223</td>
<td>-396</td>
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<td>0.53**</td>
</tr>
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<td></td>
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<td>(380)</td>
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<td>1325*</td>
<td>889</td>
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<td>(722)</td>
<td>(527)</td>
<td>(613)</td>
<td>(0.11)</td>
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*aStandard deviations are in parentheses
*bSignificantly different from zero at the 5% level
**Significantly different from zero at the 1% level

<table>
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<th>$D_2$</th>
<th>$D_3$</th>
<th>$\rho$</th>
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<td>(15.0)</td>
<td>(16.4)</td>
<td>(0.11)</td>
</tr>
</tbody>
</table>

*aStandard deviations are in parentheses
*bSignificantly different from zero at the 5% level
**Significantly different from zero at the 1% level
The Experiment Station conducts its programs without discrimination as to race, color, sex, or national origin.