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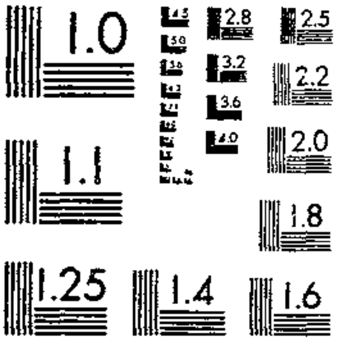

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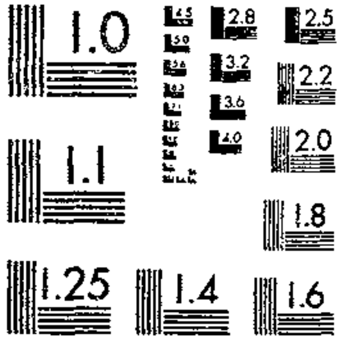

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United States
Department of
Agriculture

Economics
and Statistics
Service

Technical
Bulletin
No. 1644

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An Econometric Investigation

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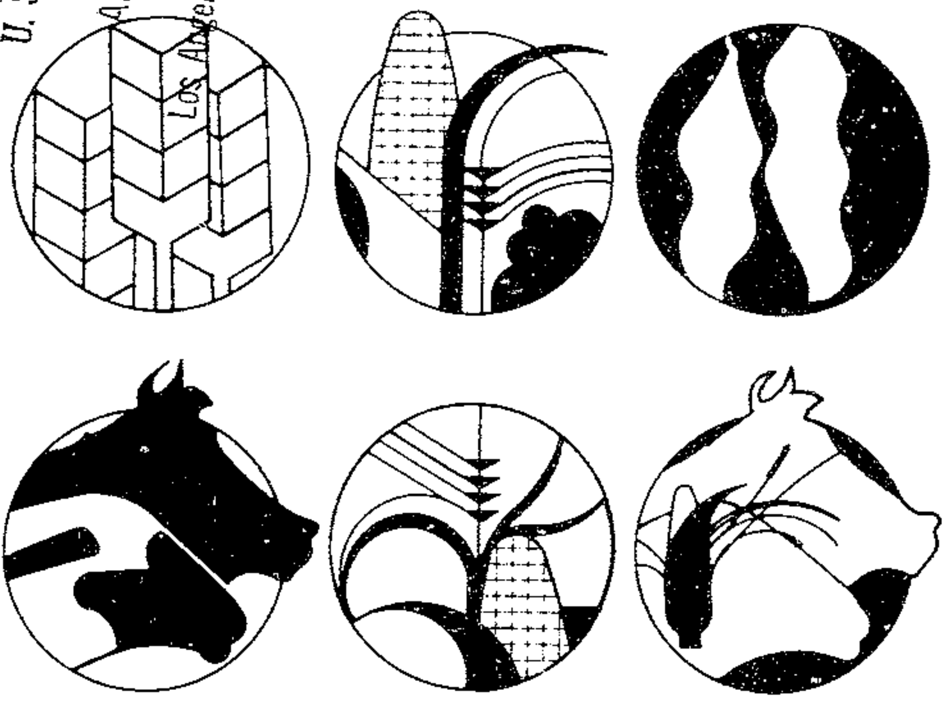

The U.S. Wheat Economy In An International Setting: An Econometric Investigation

Paul Gallagher
Michael Lancaster
Maury Bredahl
Timothy J. Ryan*

*The authors were formerly with the Economics and Statistics Service of the U.S. Department of Agriculture. Paul Gallagher is currently a research associate with the Department of Agricultural and Applied Economics at the University of Minnesota. Michael Lancaster is a research associate with Transportation and Economic Research Associates in Alexandria, Va. Maury Bredahl is an assistant professor in the Department of Agricultural Economics at the University of Missouri-Columbia. Timothy J. Ryan is an agricultural economist with the Department of Agriculture in Victoria, Australia.

Preface

This study is designed to aid outlook specialists, Government policy analysts, and students of agricultural commodity analysis. The research follows a U.S. Department of Agriculture (USDA) tradition of econometric analysis that began with K. Meinken's 1955 study of the U.S. wheat market; it was continued by the Economic Research Service during most of the seventies. Currently, this research is supported by the National Economics Division of the Economics and Statistics Service.

The authors acknowledge the support of numerous people at USDA and the University of Minnesota who provided financial assistance and technical advice. The authors are especially grateful to James Houck, Mary Ryan, Abner Womack, Jimmy Matthews, Rod Kite, and Bob Green for reading early versions of the report and offering many valuable suggestions.

The U.S. Wheat Economy In An International Setting: An Econometric Investigation; by Paul Gallagher, Michael Lancaster, Maury Bredahl, and Timothy J. Ryan; National Economics Division; Economics and Statistics Service; U.S. Department of Agriculture. Technical Bulletin No. 1 6 4 4.

Abstract

This bulletin presents an annual econometric model of the U.S. wheat economy. The research is part of a series on models for the major U.S. field crops; the goal is to provide forecasting and policy analysis tools of ultimate use for policy purposes. Prices for sorghum, a major competitor in the domestic wheat-feed industry, affect wheat supplies, domestic demand. and foreign demand. Rising incomes in less developed countries encourage purchases of U.S. wheat, but income growth in Japan and Western Europe reduces purchases. U.S. Government policy options for exportable wheat- -food aid, exports to centrally planned countries, or Government stock ownership—have significantly different influences on wheat prices.

Keywords: Wheat industry, Econometric analysis, Price formation, Domestic markets, International trade, Policy analysis

Washington, D.C. 20250 March 1981

Contents

Summary

This econometric model examines the impact of market forces and Government policies on the U.S. wheat economy. Groups of equations describe behavior in production, inventory, and domestic and foreign consumption sectors.

Shortrun fluctuations in market conditions cause little adjustment in domestic wheat consumption; the adjustments that do occur are in wheat feeding. The relationship between world wheat prices and the purchases of less developed countries (LDC's) from the United States suggests that adjustments in foreign consumption and purchases from the United States help to stabilize world prices. However, such adjustments do not occur in Japan and Western Europe because their governments set domestic prices.

In the long run, income growth in foreign countries alters the trade patterns for wheat. Rising incomes in LDC's encourage wheat purchases from the United States whereas income growth in Japan and Western Europe reduces such purchases. On balance, income and population growth worldwide will probably increase demand for U.S. wheat. However, expanding foreign demand would not necessarily lead to a period of rising U.S. wheat prices. U.S. growers would increase their production dramatically, holding prices relatively stable.

Wheat competes for acreage domestically chiefly with sorghum, barley, and cotton. Rice and feed grains (corn, sorghum, barley, and oats) are important competitors in foreign demand markets. Prices for sorghum, a major competitor in the domestic wheat-feed industry, influence wheat supplies and domestic and foreign demand for wheat.

The U.S. Government influences commodity prices through acreage, food aid, and export subsidy programs during periods of moderate surpluses and becomes the residual holder of wheat when supplies are abundant. Government policies during moderate surplus periods bring buoyant domestic prices and fairly normal marketing of wheat. With a large surplus, prices fall to loan rates; in this situation,-U.S. policies to reduce supply or expand demand generally result in a reduction of Government stocks. The choice of outlet for exportable wheat—food aid, exports to centrally planned countries, or Government stock ownership—has a significant influence on wheat prices. Increasing P.L. 480 shipments, for example, pushes up domestic wheat prices about half as much as would an equal increase in exports to centrally planned counties.

The model also provides information on adjustments that occur in the U.S. wheat economy whether the changes are (1) in the market prospects for crops competing with wheat, (2) fluctuations in shortrun market conditions. or (3) longrun shifts in supply and demand conditions.

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Introduction

Formulating an econometric model of the U.S. wheat economy in the seventies is the objective of our study. The tradition for such investigations of the U.S. wheat economy by the U.S. Department of Agriculture (USDA) began with Meinken's study in 1955 (*25*)[1] and has continued to the present (*1*, *12*, *15*, *26*). But the economic environment of the seventies merits special investigation; in that period, the U.S. wheat economy alternated between surplus and shortage. Surpluses result in Government policies intended to reduce wheat supplies, build stocks, and expand exports. Shortages bring demand for price ceilings and export embargoes; supply-reducing controls lie dormant as market forces determine price and utilization. Therefore, an econometric model appropriate for the U.S. wheat economy must be capable of representing free market periods as well as years when supply-reducing Government policies influence price formation.

Because the United States is part of the world wheat economy, we need to consider those forces that affect the large and volatile commercial export market and food aid shipments. Several authors have employed world spatial equilibrium models to study the interdependencies among geographic regions (*29*, *31*, *33*). However, when one wants to focus on the U.S. domestic market, it is cumbersome to analyze large world models, as they typically do not provide a detailed view of the U.S. economy. Therefore, in this study, we will analyze the rest of the world only to determine what major forces affect U.S. wheat exports. We will employ regional export relationships based on foreign supplies, demand competition among grains, and export policies of the United States and major wheat importers.

[1] Italicized numbers in parentheses refer to items listed in the references at the end of this report.

An Economic And Institutional Setting

The major economic causes of surplus during the fifties and sixties were steadily increasing yields, brought about by technological change, coupled with stagnant or declining domestic and foreign markets. In the early seventies, yield growth ceased, foreign demand surged to unprecedented levels, and prices rose. By 1977, however, planted area had increased far beyond levels earlier in the decade, prices had fallen, and surplus conditions had returned. The Government has influenced prices through acreage restrictions, food aid, and export subsidies during moderate surpluses. It has held wheat and supported prices when supplies have been more abundant.

In this section, we describe sets of factors that have influenced wheat price formation since World War II. The economic forces that have contributed to the surpluses and more recent shortages represent one set of factors. Another set is the array of Government policies to control supply, demand, and price in surplus periods. The policy review is a cursory summary of the Government's role in wheat price formation.[2] Because these economic and policy factors influence the wheat market, they form the basis of a realistic econometric model.

Surplus And Shortage In Markets With Price Supports

The existence of surplus and shortage is at odds with the usual notion of economic equilibrium; by definition, neither condition exists at equilibrium. With appropriate modification, however, this terminology is still useful in analyzing agricultural commodities that are subject to price supports. Our intention here is to show how the system of commodity loan. in U.S. agriculture leads to economic circumstances in which the concepts of surplus and shortage can apply. Then we show that, with sufficient qualifications, surplus and shortage periods can be identified by examining market and Government support price data.

The Agricultural Adjustment Act of 1933 introduced price support programs for many farm commodities. These provisions have been altered over the years, most recently by the Food and Agriculture Act of 1977. Despite changing rules, the basic objectives remain. The price support program guarantees farmers (1) a minimum return on production and

[2] For more extensive reviews, see (*3*) or (*10*).

(2) access to liquid capital on terms that may be more attractive than those provided by the private sector. In effect, the changes in the 1977 act delay the possibility of Government grain ownership by setting up a subsidized, farmer-owned, 3-year storage program. Nonetheless, both forms of the loan program guarantee a minimum return to producers and thereby place a floor under market prices.

The early loan program consisted of 1-year, nonrecourse loans for producers at a Government-set rate; often additional 1-year extensions were available for the following 2 crop years. The nonrecourse provision of these loans guaranteed that market prices could not fall much below the loan rate. If the market price was below the loan rate when loans matured, individual farmers found it profitable to default on loans and allow the Government to assume grain ownership. Thus, one would expect Government stocks to grow until farmers found the alternatives of marketing the grain and defaulting on the loans equally profitable—that is, until market price and loan rate were approximately equal.[3]

An important change contained in the 1977 legislation is that the terms of loan extension privileges are more restrictive. As before, producers can still obtain a loan at the Government-established rate. However, the farmer's options at the end of the initial loan period are to sell at the going market rate, default on the loan, or commit the grain to the "farmer-held reserve." In effect, the reserve program provides farmers a storage subsidy if the grain is withheld from the market until (1) a 3-year period expires or (2) the market price exceeds 140 percent of the loan rate. Once the grain is placed in the reserve, however, nonrecourse privileges are only triggered if the 3-year reserve commitment expires without market prices exceeding 140 percent of the loan rate. In the event that the market price approaches the loan rate, producers would still find it profitable to participate in the loan and 3-year reserve program. After all, the new program does leave the option of selling the grain later at a higher price. Thus, one can assume

[3] Admittedly, this rule for Government stock accumulation is one of those simplifications necessary for a manageable model. In reality, the immediate ownership of stock would require that farmers not opt for loan extension privileges. Farmers would be interested in loan extensions to the extent that they expected significantly higher prices in following years. Their ability to extend loans would depend on how they had used such privileges in the past and their ability to carry the storage and interest costs of extensive withholding.

lower limits on prices and removal of grain from the market at the lower limit price.[4]

Assuming that the loan rate defines a price floor is tantamount to suggesting that market determination of price and demand only occurs above that level. At times, farmers will find it profitable to market grain through commercial channels; then market forces will determine demand and price. This case is illustrated in figure 1; supply (S_0) and demand (D) result in a market clearing price (P_M^0) which is well above the loan rate (P_L). In contrast, farmer participation in loan programs sometimes precludes market determination of price and utilization; prices are fixed at the loan rate while the demand and the magnitude of Government- and farmer-held reserves are determined. This is also illustrated in figure 1; the equilibrium that would occur without price supports is given by the intersection of supply (S_1) and demand, which suggests a market clearing price (P_M^1). When price support loans operate, however, the market clears near the higher loan rate, P_L, and Government- or farmer-held reserves (ΔR) accumulate.

Recognizing that surplus and shortage refer to extreme cases, we define these conditions by reference to the price support/loan rate. Specifically, surplus is the discrepancy between supply and demand when price is supported at the loan rate, given that no further Government intervention takes place. A surplus amount ($Q_L Q_1$) is indicated in figure 1. Similarly, a shortage is the amount that demand deviates from what would occur if observed price were set at the loan rate. This is indicated by $Q_0 Q_L$ in figure 1.

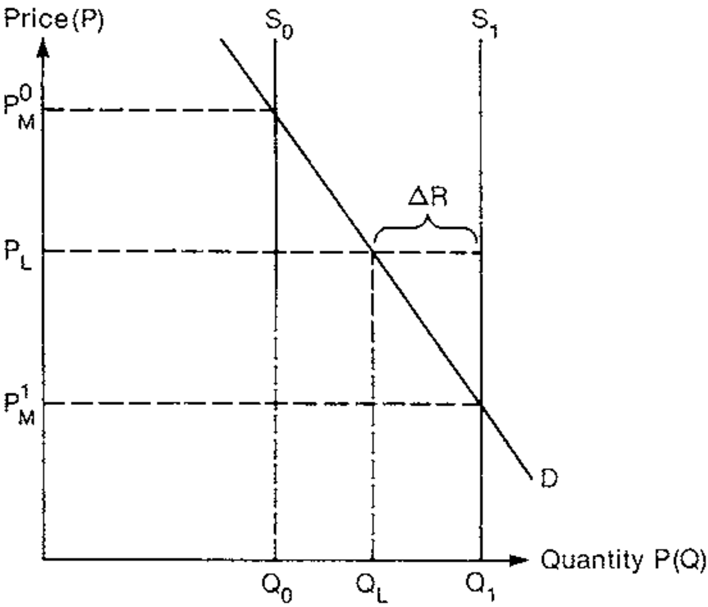
Identifying surplus and shortage periods by examining historical market prices and loan rates is possible, provided that one accounts for Government intervention beyond loan and reserve programs. For example,

[4] The amount of grain placed in the farmer-held reserve does depend on producer price expectations. Indeed, if farmers' assessment is that the market price will exceed the trigger price in 1 of 3 following years, producers would be inclined to place grain in the reserve at market prices slightly above the loan rate. If such speculative motives are operating then, the lower limit market price could be somewhat above the loan rate. Nonetheless, the loan rate will serve as an approximate lower limit on prices, in lieu of more sophisticated analyses of these new programs.

market price could fall below the loan rate if producer participation in acreage-restricting programs was required to qualify for Government loans and if farmer participation was low. Moreover, tight Government supply control and surplus disposal policies could alter conditions enough for market determination of price and demand to take place, even though the uncontrolled supply and demand outcomes would be characterized by surplus conditions. This is illustrated in figure 2, where the uncontrolled supply, demand, and price are given by S_0, D_0, and P_M^0, respectively. In this situation, it is not unusual for acreage restrictions to operate (shifting supply to S_1) and aggressive surplus disposal, such as generous food aid and commercial export subsidies, to be in effect (shifting demand out to D_1). Thus, market prices could be *moderately* above the loan rate (P_M^1), even though unrestricted supply and demand would lead to surplus conditions.

Figure 1

Market Equilibrium above (P_M^0) and at the Loan Rate (P_L)



Wheat Surplus And Shortage Periods

The conditions of the post-World War II wheat economy have resembled those of other major grains. The decades of the fifties and sixties were marked by virtually continuous surplus conditions. Then, a period of shortage in the seventies provided sharp contrast to earlier surpluses. In 1977, surpluses developed once more.

A more precise determination of these periods is possible when historical market prices and loan rates are examined. Figure 3 illustrates that surplus conditions existed between 1951 and 1971. Closer scrutiny also reveals that this period can be further divided; market prices were at or below the loan rate in the years 1951-63, whereas market prices were moderately above loan rates beginning in 1963. The shortage period is readily discernible; market prices exceeded loan rates at unprecedented magnitudes of $1 to $3 per bushel between 1972 and 1976. The market price/loan rate differential for 1977, however, resembles those of the early period.

Figure 2

Market Clearing Price (P_M^1) above Loan Rate when Surplus Conditions Exist

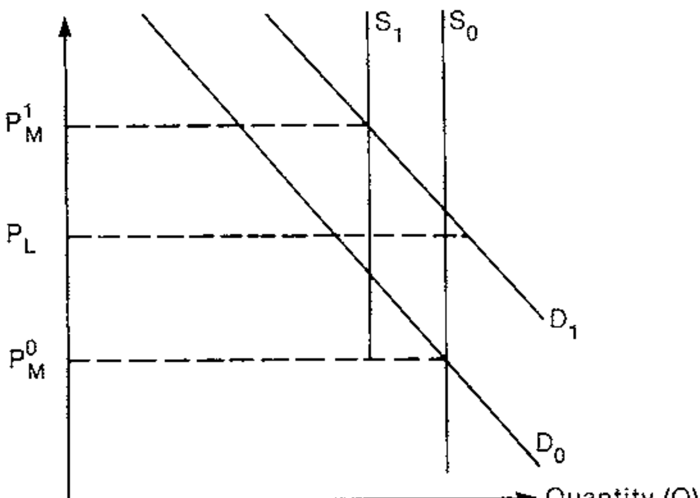
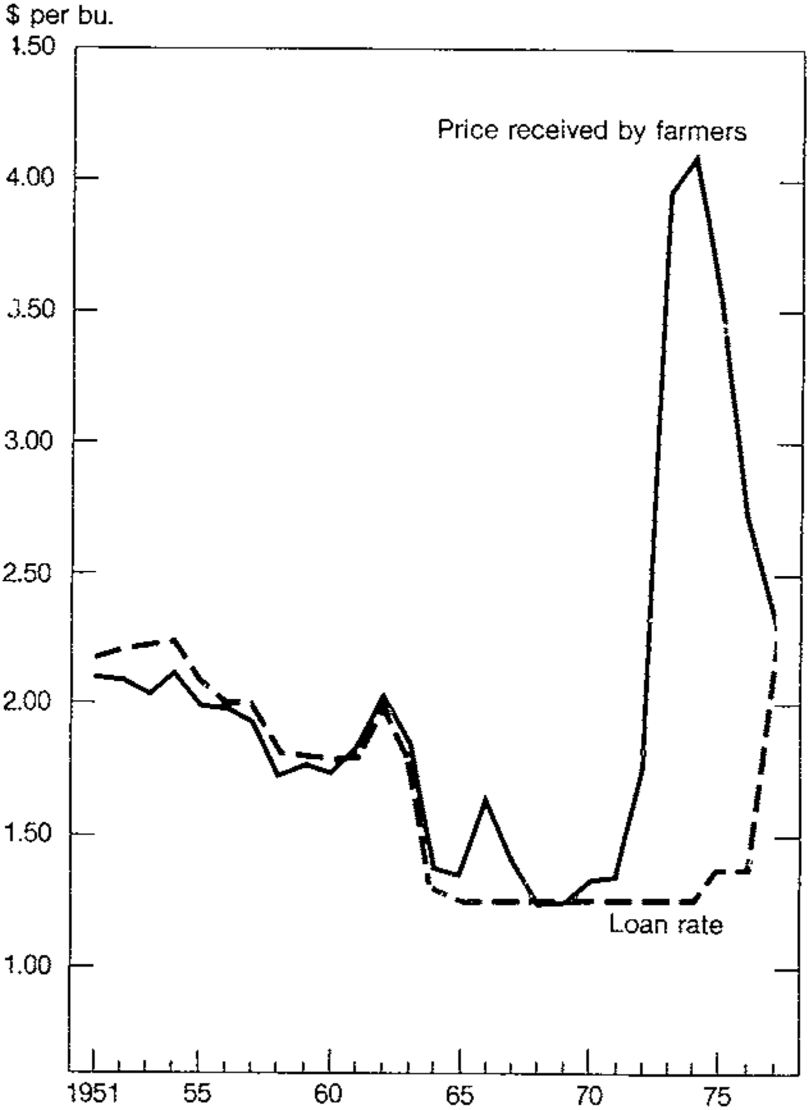


Figure 3

Wheat Farm Price and Loan Rate



The Early Surplus Period: 1951-71. As a fairly long period with a common set of economic tendencies and policy problems, the 1951-71 surplus period provides a convenient benchmark for comparing the economic forces and policy decisions of other periods. The low prices and stock accumulations resulted from a tendency to expand supplies in the face of stagnant domestic and foreign markets for U.S. wheat. Here we will elaborate on the economic forces at work during this period and describe the policies designed to control and manage these continual surpluses.

Figure 4 illustrates that supplies grew because yields expanded. Yields nearly doubled over these 20 years, rising from 18 bushels per acre in the early fifties to nearly 34 bushels per acre in the early seventies. These yield expansions are often attributed to technological advances. Indeed, farmers adopted a host of new production techniques during this period. Extensive mechanization, improved seed varieties, fertilizers, and other agricultural chemicals are often cited as major technical changes. However, other forces also contributed to yield increases. The Government's progressive tightening of acreage restrictions, for example, led to the use of higher quality land. Furthermore, a "good" weather cycle in the sixties is sometimes underlined as a cause of yield increases.

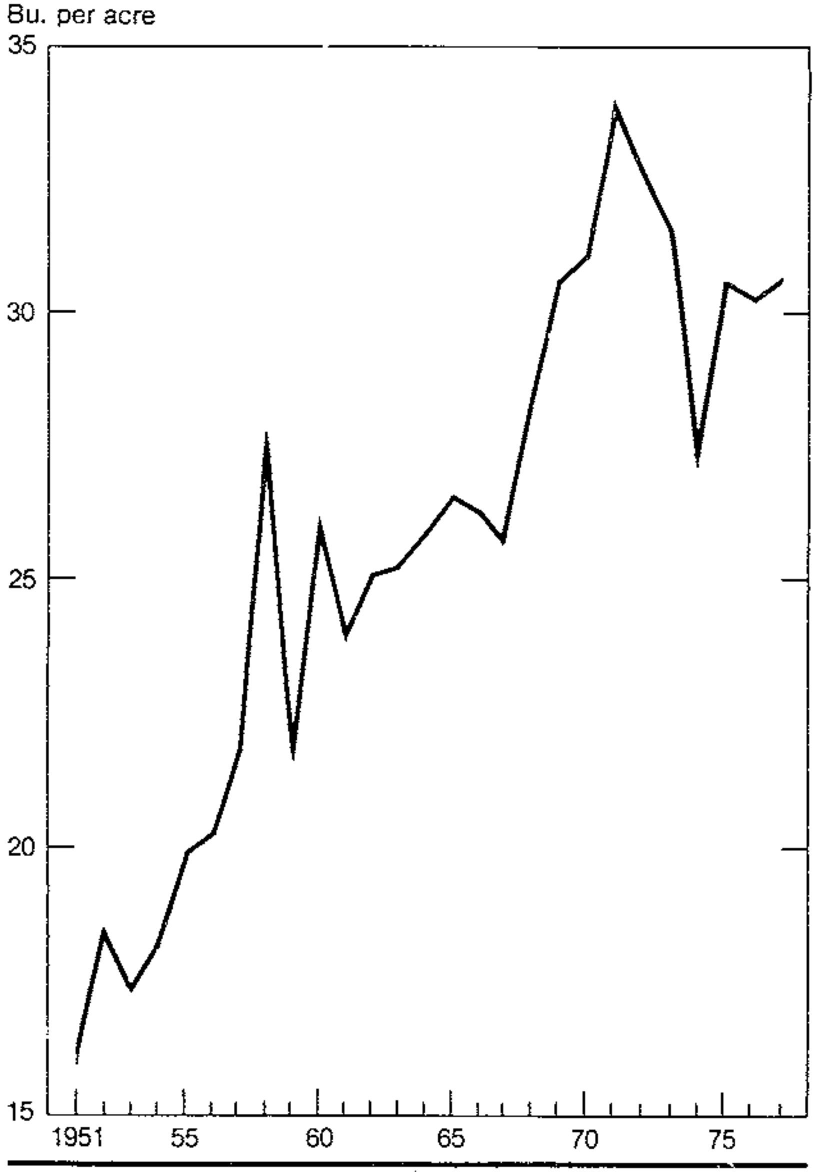
Figure 5 illustrates that domestic wheat utilization was fairly stable during the early surplus period, although moderate increases in level and variability are apparent for the sixties. Further examination of the major components of wheat use, food and feed utilization, suggests that increased wheat feeding accounted for the change in domestic demand patterns after 1960. Food use trended slowly upward over the entire period, while feed use started to expand and become more variable in the sixties.

The reasons for stagnant demand for wheat as food are well understood. Nonetheless, this lack of growth deserves elaboration, as it represents a principal cause for acute wheat surpluses in the United States. The crux is that wheat food demand has the characteristics of an inferior good, not only in the United States but also throughout economies of the developed world. Negative income elasticities thus guarantee that per capita consumption declines as income grows. Moreover, little adjustment in food demand occurs when prices fluctuate. The modest expansions in U.S. food use during the surplus period can be attributed to the fact that population increases slightly offset the consumption-depressing effects of rising incomes.

Wheat is usually thought of as a food grain. It is a suitable feed for all classes of livestock, however, and it is fed when competitively priced

Figure 4

Wheat Yield per Harvested Acre

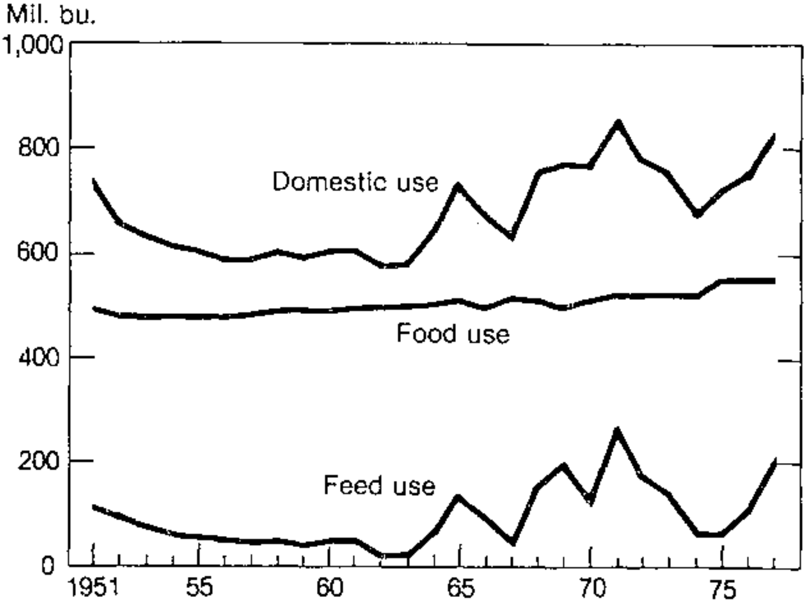


with other grains. Indeed, expansions in wheat feeding in the midsixties resulted from a sustained reduction in wheat prices during this period, which made wheat competitive with other feed grains. These low wheat prices may have also contributed to expansion in the Southwest feeder cattle industry, as cheap feed was plentiful in what had been a grain-deficit area. The variability of wheat feed use is most likely caused by cycles in the livestock and feed-grain economy.

It is misleading to document the tendency for a stagnant export market by merely examining total export data (fig. 6). Indeed, the irregular upward trend might indicate that demand was expanding during the fifties and sixties. Further examination reveals that the export increases are primarily the result of expanding food aid. Figure 6 also indicates that foreign food aid shipments increased almost continuously from the fifties to the midsixties. An increase in commercial exports coincided with the midsixties' food aid reductions. But, it was also the result of U.S. policy, rather than of changes in foreign market economic conditions.

Figure 5

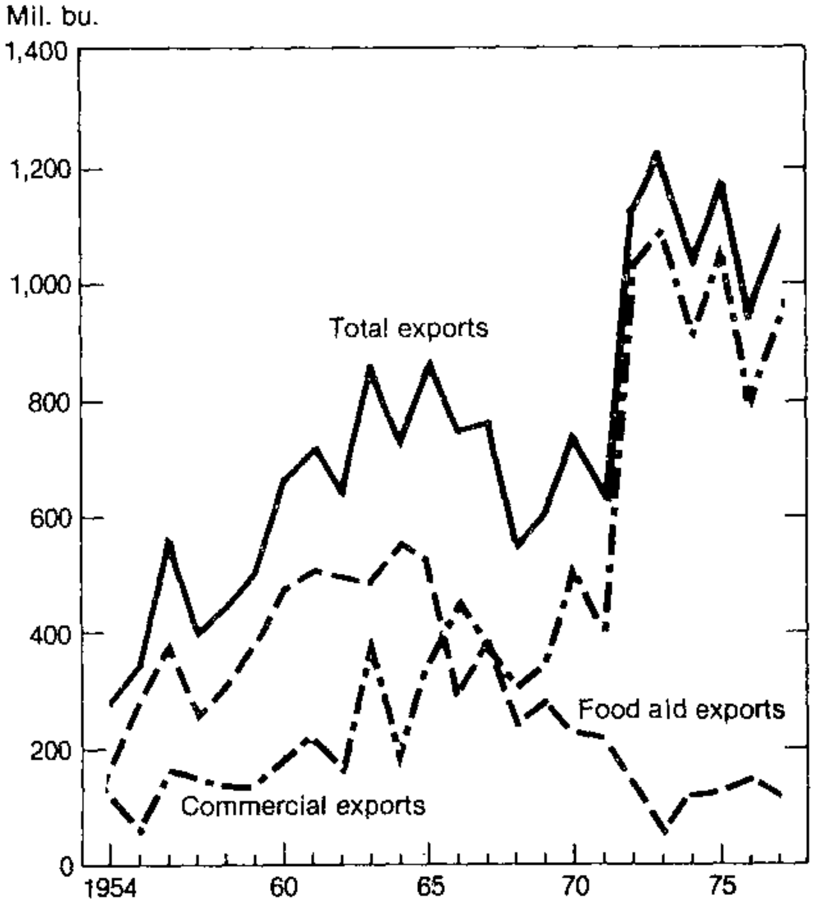
Domestic Use of U.S. Wheat



Stagnant foreign demand during the early postwar period resulted from the gradual loss of the traditional European market without sufficient compensation in other areas. European demand was strong during the immediate postwar period but declined as reconstruction progressed and the Common Market became more effective. The mutual tariff of Common Market countries gradually increased, thus encouraging indigenous

Figure 6

U.S. Wheat Exports



production and discouraging imports. Additionally, the stagnant European demand results from the fact that wheat is an inferior good in most developed countries. Expanding Japanese demand represented one encouraging spot in the foreign market. As postwar development and income growth coincided with declining real wheat prices, Japanese purchases of foreign wheat expanded almost continuously. Developing countries' purchases of U.S. wheat grew little over this period. Although population growth generally exceeded production growth, generous amounts of U.S. food aid and foreign currency shortages generally precluded a corresponding growth in wheat purchases by foreign countries.

Policymakers' strategies for handling surplus consisted of acreage restrictions and foreign surplus disposal through food aid programs and commercial export subsidies. This intervention reduced Government stock holdings below what they might otherwise have been and occasionally even resulted in buoyant market prices. However, a major tactical change coincided with wheat producers' failure in 1963 to pass a marketing quota referendum; this referendum tied the continuation of high loan rates to mandatory acreage restrictions. In subsequent years, acreage control programs featured payment for voluntary participation, and foreign wheat-trade policy favored commercial, instead of concessional, outlets.

The important characteristic of the 1951-63 period was the relatively high loan rate, from $1.80 to $2 per bushel. However, wheat producers paid a price for these high support prices; the acreage control program subjected individual producers to some form of involuntary acreage control *(18)*. Moreover, P.L. 480 expenditures and commercial export subsidies were funded generously during this period; food aid expenditures on wheat averaged $870 million, and the export subsidy ranged from 40 to 60 cents per bushel.

The loan rate was reduced to $1.24 per bushel in 1963. To maintain wheat producers' income and acreage near previous levels, the Government made payments for voluntary participation. In subsequent years, P.L. 480 expenditures and wheat subsidies were reduced; average expenditures on P.L. 480 were $385 million. The subsidy rate averaged 9 cents per bushel for 1961-71.

That foreign trade policies favored commercial channels beginning in the midsixties is apparent when one examines data on the composition of the export market (fig. 6). Beginning in 1965, P.L. 480 exports were gradually reduced, which coincided with an increase in commercial exports. Indeed, expansion in the commercial export market offset food aid reduction and total exports increased moderately in the late sixties. Food aid reductions were the result of expenditure reductions which overrode price decreases. In turn, it is likely that food aid reductions partially caused commercial export expansions, as developing countries were forced to buy sufficient wheat to meet their domestic requirements. Moreover, foreign market prices of purchased wheat were lower in the late sixties as support price reductions offset subsidy reductions. Figure 7 illustrates changes in the foreign price of U.S. wheat; the U.S. farm price minus the subsidy rate dropped substantially in the midsixties. Despite the fact that this measure ignores transportation differentials, it does suggest that lower foreign prices might have encouraged commercial purchases in the later period.

The Wheat Shortage Period: 1972-76. The high prices in the 1972-76 period are understandable if one focuses on those forces directly affecting the U.S. wheat economy—that is, the 20-year tendency for supply growth ceased and foreign demand surged to unprecedented levels. Numerous explanations for this change in the conditions of supply and demand have been advanced, but the underlying causes are still a matter of debate. Nonetheless, policymakers found intervention unnecessary during this period; consequently, market forces reconciled low supplies and strong demand.

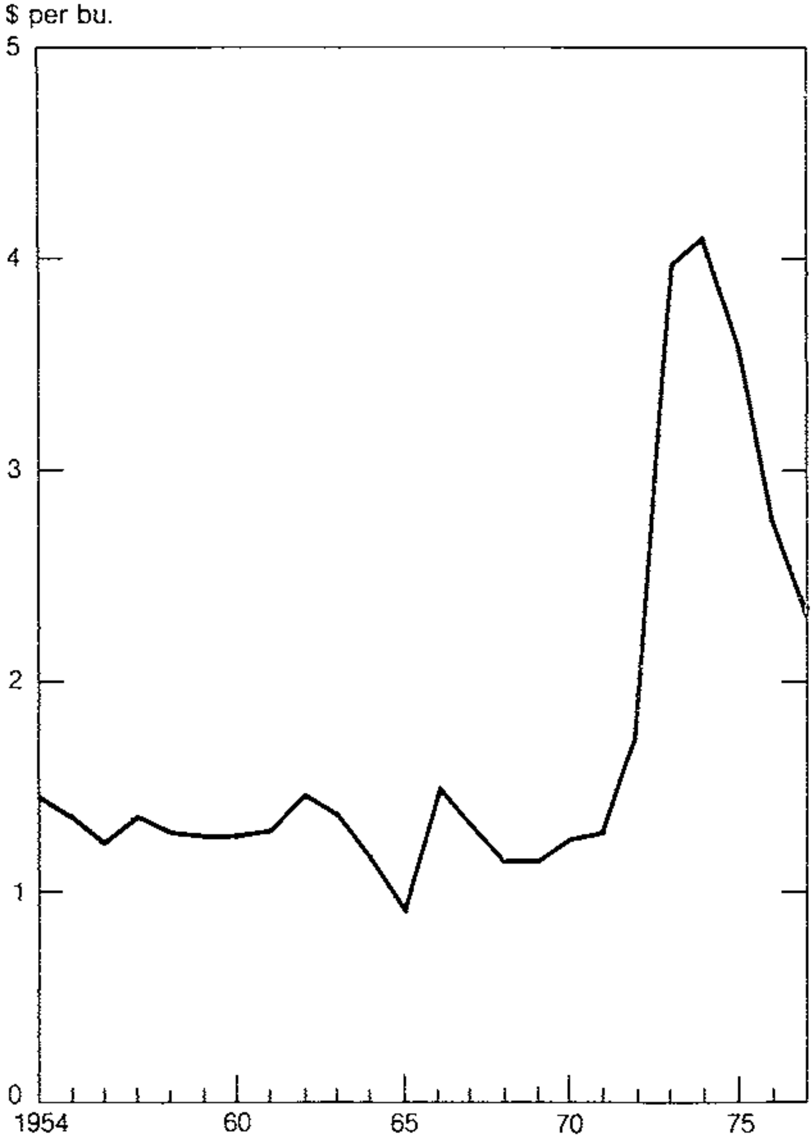
One can verify the important changes in conditions of supply and demand by inspecting yield data (fig. 4) and export data (fig. 6). Yield growth ceased around 1972 and fluctuated at about 31 bushels per acre. Annual average exports nearly doubled from 670 million bushels in 1966-71 to 1.1 billion bushels in 1972-77.

Explanations of recent yield stagnation have emphasized a wide range of environmental, technical, and economic conditions. It is the consensus that production shortfalls (1974) contributed to high prices. However, some view this occurrence as part of an extensive bad weather cycle in the seventies. Others have proposed arguments that the storehouse of technology from the fifties and sixties was depleted. Arguments which emphasize economic factors point to the implications of the past technical changes. Specifically, extensive purchases of inputs have accompanied these technical advances, and recent increases in input prices have discouraged their more intense utilization.

Bad weather conditions worldwide and international policy decisions beyond the control of U.S. agricultural policymakers caused a surge in wheat exports. World grain production fell short of normal levels, thus encouraging purchases from all major exporters including the United

Figure 7

Subsidy-Adjusted Farm Price



States. Low wheat production and a trade policy change in the USSR also added to U.S. export demand. The USSR reversed previous policies in deciding to make up production shortfalls on the international market, and the United States relaxed restrictions on trade with the USSR. Dollar devaluations of the seventies were the second major U.S. policy change; the cost of U.S. goods abroad was reduced about 15 percent as a result.

Agricultural policymakers were thus freed from the usual task of surplus control and disposal. Producers' decisions were made with benefit of minimum price guarantees, but Government acreage diversion programs were absent. Wheat acreage and output subsequently increased as farmers responded to high prices. As short world production and dollar devaluations bolstered foreign demand, export subsidies ceased. Commercial exports were further encouraged because food aid appropriations did not keep pace with price increases. Thus, P.L. 480 shipments were reduced and LDC commercial purchases were encouraged.

Return to Surplus: 1977. The combination of 5 years without acreage controls and 3 years without a major domestic production shortfall resulted in the most recent stock accumulation. U.S. wheat area increased 25 percent following the high prices of the early seventies and subsequent acreage decontrol. Low prices in the late seventies attest to the fact that this acreage increase was sufficient to fill the higher export demands, despite level yields in the seventies. Hence, in the late seventies, the U.S. Government again faced the prospect of controlling or disposing of wheat surpluses.

Policymakers' reaction to the most recent low prices has emphasized supply control rather than foreign surplus disposal; this is understandable as exports have remained near the levels of the earlier seventies. Wheat food aid exports did increase moderately in 1977, but this cannot be attributed to active Government intervention. Appropriations and expenditures on wheat food aid have remained at stable levels, so increased shipments are mainly the result of lower prices. The voluntary acreage control program guarantees income protection for farmers. The size of the cash payment depends on how much farmers have reduced plantings from the previous crop year and on how far the market price falls below the Government's "target price."

The Econometric Model

We review the art of commodity modeling for annual field crops and summarize some unique aspects of the wheat economy model. We introduce inventory speculation in a novel manner; inventory holders formulate price expectations for the following year based on acreage intentions and production reports. This method stabilizes price fluctuations between crop years. The Government supports prices at loan rates during surpluses, so that "public" stocks, instead of prices, are determined by supply and demand.

We summarize the supply, demand, and inventory components of the wheat model and list the endogenous (internal) and exogenous (external) variables.

Economic models provide the theoretical underpinning for their statistical counterparts. In the static (or timeless) case, it is assumed that the market clears at the price where an upward-sloping supply curve intersects a downward-sloping demand curve. However, some unique aspects of agricultural markets stem from the delay between seeding and harvesting and limited control by producers over their production environment. Specifically, supply relations for a given crop year are usually taken as perfectly inelastic and subject to fluctuation due to the environmental influence. However, analysts recognize that farmers use economic information to adjust production plans between crop years. Thus, present supply is positively related to price expectations which are often linked to prices that occurred in past marketing years. The longer run supply relation provides an orderly separation between the events of current and future marketing years. Current-year price is given by the intersection of the shortrun supply curve and the demand curve. The longer run supply schedule determines the position of the shortrun supply schedule in the next period which, in turn, determines demand and price in the next marketing year.

Although the underlying concepts are straightforward, econometric representations tend to become large and complex. This complexity is the result of specifying many component supply and demand relations and of including inventories. For example, the current model of wheat inventory behavior assumes that speculators forecast future price based on production information for upcoming crops. Consequently, no separation exists between current price formation and future production plans. Namely, unforeseen changes in farmers' production plans (due, for example, to changes in Government price-support policy) alter speculators' behavior and current price which further affects farmers' production plans. In the case of the wheat economy, one must also analyze the surplus case (described in the preceding chapter), as the Government becomes involved in the market and thus exerts the dominant influence on price formation.

In this chapter, we give an overview of the econometric wheat model. First, we use small linear models to illustrate properties of the larger empirical model. For example, we consider market operation and the effects of loan rate changes for the surplus case. We introduce speculative inventory behavior demonstrating that this assumption (1) dampens yearly fluctuations in price and marketings and (2) complicates measurement of crop substitutions. Second, we map the empirical wheat model and elaborate on (1) the components of supply and demand blocks and (2) the exogenous forces affecting the U.S. wheat economy.

An Annual Crop Model

Annual commodity models consist of equation blocks which can be summarized with four relations. The production block suggests that production decisions (QP_t) depend on past market conditions (P_{t-1}). In the demand block, current utilization (D_t) increases as price (P_t) falls. In some models like this one, inventories (I_t) also depend on current price. At equilibrium, production and last year's storage (I_{t-1}) are equal to utilization plus this year's storage. Equations (3.1a) through (3.4a) summarize these relationships; the separate effects of any exogenous variables are represented by constant terms. (Note: The numbering system for equations in this report will reflect both the chapter number and the equation number within each chapter.)

$$QP_t = \alpha_1 + \beta_1 P_{t-1} \qquad (3.1a)$$

$$D_t = \alpha_2 - \beta_2 P_t \qquad (3.2a)$$

$$I_t = \alpha_3 - \beta_3 P_t \qquad (3.3a)$$

$$I_{t-1} + QP_t = D_t + I_t \qquad (3.4a)$$

These relations provide a model of wheat marketing and price formation. Past price determines production and carry-in inventories. This inelastic supply is allocated between current utilization and inventories by the simultaneous solution of (3.2a), (3.3a), and (3.4a). The endogenous variables are QP_t, D_t, I_t, and P_t. P_{t-1} and I_{t-1} are predetermined.

Market Operation During Surplus Periods. When supplies are abundant, the market price falls to the loan floor and the Government accumulates reserves (see chapter 2). With some minor changes, equations (3.1a) through (3.4a) can account for this situation. First, inventories are defined to consist of a privately controlled component (I_t) and a Government-controlled component (R_t). Also, price is classified as an exogenous variable and set at the loan rate (P_t^*). The equations are rewritten as:

$$QP_t = \alpha_1 + \beta_1 P_{t-1}^* \tag{3.1b}$$

$$D_t = \alpha_2 - \beta_2 P_t^* \tag{3.2b}$$

$$I_t = \alpha_3 - \beta_3 P_t^* \tag{3.3b}$$

$$R_{t-1} + I_{t-1} + QP_t = D_t + I_t + R_t \tag{3.4b}$$

where:

QP_t, D_t, I_t, R_t are endogenous in t,

I_{t-1} is predetermined in t, and

P_t^*, P_{t-1}^* are exogenous in t.

As loan rates are subject to political pressure when surpluses are impending, one should consider some effects of an exogenous price increase when reserves are endogenous. An increase in the loan rate involves a one-for-one substitution between private-sector holdings ($D_t + I_t$) and Government-owned or -subsidized reserves (R_t). To see this, observe that exogenous prices (that is, loan rates) recursively determine consumption and inventories which, in turn, determine reserves. Thus, private-sector holdings can be written as follows:

$$(D_t + I_t) = (\alpha_2 + \alpha_3) - (\beta_2 + \beta_3) P_t^* .$$

So:

$$\frac{\partial(D_t + I_t)}{\partial P_t^*} = -(\beta_2 + \beta_3) .$$

Then, given that current-year supply is fixed ($\overline{S} = R_{t-1} + I_{t-1} + QP_t$), reserves can be written in terms of supply and private-sector holdings:

$$R_t = \overline{S} - (D_t + I_t) \ .$$

Hence:

$$\frac{\partial R_t}{\partial P_t^*} = \frac{-\partial (D_t + I_t)}{\partial P_t^*} = (\beta_2 + \beta_3) \ .$$

That is, a one-unit increase in the loan rate will result in a $(\beta_2 + \beta_3)$ unit reduction in private-sector holdings $(D_t + I_t)$ and a $(\beta_2 + \beta_3)$ unit increase in Government-held or -subsidized reserves. Thus, the additional reserves accumulated with loan rate increases depend on private-sector response to price. When the private-sector response to price is small, for example, loan rate increases cause small additions to reserves.

Introducing Inventory Speculation. Speculators hold inventories in the belief that prices will be higher in the future than in the present. In econometric models, this expectation translates to equations wherein inventories are related to the difference between next year's expected price and the current price. And as expected prices are not observable, an assumption on the determinants of expected price usually follows.

In the wheat model, production in the next crop year is assumed the crucial determinant of next year's expected price. This amounts to a "rational price expectations" model of inventory behavior. The definition of such a model is that price expectations are formulated based on the best available information (*27*). USDA intentions and crop forecast information are used in assessing price prospects and inventory holding decisions (*16*, *20*). However, it is a simplification to suggest that inventories depend on actual production in the following year, as USDA yield forecasts are subject to error. Nonetheless, this simplification enables us to specify a dynamic commodity model.

Let us restate the four-equation model before examining price fluctuations and the effects of changes in prices of substitutes. In particular, let us restate the negative relation between future production and current inventories as included in equation (3.3c). We add substitute price (PS_t) to the demand equation (3.2c) and the production equation (3.1c). The production equation is similar, except that it now states that this year's price affects next year's production. Equations (3.1c) through (3.4c) contain these relationships:

$$QP_{t+1} = \alpha_1 + \beta_1 P_t - \gamma_1 PS_t \qquad (3.1c)$$

$$D_t = \alpha_2 - \beta_2 P_t + \gamma_2 PS_t \qquad (3.2c)$$

$$I_t = \alpha_3 - \beta_3 P_t - \gamma_3 QP_{t+1} \qquad (3.3c)$$

$$I_{t-1} + QP_t = D_t + I_t \qquad (3.4c)$$

QP_{t+1}, D_t, I_t, P_t are endogenous in t,

PS_t is exogenous in t, and

QP_t, I_{t-1} are predetermined in t.

Price Dynamics.—The assumption that future production and current inventories are related produces econometric models with more price stability. The result is reasonable as the assumption is tantamount to granting speculators good foresight in making their decisions to carry grain between low and high price years. The major results can be illustrated with a standard cobweb diagram (fig. 8). S_0 and D_0 represent the supply and demand curve from the equation system (3.1a) through (3.4a). S_1 and D_1 represent the supply and demand relations from the equation system (3.1c) through (3.4c). Both sets of curves have the same longrun equilibrium price (P_e). However, the latter set of curves has slopes that guarantee smaller price oscillations and a faster rate on convergence; S_1 is more inelastic than S_0, and D_1 is more elastic than D_0.

The equality of longrun equilibrium price is readily established, once one observes that equations (3.1a) through (3.4a) are a special case of (3.1c) through (3.4c). The latter system reduces to the cobweb model when $\gamma_3 = 0$. Moreover, the equilibrium price, P_e, does not depend on γ_3, so the equilibrium price in both cases is the same. To see this, substitute (3.2c), (3.3c), and the lagged version of (3.1c) into (3.4c), and rearrange to obtain a reduced-form price equation:

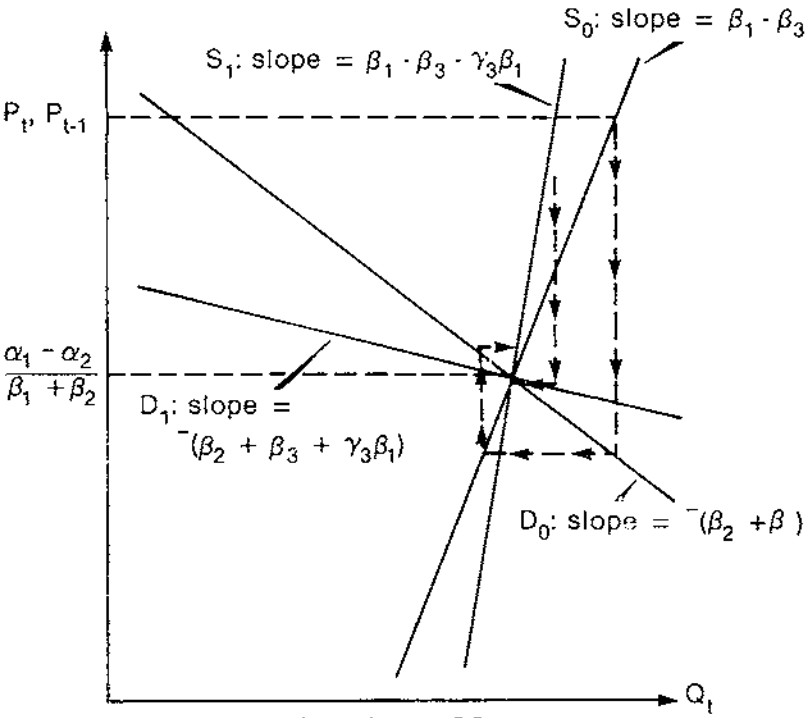
$$P_t = \frac{(\alpha_1 - \alpha_2)}{(\beta_2 + \beta_3 + \gamma_3\beta_1)} - \frac{(\beta_1 - \beta_3 - \gamma_3\beta_1)}{\beta_2 + \beta_3 + \gamma_3\beta_1} P_{t-1} \qquad (3.5)$$

Longrun equilibrium occurs when $P_e = P_t = P_{t-1}$. Upon substituting this condition into (3.5), it follows that:

$$P_e \left[1 + \frac{\beta_1 - \beta_3 - \gamma_3\beta_1}{\beta_2 + \beta_3 + \gamma_3\beta_1} \right] = \frac{\alpha_1 - \alpha_2}{\beta_2 + \beta_3 + \gamma_3\beta_1} .$$

Figure 8

Supply and Demand Curves with and without Relation Between Inventories and Future Production



$S_t = I_{t-1} + QP_t$

$D_t = D_t + I_t$

After some algebra, this equation yields:

$$P_e = \frac{\alpha_1 - \alpha_2}{\beta_1 + \beta_2} .$$

Price dynamics can be illustrated upon substituting lagged versions of (3.5) into the original equation; n successive substitutions yield:

$$P_t = k_0 \left[\sum_{j=0}^{n-1} (-k_1)^j \right] + (-k_1)^n \; P_{t-n} ,$$

where:

$$k_0 = \frac{\alpha_1 - \alpha_2}{\beta_2 + \beta_3 + \gamma_3\beta_1} \quad \text{and } k_1 = \frac{\beta_1 - \beta_3 - \gamma_3\beta_1}{\beta_2 + \beta_3 + \gamma_3\beta_1} .$$

For "large" n and $k_1 < 1$:

$$\sum_{j=0}^{n-1} (-k_1)^j = \frac{1}{1 + k_1} \quad \text{and } P_e = \frac{k_0}{1 + k_1} .$$

Therefore:

$$P_t = P_e + (-k_1)^n \, P_{t-n} .$$

Since $(-k_1)^n \rightarrow 0$ as $n \rightarrow \infty$, $P_t \rightarrow P_e$.

That is, the condition that $k_1 < 1$ delivers longrun price stability. This is the familiar cobweb condition that the slope of the supply curve $(\beta_1 - \beta_3 - \gamma_3\beta_1)$ is less than the slope of the demand curve $(\beta_2 + \beta_3 + \gamma_3\beta_1)$. Addition of the link between production and inventories ($\gamma_3 > 0$) results in a more inelastic supply from t−1 to t and a more elastic demand in t.

Therefore, the equation system (3.1c) to (3.4c) will be stable when (3.1a) to (3.4a) might not. Moreover, price fluctuations in reaching a new equilibrium will be smaller in the former system of equations.

The Effect Of A Substitute Price Change On Next Year's Production.—The analysis of a substitute price change on wheat production depends on the origin of the substitution. If competition occurs on the demand side, for example, a substitute price increase also raises wheat price. In turn, the higher wheat price encourages production in the following year. However, an increase in the price of a supply substitute does not affect current wheat price but shifts the wheat supply schedule, which discourages production in the following year. But it is not unusual for agricultural commodities to substitute on both the supply and the demand side. In this case, an increase in the substitute price may increase or decrease production in the following year; the sign of next year's production change depends on the relative strength of substitutions on the supply and demand sides.

Figure 9 illustrates a demand substitution, a supply substitution, and a case where supply and demand substitution with the same crop results in a falling wheat production with a rising substitute price. The initial price (P_t^0) and production (QP_{t+1}^0) lie on supply schedule S_0. An increase in the demand substitute raises the wheat price to P_t^1 while output increases to QP_{t+1}^1 on schedule S_0. An increase in the price of the supply substitute shifts the supply schedule back to S_1; the price remains at P_t^0 but production falls to QP_{t+1}^2. If the supply substitute and the demand substitute are the same commodity, a rise in wheat price and a supply shift both occur. In figure 9, the supply effect dominates the demand effect; production falls to QP_{t+1}^3 at price P_t^1.

The result can be illustrated with equations (3.1c) through (3.4c). A change in the price of a substitute on next year's production, $\Delta QP_{t+1}/\Delta PS_t$, exceeds zero, provided that the ratio of direct supply and demand effects $(\beta_1/\beta_2 + \beta_3)$ exceeds the ratio of indirect supply and demand effects (γ_1/γ_2). To obtain this result, substitute (3.2c) and (3.3c) into (3.4c) assuming that current-year supply is fixed ($\overline{S} = I_{t-1} + QP_t$):

$$\overline{S} = (\alpha_2 - \beta_2 P_t + \gamma_2 PS_t) + (\alpha_3 - \beta_3 P_t - \gamma_3 QP_{t+1}) \ .$$

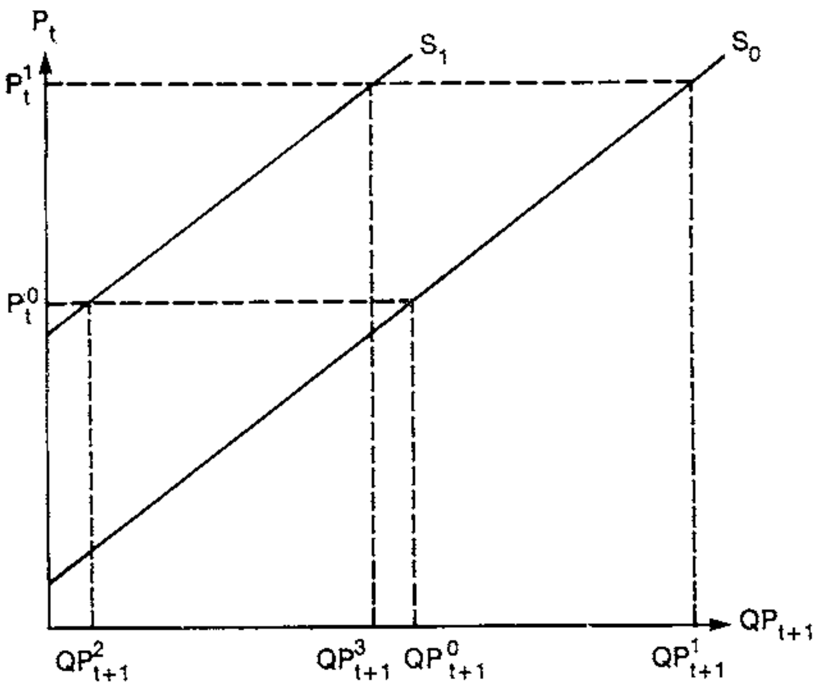
By expressing (3.1c) as P_t and substituting into the above equation, one obtains:

$$\overline{S} = \left[\alpha_1 \frac{\beta_2 + \beta_3}{\beta_1} + \alpha_2 + \alpha_3\right] + \left[\gamma_2 - \gamma_1 \frac{\beta_2 + \beta_3}{\beta_1}\right] PS_t$$

$$- \left[\gamma_3 + \frac{\beta_2 + \beta_3}{\beta_1}\right] QP_{t+1} \quad .$$

Figure 9

Effect of an Increase in the Price of a Substitute (in Period t) on Production (in Period t + 1)



Since $\overline{S}$ is fixed:

$$\frac{\Delta QP_{t+1}}{\Delta PS_t} = \frac{\beta_1\gamma_2 - \gamma_1(\beta_2 + \beta_3)}{\beta_1\gamma_3 + \beta_2 + \beta_3} \quad .$$

Thus,

$$\frac{\Delta QP_{t+1}}{\Delta PS_t} > 0 \quad \text{when } \beta_1\gamma_2 > \gamma_1(\beta_2 + \beta_3)\,.$$

The U.S. Wheat Model

The economic properties of the linear model (equations (3.1c) through (3.4c)) remain intact in the empirical wheat model, but several technical features make this wheat model more complex. Past prices and weather continue to determine current supply, and market equilibrium still produces price and utilization for the current year along with production plans for the following year. However, many estimated relationships are nonlinear. Furthermore, price lags in the production block extend beyond one period. Finally, expanded equation blocks result in long lists of endogenous and exogenous variables.

The structure of the wheat model is indicated below:

Summary Of Structural Equations And Identities

Production

(3.1)	WHESA(+1) =	AWWP(+1) + ASWP(+1) (Identity)
(3.2)	AWWP(+1) =	f(WHEPE*(+1), COLPE*(+1), SORPE*(+1), WHEPDW*(+1), WHEPF(−i), COLPF*(−i), SORPF*(−i); i = 0, 1, 2, 3)
(3.3)	ASWP(+1) =	f(WHEPE*(+1), WHEPDS*(+1), WHEPF(−i), BARPF*(−i); i = 0, 1, 2)
(3.4)	WHESP(+1) =	f(WHEPF(−1), WHEPPF*, WHESA(+1), WHEWC*(+1))

*Denotes an exogenous variable.

Domestic Demand

(3.5) WHEDH = f(POPUS*, YCAPUS*)
(3.6) WHEDF = f(WHEPF, PFEC*(+1), SORPF*)
(3.7) WHEDS = f(WHESA(+1))

Foreign Demand

(3.8) WXT = WXCNS + WXST* + WX48U* + WX48D* (Identity)
(3.9) WXCNS = WXCU + WXCJ + WXCWE (Identity)
(3.10) WXCU = f(WHEPF, PR*, PFG*, SW*, SR*, YCAP6U*, EXUS*, POPU*, QWPU*, QWSCO*, WX48U*)
(3.11) WXCJ = f(RPWJ*, CPIJ*, YCAPJ*, POPJ*, QWSJ*)
(3.12) WXCWE = f(WICWE)
(3.13) WICWE = QWDWEFE + QWDWEFO + WXTWE* + BSWWE(+1)* − QWSWE* (Identity)
(3.14) QWDFEWE = f(AUD*, PWTH*, PCTH*, SWEC*, PM*)
(3.15) QWDWEFO = f(YCAPWE*, POPWE*)

Commercial Inventories

(3.16) $WHEHA_t$ = f(WHEPF, WHESP(+1), WHESP, WHEHH*, WPI*)

U.S. Market Clearing Identity

(3.17) WHESP + WHEHA(−1) + WHEHH*(−1) = WHEDF + WHEDH + WHEDS + WXT + WHEHA + WHEHH*

Endogenous Variables In Period t

(1)	WHESA(+1)	WHEAT, TOTAL ACREAGE PLANTED, YEAR T+1, JUL-JUN	(MIL ACRE)
(2)	AWWP(+1)	WINTER WHEAT, ACREAGE PLANTED, YEAR T+1	(THOU ACRE)
(3)	ASWP(+1)	SPRING WHEAT, ACREAGE PLANTED, YEAR T+1	(THOU ACRE)
(4)	WHESP(+1)	WHEAT PRODUCTION IN YEAR T+1	(MIL BU)

(5)	WHEDH	WHEAT, UTILIZED FOR FOOD, JUL-JUN	(MIL BU)
(6)	WHEDF	WHEAT, UTILIZED FOR FEED, JUL-JUN	(MIL BU)
(7)	WHEDS	WHEAT, UTILIZED FOR SEED, JUL-JUN	(MIL BU)
(8)	WXT	U.S. WHEAT AND FLOUR EXPORTS TO ALL DESTINATIONS, JUL-JUN	(MIL BU)
(9)	WXCNS	U.S. COMMERCIAL WHEAT AND FLOUR EXPORTS TO NON-SOCIALIST COUNTRIES, JUL-JUN	(MIL BU)
(10)	WXCU	U.S. COMMERCIAL WHEAT AND FLOUR EXPORTS TO LDC's, JUL-JUN	(MIL BU)
(11)	WXCJ	U.S. COMMERCIAL WHEAT AND FLOUR EXPORTS TO JAPAN, JUL-JUN	(MIL BU)
(12)	WXCWE	U.S. COMMERCIAL WHEAT AND FLOUR EXPORTS TO WESTERN EUROPE, JUL-JUN	(MIL BU)
(13)	WICWE	COMMERCIAL IMPORTS BY W. EUROPE, AUG-JUL	(M.M. TON)
(14)	QWDWEFE	WHEAT USED FOR FEED IN WEST EUROPE, AUG-JUL	(M.M. TON)
(15)	QWDWEFO	W. EUROPE WHEAT USE FOR NON-FEED PURPOSES, AUG-JUL	(M.M. TON)
(16)	WHEHA	WHEAT, PRIVATELY OWNED STOCKS, END OF CROP YEAR, JUL-JUN	(MIL BU)
(17)	WHEPF	WHEAT, AVERAGE PRICE RECEIVED BY FARMERS JUL-JUN	($/BU)

Exogenous Variables

(1)	WHEPE	WHEAT, EFFECTIVE SUPPORT RATE, JUL-JUN	($/BU)
(2)	COLPE	COTTON, EFFECTIVE SUPPORT RATE, AUG-JUL	($/CWT)

(3)	SORPE	SORGHUM, EFFECTIVE SUPPORT RATE, OCT-SEP	($/CWT)
(4)	WHEPDW	WINTER WHEAT, EFFECTIVE DIVERSION PAYMENT RATE, JUL-JUN	($/BU)
(5)	COLPF	COTTON SEASON AVERAGE PRICE RECEIVED BY FARMERS, AUG-JUL	($/LB)
(6)	SORPF	SORGHUM, AVERAGE PRICE RECEIVED BY FARMERS, OCT-SEP	($/CWT)
(7)	WHEPD	SPRING WHEAT, EFFECTIVE DIVERSION PAYMENT RATE, JUL-JUN	($/BU)
(8)	BARPF	BARLEY, AVERAGE PRICE RECEIVED BY FARMERS, JUL-JUN	($/BU)
(9)	WHEPPF	FERTILIZER PRICE INDEX (APR-SEP AVERAGE)	(1967 = 100)
(10)	WHEWC	PASTURE CONDITION INDEX FOR MAJOR WHEAT PRODUCING REGION, JUN-AUG	(% OF NORMAL)
(11)	POPUS	POPULATION, TOTAL, U.S.	(MIL)
(12)	YCAPUS	INDEX OF REAL PER CAP PERSONAL CONS EXPS, JAN-DEC	(1967 = 1.0)
(13)	PFEC	PRICE OF FED CATTLE, JAN-DEC	($/CWT)
(14)	WX48U	U.S. WHEAT EXPORTS TO LDC'S—PL480 AND AID, JUL-JUN	(MIL BU)
(15)	WX48D	U.S. WHEAT AND FLOUR EXPORTS TO DEVELOPED COUNTRIES—PL480 & AID	(MIL BU)
(16)	WXST	U.S. WHEAT AND FLOUR EXPORTS TO SOCIALIST COUNTRIES, JUL-JUN	(MIL BU)
(17)	POPU	POPULATION IN MAJOR WHEAT IMPORTING LDC'S	(MIL)
(18)	SW	U.S. SEASON AVERAGE EXPORT PAYMENT RATE ON WHEAT, JUL-JUN	($/BU)

(19)	PFG	FEED GRAIN PRICE INDEX (This is a weighted average of U.S. feed grain prices—corn, sorghum, barley, and oats. Weights are the percentage of each feed grain in LDC human consumption of coarse grains.)	(1964 = 1.0)
(20)	PR	U.S. PRICE MEDIUM GRAIN RICE, FOB—HOUSTON, AUG-SEP	($/CWT)
(21)	SR	SEASON AVERAGE EXPORT PAYMENT RATE FOR MEDIUM GRAIN RICE	($/CWT)
(22)	YCAP6U	INDEX OF REAL CONSUMPTION EXPS. IN 6 LDC'S	(1970 = 1.0)
(23)	EXUS	EXCHANGE RATE FOR U.S.	(SDR/U.S. $)
(24)	QWPU	WHEAT PRODUCTION IN LDC'S, EXCLUDING ARGENTINA	(M.M. TON)
(25)	QWSCO	WHEAT PRODUCTION + BEGINNING STOCKS IN MAJOR EXPORTING COUNTRIES	(M.M. TON)
(26)	POPJ	POPULATION IN JAPAN	(MILLIONS)
(27)	RPWJ	THE JAPANESE FOOD AGENCY'S RESALE PRICE—WEST WHITE WHEAT	(YEN/K.G.)
(28)	CPIJ	INDEX OF CONSUMER PRICES IN JAPAN	(1970 = 1.0)
(29)	YCAPJ	PER CAP CONSUMPTION EXPENDITURES (REAL) IN JAPAN	(1970 = 1.0)
(30)	QWSJ	WHEAT PRODUCTION AND BEGINNING STOCKS IN JAPAN	(M.M. TON)
(31)	WXTWE	W. EUROPE EXPORTS—ADJUSTED FOR INTRA TRADE	(M.M. TON)
(32)	BSWWE	BEGINNING STOCKS OF WHEAT IN ALL WESTERN EUROPE	(M.M. TON)

(33)	QWSWE	WHEAT PRODUCTION + BEGINNING STOCKS IN WESTERN EUROPE	(M.M. TON)
(34)	AUD	INDEX OF ANIMAL UNITS IN EEC6 AND UNITED KINGDOM	(1963 = 1.0)
(35)	PWTH	WHEAT THRESHOLD PRICE AT ROTTERDAM, NETH.	(UOA/MT)
(36)	SWEC	SUBSIDY PAID ON WHEAT USED FOR FEED IN THE EEC	(UOA/MT)
(37)	PCTH	CORN THRESHOLD PRICE	(UOA/MT)
(38)	PM	SOYBEAN MEAL PRICE AT DECATUR, 44% PROTEIN	(CENTS/LB)
(39)	POPWE	POPULATION IN W. EUROPE	(MILLIONS)
(40)	YCAPWE	INDEX OF PERCAP INCOME IN W. EUROPE	(1970 = 1.0)
(41)	WHEHH	WHEAT, CCC OWNED STOCKS IN OWN FACILITIES, END OF YEAR, JUL-JUN	(MIL BU)
(42)	WPI	WHOLESALE PRICE INDEX, U.S.	(1967 = 100)

The production, demand, and inventory blocks contain 12 structural relations; 5 identities add component supply and demand relationships and impose the condition that the market must clear. Both structural relations and identities comprise a model with 17 endogenous variables. Solution values are conditioned on the values of 42 exogenous variables.[5] These exogenous variables measure the effects of a range of environmental, grain policy, and macroeconomic factors.

The production block contains three structural equations and an identity. We estimated separate acreage relations for winter and spring wheat (equations (3.2) and (3.3)); those relations depend on the policy variables and market prices for wheat and the appropriate competitive crops. Moreover, both acreage equations contain relatively long price lags (3-4 years). The production relation (equation (3.4)) reflects economic factors (fertilizer prices) influencing the allocation of nonland inputs, as well as the usual de-

[5] The usual dummy variables and trend terms have been omitted from this list.

pendence on environmental and technical factors. The identity (equation (3.1)) adds the component acreages used to obtain total planted acreage.

The demand block contains structural relations for explaining the major elements of domestic and foreign utilization. Domestic demand contains the usual components. Wheat used for food (equation (3.5)), regarded as a consumer demand, provides relations with the domestic macroeconomy. Feed demand (equation (3.6)) is derived from livestock economy requirements; this relationship provides exogenous links with the livestock and other grain economies. Seed use (equation (3.7)) is explained by planted acreage.

The foreign demand sector contains relations which explain U.S. wheat exports to major regions. LDC demands (equation (3.10)) depend on major U.S. policies (subsidies and P.L. 480 exports) and the determinants of consumer demand (for example, income and the price of substitute grains). Japanese demands (equation (3.11)) also depend on the forces affecting human consumption in that country. U.S. exports to Western Europe are determined by a small block of equations (3.12 through 3.15). Two of these relations (equations (3.14) and (3.15)) explain the food and feed components of internal demand. An identity, equation (3.13), determines imports from demand equations, given fixed supplies. Equation (3.14) relates imports to imports received from the United States.

The empirical inventory equation (3.16) bears some similarity to equation (3.3c)--there is a response to current price and following year production. However, the price response is nonlinear. Furthermore, several shifters have been included to account for such effects as an inventory component that is not price responsive.

Equation (3.17), an identity, imposes the condition that the U.S. market clears.

The U.S. Wheat Economy: Demand, Inventories, And Production

We estimate the relationships governing the domestic U.S. wheat market. Wheat used for human consumption increases as population grows and decreases as per capita income rises. Wheat used for animal feed depends on the prices of wheat, sorghum grain, and livestock. Fluctuations in privately owned wheat inventories usually result from changes in production (current and future), Government stocks, and wheat prices. Acreage is determined by prices that occurred up to 3 or 4 years ago. The most important competitive crops are barley in the spring wheat area of the Northern Plains and cotton or sorghum in the winter wheat area of the Southern Plains. Production coming from a given planted area increases over time and fluctuates with relative wheat and fertilizer prices as well as weather conditions.

Let us turn to the estimation of supply, demand, and inventory relationships. In this chapter, we describe the behavior of participants in the U.S. wheat economy. This exercise follows the usual prescription for econometric method. First, we use a theoretical model based on utility or profit maximization to deduce the factors that should influence an agent's market behavior. Then, under the assumption that behavior in the aggregate is similar to that for individuals, we use economywide data to gauge the importance of individual variables.

Much of the underlying theory has been articulated elsewhere. Consequently, this chapter contains a brief literature review. The reader may notice that the divergence between theory and practice varies with the complexity of the economic relationship. For example, the food and feed demand results follow directly from neoclassical models of consumer and producer behavior. However, the postulate of uncertain prices in the inventory specification results in less rigorous application of the profit maximizing principle. Production response analysis also requires the assumption of uncertain prices. In this instance, Government support prices and acreage restrictions complicate producers' expectations further. Environmental and technological factors also impinge on production response.

We assign wheat its proper role in the field crop sector. In theoretical terms, this involves including substitute prices in the appropriate supply and demand relationships. In practice, this requires knowledge of consumers' habits, the practices of commercial feedlot operators, and climate limitations on the choices of wheat producers.

We estimated all relationships with data from the U.S. wheat economy.[6] Moreover, we estimated all coefficients with ordinary least squares. This procedure is not intended to deny the theory of simultaneous equation estimation. In practice, however, the distinction between least squares and simultaneous equation estimation vanishes in large econometric models.

Domestic Demand

We now turn to the estimation of wheat for human consumption, livestock feed, and seed.

Human Consumption. We can specify the food demand equation from a straightforward application of consumer demand theory, which shows the outcome for a utility-maximizing consumer who faces known prices and a fixed income when making commodity purchase decisions (*14*). Demand depends on the commodity price, the price of substitutes, and income. Hence, an individual's wheat demand (DH_i) is functionally related to wheat price (PW), price of substitutes (PS), and income (Y_i):

$$DH_i = f(PW, PS, Y_i) .$$

Under the assumption of identical consumer tastes, market demand (DH) can be written in terms of population (POP) and individual demands:

$$DH = POP \cdot f(PW, PS, Y_i) .$$

The assumption of similar consumer tastes leads to population elasticities of one. Thus, we rewrite this equation in per capita terms for estimation:

$$\frac{DH}{POP} = f(PW, PS, Y_i) .$$

This specification restricts the population elasticity at one, thereby avoiding multicollinearity between population and income.

Elasticities of wheat food use for *price and income* in developed countries have been measured by Schmitz and Bawden (*31*). They found food demands to be inelastic with respect to prices. Computed price elasticities

[6] The data and sources are tabulated in appendix A. Most variables were defined in the list of equations and variables in chapter 3. Dummy variable and trend terms are defined as needed.

were less than −0.30, except those for West Germany and the Netherlands (−0.41 and −0.43, respectively). Income elasticities were also found to be small, and consistently negative, except for Japan. For the United States, estimated price and income elasticities were −0.035 and −0.347, respectively. These results suggest little response by millers and consumers to changes in price or income.

Thus, a declining food consumption of wheat is associated with rising income. Wheat is an inexpensive source of protein and calories in terms of the resources required for its production. As income rises, more expensive sources of protein and calories become affordable and are substituted for wheat. As the proportion of meat and animal protein, fruits, vegetables, and sugar in the diet increases with income, per capita consumption of wheat also declines. As incomes rise, the form in which wheat is consumed also changes. Per capita consumption of commercially baked breads is positively related to income.

The estimation results below show that the quantity of wheat demanded for food is responsive to neither wheat price nor the price of substitutes. In preliminary regressions, wheat price was included but elasticities were small and t-values were near zero. The following equation, with income as the only independent variable, explains satisfactorily the historical variation in food demand:

$$WHEDH_t/POPDS_t = \underset{(55.09)}{3.4586} - \underset{(-12.99)}{85.0448}\ YCAPUS_t$$

R-SQUARED(CORR.): 0.903
SEE: 0.37435E-01
DW: 0.86

ELASTICITIES:
E(WHEDH.YCAPUS) = −0.31
E(WHEDH.POPUS) = 1.00

PERIOD OF FIT: 1956-74

(4.1)

Consistent with the results of Schmitz and Bawden, wheat is shown to be an inferior good and to have a similar income elasticity. The equation differs, though, from earlier results in that the coefficient of wheat price is zero.

Feed Use. The feed demand specification hinges on derived demand theory. This model outlines the behavior of a profit-maximizing producer in purchasing inputs for his enterprise (*38*). Our analysis considers the case in which all relevant factors of production are variable. Under these circumstances, input demand depends on the prices of the input, substitute inputs, and output. Moreover, considering wheat feed demand requires one to consider (1) the dominance of the U.S. southern feeder cattle industry and, therefore, (2) the fact that sorghum is the principal competitive grain. The quantity of wheat demanded for feed can be written thus:

$$QWDF = f(PW/PFB, PS/PFB, PFC/PFB)$$

where:

QWDF = quantity of wheat demanded for feed use,
PW = price of wheat,
PS = price of sorghum grain,
PFC = price of feeder cattle, and
PFB = price of fed beef.

Our analysis of wheat feeding builds on a previous investigation reported by Gomme, which contains two important observations (*8*). First, wheat feeding is largely confined to the High Plains States and the Southeast. Wheat feed demand in both regions is associated with increased regional fed cattle marketings. In the traditionally feed-grain-deficit Southeast, fed cattle marketings have grown with the spread of farmer-feeder operations in which farmers produce their own wheat for feed. Increased fed cattle production in the High Plains States, however, is associated with emergence of the commercial feedlot industry. Commercial feedlots are permanent feeding facilities with a capacity exceeding 1,000 head annually. The number and capacity of commercial feedlots have been increasing, which result in an increasing proportion of fed cattle in the region. Feeding rations in large-scale feeding operations favor high levels of grain and low levels of roughage. Second, prices especially favoring wheat feeding prevail during late summer and early fall. The harvest of wheat planted in the fall precedes by several months the harvest of feed grains planted in the spring. As the supply of wheat increases following harvest and wheat prices fall to seasonal lows, feed grain prices reach seasonal highs. Hence, any disturbance in the normal seasonal pattern of prices for wheat and other grains may result in wheat-feeding fluctuations that are not measured in annual average prices.

The estimated feed demand equation in our model differs in two important respects from that of earlier research. First, all inputs are assumed to be variable. Previous models assumed the cattle population fixed in an annual time frame due to biological restrictions on herd additions. The assumption of variable feeder cattle inputs is plausible, as substitution between feeder and range cattle may take place even though the total population is fixed. Second, the estimated feed equation differs from previous models in the assumption of zero degree homogeneity. By definition, proportional changes in all prices will not affect the estimated quantity of wheat demanded for feed.

The regression equation actually estimated is:

$$
\begin{aligned}
\text{WHEDF} = {} & \underset{(8.29)}{268.471} - \underset{(-9.43)}{4957.59}\ \text{WHEPF/PFEC}(+1)\\
&+ \underset{(3.08)}{2170.98}\ \text{SORPF/PFEC}(+1)\\
&- \underset{(-4.96)}{99.1894}\ \text{DV6467} + \underset{(5.26)}{147.022}\ \text{DV73}
\end{aligned}
$$

R-SQUARED(CORR.): 0.883
SEE: 25.322
DW: 2.08

ELASTICITIES:
E(WHEDF.WHEPF) = -3.29
E(WHEDF.SORPF) = 1.62
E(WHEDF.PFEC(+1)) = 1.67

PERIOD OF FIT: 1956-74 (4.2)

The dummy variable DV6467, which takes on values of one in 1964 and 1967, is included to account for distortions in the usual seasonal patterns of wheat and grain sorghum price *(8)*. DV73 takes on a unit value for 1973; including this variable (DV73) gives the same result as omitting the observation from the historical period. The rationale is that a price freeze was imposed in this year and producers overestimated the extent of future beef price increases. Hence, feed demand was abnormally high during this crop year *(38)*. Each variable is significant at the 0.05-percent level, and the other statistical properties of the equation are acceptable.

Seed Use. Seed use is a relatively minor component of demand. Without elaborate theoretical devices, the historical variation is explained well by acreage in the following year. With the addition of trend (TIME) to account for the regular rise in per acre plant population, the following specification is adequate:

$$\text{WHEDS} = -10.7006 + 1.1688\ \text{WHESA}(+1) \quad (-4.08) \quad (49.24)$$
$$+ 0.01475\ \text{TIME} \quad (4.91)$$

R-SQUARED(CORR.): 0.990
SEE: 1.049
DW: 1.21

ELASTICITY:
E(WHEDS.EWHESA) = 1.02

PERIOD OF FIT: 1950-74 (4.3)

Inventories

The traditional theory of inventory behavior holds that inventories are an element of demand. Briefly, the argument is that speculators will accumulate grain until the marginal cost of stockholding equals the expected gain from holding inventories. Usually, the expected gain is taken as the difference between the expected price for the next year and the currently observed price. Others argued that one should use accelerator models, which related inventories to the level of economic activity. For agricultural commodities, inventories could be related to output because of: (1) time lags involved in moving grain through marketing channels and (2) processors' need for material to meet production goals. Labys reviews these theories, as well as some examples of empirical applications (*22*).

An alternative view, that inventories are a measure of market disequilibrium, has also been suggested (*13*). This latter view also includes the postulate that inventories (relative to output) determine the sign and rate of price adjustment. Thus, one might estimate the following price adjustment equation:

$$P_t = \alpha + \beta \frac{I_t}{QP_t} + \gamma P_{t-1}$$

where:

P_t = current price,

I_t = inventory change from previous period, and

QP_t = current production.

The relevance of this specification hinges on the estimated coefficient for lagged price (8). When γ approaches 1.0, market adjustment towards equilibrium price is slow. Adjustments toward equilibrium occur more quickly as γ approaches zero and, at the extreme equilibrium, occur within 1 crop year. Heien's estimates for wheat price, based on 1950-70 data, gave estimates for γ at approximately 0.1. We included data through 1975 and obtained γ estimates of 0.95.

The disequilibrium approach may be appropriate for quarterly or monthly crop models. However, simulations of the complete wheat model with a price adjustment equation based on recent information showed that turning points were consistently missed. In short, this inventory specification suggests a rigidity not present in agricultural markets—at least not in annual averages. Thus, the inventory demand specification seems superior for annual models.

Algebraic statements of inventory demand hinge on the assumptions that: (1) transactions demand is measured by current production and (2) expected speculative gains are reflected by the difference between expected price for the following year and current price. Upon summation of transactions and speculative demands, a linear representation of inventory demand could be written as:

$$IC_t = a + bQP_t + c(PW^*_{t+1} - PW_t)$$

where:

IC_t = commercial wheat inventories, end of year t,

QP_t = commercial wheat production, year t,

PW_t = commercial wheat price, year t, and

PW^*_{t+1} = expected wheat price, year t+1.

Various extensions of this inventory model have been proposed. One hypothesis is that transactions demand is based on desired output and only a fraction of the difference between desired output is amenable to adjustment between years. This model requires the inclusion of current production and lagged inventories for measuring transactions demand. The determinants of speculators' price expectations have also received considerable attention. Some specifications suggest that next year's expected price depends on current and past prices. Others have argued that actual futures market prices are a better proxy for price expectations, as the futures should discount the information available at the time decisions are made.

The hypothesis considered here is that inventory-holders formulate price expectations by observing the prospects for supply conditions in the following year. In analyzing the wheat economy, one must include USDA production forecasts as well as the accumulation of Government-owned grain. Under the assumption that USDA production projections and speculators' assessment of Government stockholding are accurate, one might represent this hypothesis as follows:

$$PW^* = d - eQP_{t+1} - fIG_t$$

where:

IG_t = Government-owned wheat inventories.

The inventory relation also can be written in terms of observable variables as follows:

$$IC_t = (a + cd) + bQP_t - ceQP_{t+1} - cfIG_t - cPW_t .$$

The empirical inventory equation followed this hypothesis with minor alterations. Specifically, we included a wholesale price index as a proxy for wholesalers' output prices. We also specified a nonlinear inventory response to price. This hypothesis improved the Durbin-Watson statistic; linear price response specifications produced negative residuals with low prices and positive residuals with high prices. The following equation is the best of a series of preliminary regressions:

$$\begin{aligned} WHEHA = &-105.586 - 404.155\ LOG(WHEPF) \\ &\quad(-0.76) \qquad (-5.46) \\ &+ 6.9445\ WPI + 0.2448\ WHESP \\ &\quad(2.30) \qquad\quad (2.08) \\ &- 0.1399\ WHEHH - 0.2640\ WHESP(+1) \\ &\quad(-2.74) \qquad\quad (-1.94) \end{aligned}$$

R-SQUARED(CORR.): 0.825
SEE: 70.385
DW: 1.47

ELASTICITIES:

E(WHEHA.WHEPF)	= -1.70
E(WHEHA.WPI)	= 2.97
E(WHEHA.EWHESP(-1))	= 1.34
E(WHEHA.EWHESP)	= -1.50
E(WHEHA.WHEHH)	= -0.34

PERIOD OF FIT: 1951-74 (4.4)

Production

Producer response investigations are usually cast as separate analyses of acreage and yield. Indeed, "acreage response" and "production response" are often used interchangeably, as land is the dominant factor of production. The focus on planting decisions is also justified because planting occurs prior to most weather influences and Government programs usually require planting within guidelines. Yields are traditionally viewed as dependent on environment and technology. To the extent that factors such as fertilizer and chemical applications influence productivity, however, it is likely that yield (or production) outcomes are partially the result of economic decisions.

Farmers' planting decisions would depend mainly on anticipated prices in a free market environment. However, the array of Government commodity programs complicates the analysis for most major U.S. crops; guaranteed minimum prices on production, payments for removing land from production, and planting within Government guidelines as a prerequisite for access to payments are common forms of public acreage control. Realistic analyses of acreage response must account for the market and for Government influence.

Wheat acreage response relations feature the "effective support and diversion payment rate" method for measuring Government program attractiveness and employ past market prices as indicators of upcoming market conditions. Previous wheat acreage estimates using this method and supporting data have been reported in other studies (*15*, *18*). Effective Government payment rates are the product of nominal payment rates and the proportion of base acreage eligible for planting (or required for diversion and set aside). In effect, these variabl. : state the payment rate in terms of the base acreage; announced payment rates are typically stated in terms of planted or diverted acreage. When Government programs or market conditions for substitute crops are not important, an estimating relation is as follows:

$$AP_t = f(PF_t, PD_t, PM_{t-i}: i = 1, ..., n)$$

where:

AP_t = planted acreage,

PF_t = effective support rate,

PD_t = effective diversion payment rate,

PM_{t-i} = market price in year t−i,

$PF_t = \gamma_1 PA_1$,

γ_1 = proportion of acreage eligible for planting,

PA_1 = announced payment rate on planted acreage,

$PD_t = \gamma_2 PA_2$,

γ_2 = proportion of base acreage required for diversion, and

PA_2 = payment rate on diverted (or set-aside)acreage.

It is assumed that the choice of nonland inputs occurs after the planting decision. A shortrun production response relation then follows from standard production theory (*17*). Given the technical relation between production (QP), fixed land use (L^0), and other inputs—such as fertilizer (F):

$$QP = f(F, L^0) ,$$

the first-order conditions for profit maximization suggest the following output response:

$$QP = g\left(\frac{P^*}{PF}, L^0\right)$$

where PF is an index of fertilizer prices and P^* is the expected output price. This relation among production, relative prices, and acreage provides the economic foundation for the production analysis that follows.

Acreage Response. Previous studies of wheat acreage response focused on measuring the effect of Government programs but included market prices with a 1-year lag. A single-equation model produced acreage elasticity estimates of 0.64 for effective price supports, −0.02 for effective diversion payments, and 0.4 for lagged market price *(18)*. A regional study produced total acreage elasticities that were similar to those in the single-equation model *(15)*. However, all elasticities were slightly smaller in absolute value. In addition, the regional estimates: (1) confirm that wheat acreage in the Great Plains States dominates the adjustment to Government programs and market conditions and (2) show a cotton/wheat substitution in the Southern Plains.

This wheat acreage analysis extends the results of earlier research in two respects. First, we measure important substitutions between wheat and other commodities. Second, we show that market price lags exceeding 1 year are plausible for wheat acreage.

Acreage response relations preserve the distinction between winter and spring wheat. For example, crop substitutions are defined along these lines. Winter wheat, grown mainly in the Southern Plains, competes with sorghum and cotton for land use. Spring wheat grown in the Northern States substitutes for barley acreage. If the Government sets acreage restrictions and price supports in the fall, winter wheat producers will plant under these rules. However, these provisions have occasionally been altered after winter and before spring seeding.

Some characteristics of Great Plains agriculture lead to the hypothesis of long, gradual adjustments to changing market conditions. For example, fallowing is a common practice in semiarid regions. This leads to a more complex model of land use, as farmers must decide what crop mix to plant, as well as what acreage to fallow. Consequently, acreage levels for any given year depend on recent fallowing decisions. Moreover, higher prices could call for gradual alterations in fallowing patterns, as price increases would offset productivity loss resulting from more frequent land use. Also, a recent Soil Conservation Service inventory shows that the amount of land in the Southern Plains that could be readily converted to cropland is much higher than the national average (*36*). Adjustments to the land base also suggest long and gradual adjustments to market conditions, as land clearing, draining, and initial tilling occur over a number of years.

Estimates of winter and spring acreage response confirmed that sorghum, cotton, and barley compete with wheat for land use. In the winter wheat equations, market prices and effective support rates for wheat, sorghum, and cotton were all significant. In the spring wheat equation, barley support rates were not significant but barley market prices are included in the relationship. Wheat diversion payment rates and a dummy variable (DV62*72) are included: these variables measure the effects of diversion policy for wheat and competitive crops.[7]

The results below show 4-year price lags for winter acreage and 3-year lags for spring acreage In both equations, we assumed that the lag lengths are equal for wheat and competitive crop prices. We computed the market price coefficients via the Almon method of estimating distributed lags; we assumed that the lag structure declined on a straight line and constrained the weight for the period after the last price at zero.

$$
\begin{aligned}
AWWP(+1) = {} & \underset{(0.17)}{922.3176} - \underset{(-4.16)}{9482.5059}\ WHEPDW(1) \\
& + \underset{(4.34)}{12458.5342}\ WHEPE(1) \\
& - \underset{(-3.63)}{38930.5646}\ COLPE(1) \\
& - \underset{(-1.71)}{2370.02}\ DV62{*}72 - \underset{(-0.96)}{2297.2023}\ SORPE(1) \\
& + \underset{(6.18)}{3569.5321}\ \frac{WHEPF}{COLPF} + \underset{(6.18)}{2677.1491}\ \frac{WHEPF(-1)}{COLPF(-1)} \\
& + \underset{(6.18)}{1784.7661}\ \frac{WHEPF(-2)}{COLPF(-2)} + \underset{(6.18)}{892.3830}\ \frac{WHEPF(-3)}{COLPF(-)} \\
& - \underset{(-4.09)}{856.5352}\ \frac{SORPF}{COLPF} - \underset{(-4.09)}{642.4014}\ \frac{SORPF(-1)}{COLPF(-1)} \\
& - \underset{(-4.09)}{428.2676}\ \frac{SORPF(-2)}{COLPF(-2)} - \underset{(-4.09)}{214.1338}\ \frac{SORPF(-3)}{COLPF(-3)}
\end{aligned}
$$

[7]The dummy variable DV62*72 takes on values of one in the 1962-72 period.

R-SQUARED(CORR.): 0.876
SEE: 2018.3
DW: 2.02

ELASTICITIES:

(1) PRICE SUPPORTS:
E(AWWP.WHEPDW) = −0.3
E(AWWP.WHEPE) = 0.42
E(AWWP.COLPE) = −0.22
E(AWWP.SORPE) = −0.04

(2) FARM PRICE, 1ST YEAR:
E(AWWP.WHEPF) = 0.51
E(AWWP.SORPF) = −0.14
E(AWWP.COLPF) = −0.37

(3) FARM PRICE, 4TH YEAR:
E(AWWP.WHEPF) = 1.24
E(AWWP.SORPF) = −0.33
E(AWWP.COLPF) = −0.92

PERIOD OF FIT: 1955-75 (4.5)

$$
\begin{aligned}
\text{ASWP}(+1) = {} & \underset{(0.28)}{687.792} - \underset{(-2.44)}{3861.36}\ \text{WHEPDS}(1) \\
& + \underset{(6.30)}{9216.4}\ \text{WHEPE}(1) - \underset{(-3.09)}{2364.6}\ \text{DV62*72}(1) \\
& + \underset{(1.57)}{1351.95}\ \text{WHEPF} + \underset{(1.57)}{901.3}\ \text{WHEPF}(-1) \\
& + \underset{(1.57)}{450.65}\ \text{WHEPF}(-2) \\
& - \underset{(-1.32)}{1866.6}\ \text{BARPF} - \underset{(-1.32)}{1244.44}\ \text{BARPF}(-1) \\
& - \underset{(-1.32)}{622.219}\ \text{BARPF}(-2)
\end{aligned}
$$

R-SQUARED(CORR.): 0.864
SEE: 1436.5
DW: 1.55

ELASTICITIES:

(1) PRICE SUPPORTS:
E(ASWP.WHEPDS) = 0.25
E(ASWP.WHEPE) = 0.98

(2) FARM PRICE, 1ST YEAR:
E(ASWP.WHEPF) = 0.18
E(ASWP.BARPF) = -0.29

(3) FARM PRICE, 3RD YEAR:
E(ASWP.WHEPF) = 0.35
E(ASWP.BARPF) = -0.29

PERIOD OF FIT: 1949-75 (4.6)

These estimates of Government wheat policy and the shortrun effect of wheat prices conform with previous work. The mean value elasticity of total wheat acreage with respect to the wheat effective support rate is 0.43, this result is virtually identical with the estimates of Houck and others (*18*). The wheat diversion response, an elasticity estimate of −0.03, is slightly larger than the earlier estimate. The response to changes in last year's market prices is also similar; these estimates give an elasticity of 0.42, compared with 0.43 in the earlier study. However, the results differ from previous wheat acreage research in that measurements of crop substitution are provided and the distinction between long and shortrun response is introduced. The estimated substitution is largest for cotton, followed by sorghum and barley. The total wheat acreage elasticity for a 4-year sustained price increase is in the elastic range (1.04) largely due to winter acreage response.

Shortrun Production Response. While the shortrun production response relation can be specified on the basis of an economic model, one must consider several other factors in an empirical analysis. The influence of weather is partially measured with a season pasture condition index for the spring and winter wheat areas. Linear trend accounts for the technological advances of past years. The time lag between production and harvest decisions must also be considered when one specifies appropriate price lags.

As winter wheat is dominant, the season average price for the 2 marketing years prior to harvest is employed, and the fertilizer price index is an average of spot observations for the April and September prior to winter wheat planting. Thus, the equation below is a reasonable result:

$$
\begin{aligned}
\text{WHESP}(+1) = &- \underset{(-5.42)}{2778.32} + \underset{(1.02)}{10189.4}\ \text{WHEPF}-1/\text{WHEPPF} \\
&+ \underset{(5.76)}{15.6994}\ \text{WHESA}(+1) + \underset{(3.17)}{8.8170}\ \text{WHEWC}(1) \\
&+ \underset{(6.81)}{36.9061}.\text{TIME}
\end{aligned}
$$

R-SQUARED(CORR.): 0.896
SEE: 95.025
DW: 2.69

ELASTICITIES:
E(WHESP.WHEPPF-1) = 0.13
E(WHESP.WHEPPF) = -0.13

PERIOD OF FIT: 1952-74 (4.7)

Foreign Demand

We measure the factors which strongly influence U.S. exports for two dramatically different markets. The standard free trade model describes the commercial demands of the less developed countries (LDC's), but export subsidies and U.S. food aid policies also strongly influence commercial exports. Results show competition among major food grains (wheat, rice, and coarse grains) at world price levels. Measurements also indicate extensive, but not perfect, substitution between U.S. food aid exports and LDC commercial wheat demands. Demands in the developed countries are restricted by the insulating price policies in Japan and the European Economic Community (EEC). We measure other important influences on this smaller, but more complicated, segment of the U.S. export market; we consider the effect of rising incomes on human consumption and importation of U.S. wheat and the widespread practice of wheat feeding in the EEC.

Numerous trade restrictions, such as policy-determined internal consumption prices, price fixing by exporters, and food aid policies, have characterized international wheat trade. When quantifying export demand for U.S. wheat, one must consider these policies; an appeal to the usual free trade arguments does not provide a sufficient background for modeling the export demand for U.S. wheat.

We do not attempt here to consider all dimensions of international wheat trade. Rather, we develop techniques applicable to measuring the demand of major importing regions for U.S. wheat. In particular, we develop and estimate a relatively simple empirical model in which the role of institutions in wheat trade for Japan, the LDC's as a region, and Western Europe is taken into account.

We develop the background for the empirical model by first reviewing some important international wheat trade policies. With these policies in mind, we then elaborate on an estimation method which builds on the rigid relationship between regional imports and their purchases from the United States. We then present the results for the LDC's, Japan, and Western Europe. Finally, we draw overall implications for U.S. exports.

The Institutional Setting

An exhaustive study of international wheat trade policies would require volumes rather than pages. Although we highlight specific policies, we encourage the reader to examine the excellent summary of Hadwiger (*10*) and the important empirical studies of Schmitz and Bawden (*31*) or Takayama and others (*33*).

Major Importers. Unlike the trade in coarse grains and soybeans, homogeneous regions may be important importers as well as exporters of wheat. This paradox is resolved by the widely varying qualities of wheat produced. A region (the European Economic Community (EEC), for example) may produce a surplus soft wheat, which is marginal in the production of flour (bread), but also need to import large quantities of hard wheat. Developing a measure for a region's wheat imports is further complicated by the importance of food aid shipments to some regions.

Thus, we consider the importance of several regions in U.S. wheat exports (table 1). The percentage of U.S. wheat exports to developed countries has been stable since 1960 (20-25 percent of total exports); a slight decline over time reflects the reduction in AID shipments to these countries. Japan is the most important single importer, accounting for about 10 percent of total exports. The EEC is the second most important importing region.

LDC's accounted for the remaining proportion of total exports until the centrally planned countries (primarily the USSR and China) entered the market in the early seventies. The pattern of exports to LDC's illustrates the importance of P.L. 480 and AID exports to U.S. wheat exports. In the early sixties (1960/61-1963/64), an average 87 percent of exports to LDC's occurred under the several programs of U.S. food aid. Although the volume of exports to LDC's increased dramatically from the early sixties to the early seventies, the percentage of exports made under food aid programs fell to about 25 percent.

The market for U.S. wheat in the developed countries is dominated by Japan and the EEC. Moreover, both Japan and the EEC pursue policies that fix internal prices (*11*, *32*). In the EEC, this is achieved with a fixed minimum import price (threshold price); a variable levy ensures that wheat does not enter the EEC at less than the threshold price. If this system functions correctly, internal price equilibrium is near the threshold price. In Japan, a Government monopoly maintains a fixed wheat price on the purchase and sale of wheat. All imported and domestically produced wheat is sold to the Japanese Food Agency at established prices. Government revenue is raised by requiring that Japanese wholesalers purchase wheat from the agency at a price generally above the world market price.

Table 1—Total U.S. wheat exports, by destination

Crop year beginning July 1	Total exports	Commercial	P.L. 480	Commercial		P.L. 480		Centrally planned country imports
				Developed countries	Less developed countries	Developed countries	Less developed countries	
	Million bushels	*Percent*						
1960	659	28.6	62.8	21.3	7.3	6.4	56.4	8.6
1961	723	30.6	61.7	22.4	8.2	4.0	57.7	7.8
1962	635	22.5	67.1	12.8	9.7	1.1	66.0	10.3
1963	845	31.7	53.3	22.0	9.7	1.2	52.1	15.0
1964	710	22.9	70.9	14.6	8.3	1.3	69.6	6.3
1965	867	38.1	55.2	22.5	15.6	.4	54.8	6.7
1966	744	57.8	39.8	24.5	33.3	.2	39.6	2.4
1967	761	46.9	51.4	21.0	25.9	—	51.4	1.6
1968	544	55.2	44.7	27.9	27.3	—	44.7	—
1969	607	55.7	44.3	28.0	27.7	—	44.3	—
1970	738	63.6	32.0	34.8	28.8	—	32.0	4.4
1971	632	63.2	36.6	25.9	37.3	—	36.6	.2
1972	1,186	53.0	11.8	22.1	30.9	—	11.8	35.3
1973	1,148	72.6	5.6	20.0	52.6	—	5.6	21.8
1974	1,039	78.3	12.4	20.2	58.1	—	12.4	9.0
1975	1,164	73.5	10.7	23.5	49.9	—	10.7	15.4

— = 0.

Japanese and EEC policies insulate these countries' markets from fluctuation in world wheat prices. In other words, excess demands are perfectly inelastic functions of world price. EEC import demand functions are inelastic only as long as the threshold price exceeds the c.i.f. price; this has generally occurred, excepting a few months during the 1973 crop year. In contrast, Japanese internal prices are fixed by law. Thus, the excess demand function is inelastic regardless of world price levels.

As import demands are perfectly inelastic for most of the developed world, the elasticity of demand for wheat imports is less than in the free trade case. Alternatively stated, export response to world prices in the traditional commercial markets originates primarily in the LDC's. Export demand by the LDC's is highly fragmented. Their share of the U.S. market is characterized by many importers holding a relatively small share individually but a relatively large share in aggregate. We assume that the export demand of the LDC's may be characterized by free trade.

Major Exporters. The supply side of the market is dominated by the United States, Canada, and Australia (see table 2). Over much of the historical period, these wheat producers have accumulated and stored large stocks of wheat. This oversupply pressured price downward and resulted in agreements to set price and limit supply.

Table 2—Average level of wheat exports and market share, by country, by selected period

Country	Average for 1960/61-1963/64 crop years		Average for 1972/73-1975/76 crop years	
	Exports	Market share	Exports	Market share
	Mmt.	*Pct.*	*Mmt.*	*Pct.*
Argentina	2.234	0.053	2.531	0.039
Australia	5.948	.141	7.022	.108
Canada	10.821	.257	12.825	.197
European Economic Community (EEC)	3.635	.086	11.622	.178
United States	19.509	.463	31.160	.478
Total	42.147	1.000	65.160	1.000

Source: Foreign Agricultural Service.

The excess supplies of Canada and Australia are controlled by monopolistic governmental agencies. The actions of these agencies largely determined the trade shares held by each exporter for much of the historical period.

McCalla argued that the United States and Canada acted like a duopoly until the midsixties (*24*). He maintained that the United States was willing to let Canada set the world market price and acted in concert with Canada in determining market shares.

U.S. policies in the fifties and sixties were designed to accommodate growing supplies and stable internal demands. The commercial export market was enlarged by offering a wheat export subsidy. Supplementing the subsidy program, P.L. 480 provided for wheat gifts and long-term credit sales to the LDC's.

In recent years, it has been unnecessary to bolster the U.S. export market; subsidies have been discontinued and P.L. 480 shipments have been drastically reduced. But subsidies and P.L. 480 are relevant to the historical analysis of wheat exports. Traditional tax/subsidy theory suggests that an export subsidy reduces world prices and increases U.S. exports (*4*, p. 20). Additionally, Fisher and Schultz have argued that P.L. 480 shipments influence recipient countries' wheat economies in the same manner as an increase in domestic supplies. Consequently, one would expect substitution between purchased wheat and gift wheat in the LDC's.

Implications for Analysis. These characteristics of the world wheat trade have led us to consider two postulates in our analysis. First, it is reasonable to assume that the U.S. share of foreign wheat markets is rigid. This assumption is buttressed by the fact that a few suppliers often cooperate and dominate world wheat trade. Moreover, the substitution between the traded hard wheats and domestically produced soft wheats is somewhat limited. Second, because of wheat price-setting policies in Japan and the EEC, imports do not respond to world prices in these countries.

A Model

We now provide algebraic statements of the relations we hypothesize to govern U.S. wheat exports. Regional import demands should be negatively related to domestic prices (P_i) and internal supplies (QS_i). Imports should also respond to other shifters (S_{ij}), such as the price of close substitutes or income, which are unique to the region under consideration. This relationship can be represented by:

$$M_i = a_i - b_iP_i - QS_i + \Sigma c_jS_i \qquad (5.1)$$

Wheat trade flow analysis can be conducted without rigorous application of the usual principle of transport arbitrage between regions because of the rigidities earlier suggested. The remaining task is to specify a technique which allows us to estimate U.S. exports to selected regions directly.

Unconditional Constant Marginal Share. The exports of an exporting region may be estimated directly as a function of price and demand shifters if the exporting region holds a constant marginal share of that region's imports. Let the constant marginal share equation be:

$$X_i = d_i + e_iM_i \qquad (5.2)$$

where X_i represents U.S. exports to the ith region and M_i represents the ith region's total imports. The coefficient e_i may be termed the marginal propensity to import from the United States. Substituting the import demand equation (5.1) yields:

$$X_i = d_i + e_ib_iP_i + \Sigma e_ic_jS_i - e_iQS_i \qquad (5.3)$$

Thus, we can estimate U.S. exports directly by using the variables of the import demand equation as arguments.

The constant marginal trade share (constant marginal propensity to import from the United States) should not be confused with a constant average trade share (constant average propensity to import from the United States) which assumes X_i/M_i is a constant. If the constant term is zero, the constant marginal trade share degenerates to a constant average trade share. If the constant term is positive, the constant marginal trade share exceeds the average trade share at all levels of imports. The United States is assumed to capture (lose) a fixed proportion of an increase (decrease) of the increased imports of a region.

The constant marginal trade share hypothesis implies the elasticity of U.S. exports to the ith region may be less than or greater than the own-price elasticity of the import demand of that region. Differentiating equation (5.2) and expressing the elasticity of the ith region's imports from the United States (E_{X_i,P_i}) as a function of appropriate elasticities yields:

$$E_{X_i,P_i} = \frac{MPI_i}{API_i} E_{M_i,P_i}$$

where MPI_i and API_i represent the marginal and average propensity to import from the United States, and E_{M_i,P_i} represents the own-price elasticity of the ith region's imports.

The own-price elasticity of ith region's imports from the United States can be related directly to internal own-price consumption elasticity (E_{D_i}). Expanding the elasticity relationship with this intent yields:

$$E_{X_i,P_i} = \frac{MPI_i}{API_i} \cdot \frac{D_i}{M_i} \cdot E_{D_i}$$

where D_i and M_i represent the reciprocal of the proportion of consumption (demand) imported. If the imports of a region are characterized by a constant average propensity to import from the United States, the own-price elasticity of imports from the United States is a proportion of the own-price demand elasticity of internal consumption demand.

Conditional Constant Marginal Share Hypothesis. We retain the assumption that each region's marginal propensity to import U.S. wheat is a constant. However, we also assume U.S. exports are influenced by excess supply conditions in major competing countries. Crop year supplies are an acceptable proxy for excess supply.

The appropriate linear expression for the conditional constant marginal trade share hypothesis is:

$$X_i = d_i + e_i M_i - f_i CS \qquad (5.4)$$

where f_i is the marginal propensity of the ith region to import from competing exporting countries based on exporters' supply (CS). Combining the conditional constant marginal share hypothesis (5.4) with the import demand equation (5.1) leads to:

$$X_i = (d_i + e_i a_i) - e_i b_i P_i + e_i \Sigma C_j S_j - e_i QS_i - f_i CS . \qquad (5.5)$$

The regional export demand equation can be estimated directly from observed data. Given sufficient degrees of freedom, other variables which systematically influence U.S. market share could be included in the estimation of the regional export demand equation.

Test Of The Constant Marginal Trade Share Hypothesis. The validity of the constant marginal trade share hypothesis can be tested by the direct estimation of equations (5.2) and (5.4). Table 3 reports estimates for Japan, the LDC's, and Western Europe. In general, the results are favorable and tend to validate the conditional constant trade share hypothesis.

The explanatory power of the unconditional constant marginal trade share equation for Japan is excellent. The explanatory power is not improved by conditioning the trade share on supplies in competing exporting countries. The fit of the equation is improved by conditioning the trade share on a qualitative dummy variable for west coast dock strikes.

Both the supplies of competing exporters and importers are significant variables in explaining U.S. commercial wheat exports in LDC's. The positive intercept (equation (1.5) in table 3) indicates that internal own-price elasticity will exceed the elasticity of U.S. exports to the LDC's.

The trade share equation for Western Europe is dominated by the EEC. From the beginning of the EEC in 1962 to the harmonizing of prices in 1966/67, the structure of European trade had to adjust to the Common Agricultural Policy. Consequently, the fit of the equation in table 3 is relatively poor. An additional conditioning variable is a dummy variable for 1972/73-1974/75 which reflects the imposition of policies to counteract the diverging value of member countries' currencies. Reducing the historical period to 1966/67-1974/75 markedly improves the explanatory power of the equation. Again, monetary policy is an important conditioning variable.

For Japan, Western Europe, and the LDC's, these results suggest that the conditional constant market share hypothesis may adequately explain the U.S. trade share. Certainly, other explanations could be advanced which justify the explanatory power of these equations. A key point, however, is that the results do not lead one to reject the conditional constant share hypothesis.

Table 3—Marginal trade share equations, by selected regions, by historical period, 1960-74 crop years

Region	Constant	M_i	CS	Z_i	R^{-2}	Standard error of estimate	Durbin-Watson coefficient
Japan:							
(1.1)	-1.04	0.776	—	—	0.904	0.245	2.89
	(3.70)	(11.53)					
(1.2)	-.86	.785	-0.0044	—	.898	.253	2.83
	(1.78)	(10.86)	(-.47)				
(1.3)	-.84	.754	-.0022	-0.187	.950	.176	2.13
	(2.51)	(14.74)	(.34)	(-3.70)			
LDC's:							
(1.4)	-2.76	.593	—	—	.916	1.43	1.11
	(3.52)	(12.39)					
(1.5)	2.44	.595	-.104	—	.938	1.22	1.58
	(1.08)	(14.52)	(-2.40)				
Western Europe:							
Historical period 1962-74 crop years							
(1.6)	-12.546	.560	—	1.178	.630	.52	3.04
	(2.86)	(4.11)		(2.08)			
Historical period 1966-74 crop years							
(1.7)	-1.298	.487	—	1.673	.936	.18	2.50
	(3.29)	(9.98)		(9.89)			

Dependent variable: U.S. commercial exports to ith region (mmt). Conditioning variables: M_i = total commercial imports (mmt); CS = supply in competing exporting countries (mmt); Z_i = Japan—dummy variable for west coast dock strikes, and Western Europe—currency realignment dummy variable.
( ) indicate t-values.

Regional Estimation Results

We now present estimates of the factors influencing U.S. commercial wheat exports to the LDC's, Japan, and Western Europe.

LDC's. The LDC's are by far the most important foreign outlet for U.S. wheat. Most of this wheat was received under concessional programs in the early sixties. But starting in the midsixties, P.L. 480 exports were gradually reduced (see fig. 10). Simultaneously, the U.S. commercial market expanded, and commercial exports to LDC's in 1974 accounted for 60 percent of the U.S. market.

As wheat is used almost exclusively for human consumption in the LDC's, consumer theory provided a complete specification of the excess demand relation. Prices of substitute food grains, income, and population were all considered as explanatory variables.

The important substitute food grains are rice and coarse grains. Rice is a staple food throughout Asia, and this region imports substantial quantities of U.S. wheat. A substitution between wheat and coarse grains is also plausible, as more than 90 percent of LDC coarse grain supplies is used for human consumption.

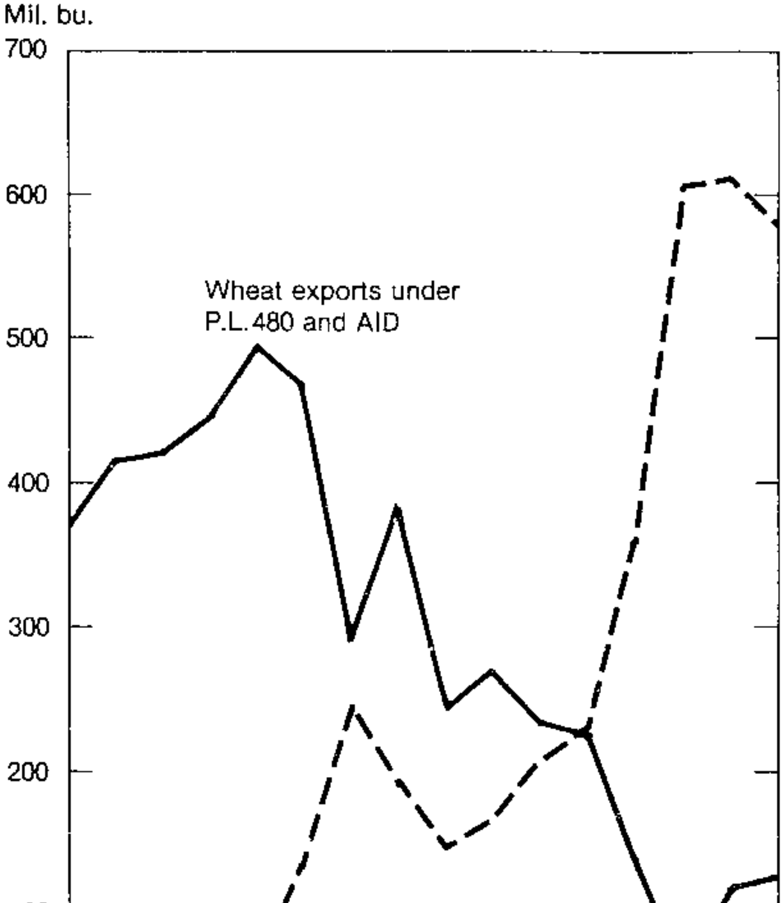
The hypothesis that the LDC's respond to world price levels carries implications for this analysis. Accordingly, U.S. prices of wheat, rice, and feed grains are used as indicators of world price levels. U.S. wheat and rice prices are adjusted by export subsidy rates for these commodities, thus accounting for world price levels being lower than U.S. prices during the sixties.

Given that wheat is a necessity, one would expect a fairly elastic, positive income response in the LDC's. Of course, attempts to construct an index of LDC incomes are beleaguered by poor or unavailable information. Thus, a tentative measure of LDC purchasing power was constructed from data for five major wheat-importing countries (Korea, Brazil, Venezuela, Algeria, and Morocco).

The population influence on internal demands is commonly specified in a per capita equation, which implies that the demand elasticity for population is unity. This argument suggests that import demands can also be expressed in per capita terms, as long as domestic supply variables are also expressed in per capita terms. We use this specification in the analysis of regional export data.

Figure 10

Commercial Exports and Exports under P.L. 480 and AID Programs to Less Developed Countries



It is also possible that U.S. currency devaluations of the early seventies influenced exports to the LDC's. Under the assumption of free trade, devaluation results in reduced internal price and a greater demand. Given the additional assumption that free trade prevails for the relevant substitute goods, a devaluation can also be expressed as an income expansion.

Let the import demand for a untry be:

$$M_i = f\ PW^*, PR^*, PFG^*, Y) \qquad (5.6)$$

where PW*, PR*, PFG* represent the internal price of wheat, rice, and feed grains, respectively, and Y represents income.

Under a free trade assumption, each internal price (P_i^*) is directly related to world market price (P_i) by the exchange rate (e). This relationship is:

$$P_i^* = eP_i \qquad (5.7)$$

which may be directly substituted in the import demand equation (5.6), yielding:

$$M_i = (ePW, ePR, ePFG, Y) \qquad (5.8)$$

Finally, as consumer demand is homogeneous of degree zero, the import demand may be rewritten as:

$$M_i = (PW, PR, PFG, Y\ e) \qquad (5.9)$$

Therefore, either inflating income *or* deflating prices yields the same result.

The estimated equation indicates that the export demand for U.S. wheat in the LDC region is moderately responsive to the wheat and rice prices and the price index for feed grains.[8] The equation below shows that the price elasticities for these commodities are -0.71, 1.06, and 0.27, respectively. The demand is also positively related to income with an elasticity of 1.12.

[8] An index of U.S. feed-grain prices (corn, sorghum, barley, and oats). Each commodity price is weighted by its percentage of human coarse grain consumption in the LDC's.

$$\frac{WXCU}{POPU} = \underset{(2.44)}{0.618} - \underset{(1.37)}{0.069}\,(WHEPF - SW) + \underset{(2.11)}{0.200}\,PFG$$
$$+ \underset{(0.95)}{0.005}\,(PR - SR)$$
$$+ \underset{(1.19)}{0.204}\,\frac{YCAP6U}{EXUS} - \underset{(2.69)}{8.29}\,\frac{QWPU}{POPU} - \underset{(1.84)}{3.70}\,\frac{QWSCO}{POPU}$$
$$- \underset{(4.4)}{0.60}\,\frac{WX48U}{POPU}$$

R-SQUARED(CORR): 0.952
SEE: 0.033
D.W. = 2.26

ELASTICITIES:
E(WXCU WHEPF) = -0.71
E(WXCU·QWPU) = -2.04
E(WXCU·YCAP6U) = 1.12
E(WXCU·PR) = 0.27
E(WXCU·WX48U) = -2.95
E(WXCU·QWSCO) = -0.94.
E(WXCU·PFG) = 1.06

PERIOD OF FIT: 1960-74 (5.10)

The estimated coefficients and related elasticities are within reasonable ranges. Usually, own-price elasticity exceeds the sum of cross-price elasticities. Estimates of these coefficients might be improved with an extended sample period and better measures of LDC grain import prices. The measured income response confirms the hypothesis of an elastic income response. It also highlights the impact of U.S. devaluation on the level of exports to the LDC's.

Japan. Japanese purchases of foreign wheat have expanded steadily since the early sixties. Simultaneously, Japan's share of the U.S. export market rose from 5 percent in the early sixties to roughly 12 percent in the seventies. The Japanese Food Agency's influence on the internal supply and demand circumstances is substantial. The resale price of wheat (in real terms) steadily declined over the historical period. Moreover, the Agency began discouraging domestic wheat production in the midsixties by gradually reducing the pegged farm level wheat purchase price (*37*, p. 108).

Both these factors increased Japanese foreign wheat demands. The deflated resale price of wheat, domestic wheat supplies, and U.S. exports to Japan are shown in figure 11.

As wheat is used mostly for human consumption in Japan, consumer demand theory again provides the cornerstone for specifying a regional export relation. Initial specifications include the controlled wholesale prices of wheat and rice, deflated by the consumer price index. We used an index of real per capita consumption expenditures to measure the income effect. We took the effect of expanding population into account by stating regression in per capita terms.[9]

Four general results emerged from a wide variety of preliminary regressions. The rice price effects either had the wrong sign or a low t-value. Additionally, all specifications showed a reasonable, significant, negative income response; this inferior foods result is in contrast to some previous research on Japanese wheat consumption.[10] Preliminary examination of data suggests that the extended west coast dock strike of 1971 had a substantial influence on 1971 wheat exports to Japan. Measures of dock strike length improved the R^2's substantially, but the significance and coefficient estimates for other explanatory variables were unaltered by the addition of this variable. Also, preliminary analysis indicated that supplies in competing exporting countries do not significantly influence Japanese purchases of U.S. wheat.

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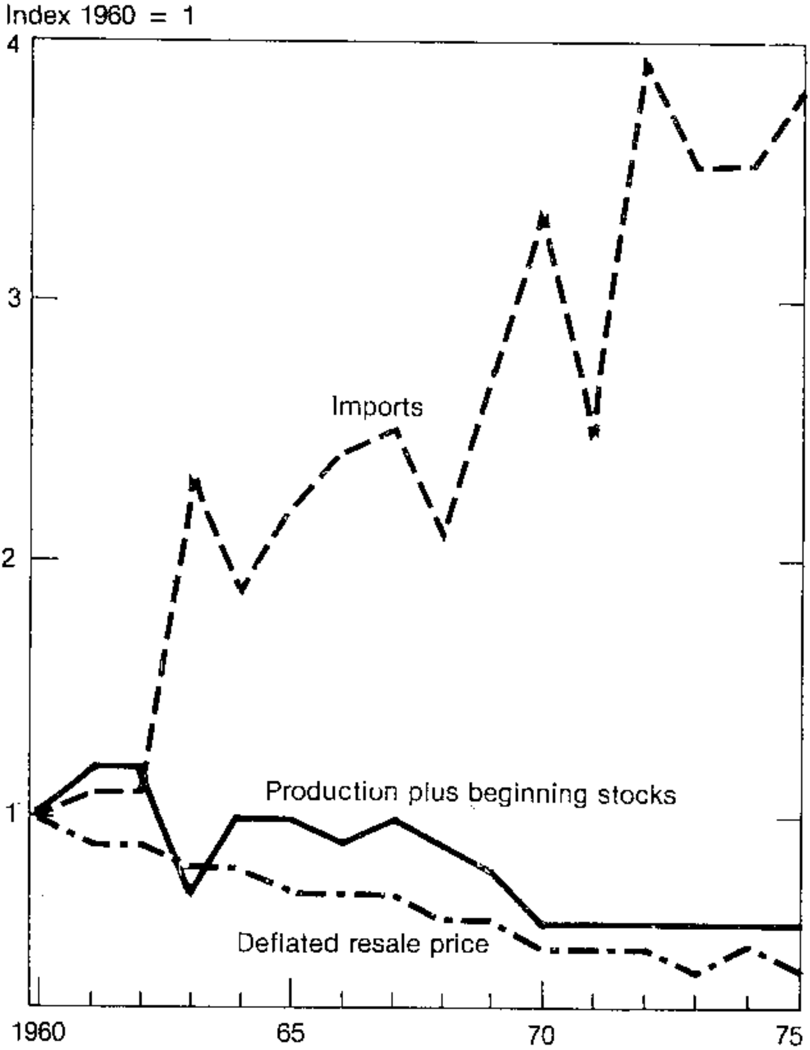
[9] A recent study of Japanese wheat consumption employs a similar specification. Takayama and others report a per capita consumption equation which depends on the real resale prices of wheat and rice (*33*).

[10] Schmitz and Bawden (*30*) show estimates of wheat food income elasticities for developed countries. Except for Japan, these estimates suggest that wheat is an inferior good in these countries. The Takayama study (*33*) includes an extended sample period; the authors conclude that income is an insignificant explanatory variable. Another study of Japanese demand extended a preliminary report of the findings in this study (*9*); the study utilized Takayama's specification with a short time series (1960-74). The estimated income response is negative and marginally significant. These results are not surprising in light of Japan's postwar economic growth. In fact, more refined estimates of the income effect should feature a log-log inverse form for the demand function, which allows wheat to become an inferior good at some stage of Japanese economic development.

Figure 11

Japanese Wheat Imports from the United States, Wheat Production Plus Beginning Stocks, and Deflated Resale Price



The relatively simple relationship between U.S. exports to Japan and (1) the wheat resale price, (2) own supply, (3) real income, and (4) a dock strike variable was selected as the "best" of several alternative equations.

$$\frac{WXCJ}{POPJ} = 2.07507 - \underset{(2.87)}{0.0018}\frac{RPWJ}{CPIJ} - \underset{(0.77)}{23.5319}\,YCAPJ - \underset{(2.52)}{17.2810}\,QWSJ - \underset{(3.88)}{0.0749}\,DSTRIKE$$

R-SQUARED(CORR): 0.930
SEE = 0.067
D.W. = 1.86

ELASTICITIES:
E(WXCJ·RPWJ) = −0.97
E(WXCJ·YCAPJ) = −0.33
E(WXCJ·QWSJ) = −0.43

PERIOD OF FIT: 1960-74 (5.11)

The variable DSTRIKE was included to account for years when prolonged west coast dock strikes occurred. The demand is relatively responsive to the wheat resale price with an own-price elasticity near minus one. The income variable is negative and marginally significant. The income elasticity is negative, which indicates that wheat is an inferior good in Japan.

Western Europe. For more than a decade, wide fluctuations in U.S. exports have characterized the West European market. Moreover, it is likely that policies in the dominant EEC have contributed to this instability. Threshold price policies have achieved a basic EEC objective—namely, domestic supplies have been increasing and imports have simultaneously declined. In fact, EEC wheat production expanded to the point where surplus disposal activities were enacted. For example, farmers were subsidized for wheat feeding of livestock throughout the sixties and the early seventies. In addition, subsidies were granted for exporting wheat to specified deficit areas outside the EEC. These latter policies have made internal demands dependent on fluctuating government subsidy rates in the EEC. And as a result of extensive wheat feeding, internal demands also depend on cycles in the feed-grain and livestock economies (*7, 11, 21*).

Further complexity is added by potential instability in the U.S. share of the West European import market. There are, however, well-defined periods of structural stability. In principle, the EEC was established in 1962, but members were allowed to set threshold prices independently through 1966. Only after 1966 were all countries subject to uniform threshold levels. Thus, it is a reasonable hypothesis that coefficients in the share relation changed after 1966. It is also plausible that the U.S. share of the West European market increased in 1972. Border compensation payments, which may have made intra-EEC trade more profitable, were initiated at that time.

It is not surprising, then, that estimating U.S. exports to Western Europe directly resulted in limited success. In some preliminary specifications, the assumed internal demand influences were limited to food and feed components. But the addition of variables for explaining structural change for the share relation nearly exhausted degrees of freedom. Estimated equations fit the data poorly, and individual variables often had incorrect signs.

Better results were obtained with separate demand (food and feed) and share equations. The implications for the U.S. export market, in this instance, are obtained by an algebraic combination of the more basic relationships.

Specification for feed demand relationships is well documented; the determinants are own and substitute feed prices, along with livestock population and price (*38*). In the EEC, wheat and corn are subject to variable levy policy, so threshold prices for these commodities are viewed as the feed-inducing prices. The wheat threshold price, however, is adjusted by subsidy rates for wheat feeding. In contrast to the controlled wheat and corn prices, free trade in soybeans prevails throughout Western Europe, and wheat feed demands should be influenced by world soybean prices. Thus, U.S. soybean meal prices are also included as an explanatory variable. The animal units and livestock price indexes are constructed from country data for the original six members of the EEC and for the United Kingdom; these countries account for over 90 percent of West European wheat feeding.

The estimated equation confirms the significance of feed prices in explaining Western Europe's feed demand:

$$\begin{aligned}QWDWEFE = {} & 1.8517 + \underset{(0.75)}{0.1253}\ AUD - \underset{(3.72)}{0.1730}\ (FWTH - SWEC) \\ & + \underset{(1.22)}{0.1334}\ PCTH + \underset{(2.91)}{0.4466}\ PM\end{aligned}$$

R-SQUARED(CORR): 0.864
SEE = 0.929
D.W. = 1.209

ELASTICITIES:
E(QWDWEFE·AUD) = 1.0
E(QWDWEFE·PCTH) = 1.04
E(QWDWEFE·PWTH) = -1.43
E(QWDWEFE·PM) = 0.19

PERIOD OF FIT: 1962-74 (5.12)

Coefficients for wheat, corn, and soybean prices are all significant at high confidence levels, and all coefficients have correct signs. Moreover, the high direct price elasticity (−1.43) seems reasonable, as it is consistent with other estimated wheat feed relationships.

The evidence of dependence on the livestock economy, however, is less conclusive. In preliminary regressions, livestock prices were insignificant and were entered with incorrect signs. When livestock prices are excluded, the population effect has the correct sign and a reasonable elasticity (near 1.0), but the t-value is very low. One explanation is the high intercorrelation between the animal units index and the corn threshold price: $r = 0.967$. Note also that the livestock economy indexes were defined for corn and soybean feed demand. Refined estimation should be based on more appropriate livestock economy indexes.

Studies of wheat food demand for individual European countries have found that income and population are the principal determinants (*31*, p. 23). As in most developed countries, price elasticities are very small and contribute little to demand variation. In preliminary regressions, therefore, per capita wheat consumption was expressed as a function of income and threshold prices.

The best explanation for per capita food use variation features income as the sole explanatory variable:

$$\frac{QWDWEFO}{POPWE} = \underset{(48.1}{0.1514} - \underset{(9.23)}{0.0310}\ YCAPWE$$

R–SQUARED(CORR): 0.876
SEE = 0.002
D.W. = 2.36

ELASTICITIES:
E(QWDWEFO·POPWE) = 1.0
E(QWDWEFO·YCAPWE) = −0.233

PERIOD OF FIT: 1962-74 (5.13)

The inferior goods result (income elasticity = −0.233) is consistent with studies of individual West European countries. The fit of this equation ($R^2 = 0.876$) could be improved. However, as Western Europe's food demand has been stable, the results are probably adequate.

Equipped with the estimated marginal share relation (equation (1.7) in table 3), food and feed demand elasticities can be translated into regional export elasticities. Table 4 gives this information for all the explanatory variables contained in the food and feed demand equations. The first column contains mean value elasticities for food and feed use, while the second column shows implied regional export elasticities.

The regional export demand elasticities highlight the importance of several variables not normally associated with wheat trade to U.S. wheat exports. For example, a 1-percent *increase* in the corn threshold price and soymeal price *increases* wheat exports to Western Europe by 2.2 and 0.4 percent, respectively. The threshold price for wheat also has a significant impact on wheat exports; the elasticity is −3.4.

Table 4—U.S. wheat elasticities, internal demand and regional export demand, Western Europe

Variable	Internal demand elasticity (mean value)	Implied regional export demand elasticity
Population	1.000	6.848
Income	−.233	−1.596
Wheat threshold price	−1.594	−3.396
Corn threshold price	1.038	2.212
Animal units	.996	1.598
Soymeal price	.187	.398

Implications

We have measured the factors which strongly influence U.S. exports for two dramatically different markets. The external demands of the LDC's were adequately described by the standard free trade model, with extensive influence exerted by U.S. export policies. The estimated relations show competition between major food grains (wheat, rice, and coarse grains) at world price levels. Measurements also indicate extensive, but not perfect, substitution between U.S. food aid exports and LDC commercial wheat demands. In contrast, demands in the developed countries are restricted by the insulating price policies in Japan and the EEC. We also measured other important influences for this smaller but more complicated segment of the U.S. export market; we have considered both the depressing influence of income growth and the effect of widespread West European wheat feeding.

Table 5 summarizes the elasticity of total U.S. exports (based on 1974 data) for several variables in the regional equations. The positive income response in the LDC's offsets the negative response in Western Europe and Japan. Hence, if income in each region increases 10 percent, U.S. exports of wheat will increase about 5 percent.

It is useful to examine the effect that developed country price policies have on the U.S. export demand elasticity. Under the assumption of continued internal price control in Japan and Western Europe, the own-price elasticity of total wheat exports is −0.41. In contrast, we used the market share weighted regional elasticity in the free trade case, as exports would respond to world price fluctuations. Under free trade, the own-price elasticity would be the sum of the own price, Japan's resale price, and EEC threshold price elasticities. Under the current set of policies, the own-price elasticity, −0.1401, is roughly half the size it would be under a free trade arrangement (−0.863).

Table 5—Elasticity of total U.S. export demand, by variable, 1974[1]

Variable	U.S. export demand
	Elasticity
U.S. prices:	
Wheat	-0.413
Rice	.157
Feed grains	.616
Soymeal	.037
Foreign prices:	
Japan wheat resale	-.107
EEC wheat threshold	-.313
EEC corn threshold	.095
Foreign income:	
Japan	-.038
Western Europe	-.147
LDC	.651
Total	.466
Other variables:	
P.L. 480 exports	-1.720

[1] An elasticity of U.S. export demand is the product of the corresponding regional demand elasticity and the market share for the region. This table is based on mean value elasticity estimates from the regressions and 1974 market shares. These market shares are 11 percent for Japan, 9 percent for Western Europe, and 58 percent for the less developed countries (LDC's).

Impact Multipliers

Changes that occur outside the U.S. wheat economy set off a chain reaction of adjustment in consumption, inventories, prices, and production in current and future years. We discuss the net effect of exogenous (external) changes in this section. Some of the more interesting estimates are: (1) The prospect of a U.S. drought in a subsequent year could increase the season average wheat price by 15 cents per bushel as inventories are built up and demand is reduced in the current year. (2) A change in the quantity of exports to centrally planned economies could influence wheat prices more than an equal amount of Government storage. In turn, Government storage could change prices more than the same quantity of P.L. 480. (3) When the Government is supporting prices at the loan rate, a demand expansion or a supply reduction call for a Government stock reduction of about equal magnitude. (4) If market forces resolve changes in supply and demand without Government intervention, a production-inventory and price cycle of about 6 years could occur.

The multipliers presented here measure the overall effect of changes that occur outside the U.S. wheat economy. For example, the single-equation analysis of chapter 4 showed that income expansions tend to reduce wheat food use. Multipliers provide a method for recognizing that the food demand reduction will reduce price, which will encourage wheat feeding and export.

Econometricians have developed multipliers which describe the shortrun, intermediate, and longrun effects of changes which occur outside the wheat economy. Intermediate and longrun multipliers for a crops model, such as ours, provide insights into the conditions for dynamic stability. Accordingly, the following section reviews the algebra for multipliers of all durations. Thereafter, we present results using the estimated equations in previous chapters of this analysis.

The Algebra Of Impact Multipliers

The analysis presented here assumes that all relationships are linear. The wheat economy results of subsequent sections are computed under the assumption that the underlying relationships are approximately linear in the neighborhood of a base solution for the model.

Reutlinger starts with the structural relations (chapters 4 and 5) and obtains expressions which show the immediate effect of exogenous variable changes (*28*). Suppose the estimated equations of previous chapters are written in matrix form as:

$$\Gamma Y_t = BY_{t-1} + \phi X_t \tag{6.1}$$

where:

Γ and B are n $\times$ n matrices of regression coefficients,

ϕ is an n $\times$ m matrix of regression coefficients,

Y_t is an n $\times$ 1 vector of endogenous variables, and

X_t is an m $\times$ 1 vector of exogenous variables.

The reduced form of (6.1) relates current endogenous variables (Y_t) to current exogenous (X_t) and lagged endogenous (Y_{t-1}) variables:

$$Y_t = AY_{t-1} + BX_t \tag{6.2a}$$

where:

$A = \Gamma^{-1}B$, and $B = \Gamma^{-1}\phi$.

The shortrun multiplier matrix measures the effect of a change in current values of exogenous variables:

$$\frac{\partial Y_t}{\partial X_t} = B = \Gamma^{-1}\phi \tag{6.2b}$$

Theil and Boot present further manipulations of equation (6.2a). Their expressions describe the evolution of Y over time and help one discern the conditions for dynamic stability (*35*). The final form of the equation system is obtained by successive substitution of (6.2a):

$$Y_t = \sum_{j=0}^{\infty} A^j BX_{t-j} \tag{6.2c}$$

Interim multipliers show the effect of a period t−j change in X on values of Y in period t:

$$M_j = \frac{\partial Y_t}{\partial X_{t-j}} = A^j B \tag{6.3a}$$

The interim multipliers are the building blocks for describing the dynamic behavior of Y. Suppose that in period 0, a longrun equilibrium is in effect; that is, $Y_0 = Y_{-1}$. Given a period 0 change in X that is sustained in subsequent periods (for example, $\Delta X_0 = 1$), the change between period k and period 0 values of $Y(\Delta Y_{k,0})$ is obtained by summation of the interim multipliers:

$$\Delta Y_{k,0} = \sum_{j=0}^{k} M_j = \sum_{j=0}^{k} A^j B \tag{6.4a}$$

On the other hand, one might consider the effect of a single shock in the period 0 value of X; that is, X returns to the initial level after period 0. In this case, the change in Y between periods j and $j-1(\Delta Y_{j,j-1})$ is:

$$\Delta Y_{j,j-1} = \left\{ \begin{array}{ll} M_j - M_{j-1} = A^j B - A^{j-1}B; & j \geqslant 1 \\ B; & j = 0 \end{array} \right\} \tag{6.4b}$$

The net deviation from initial value results on summation of period-to-period changes:

$$Y_{k,0} = \sum_{j=0}^{k} (A^j B - A^{j-1}B) = A^k B \tag{6.4c}$$

Equation (6.4c) illustrates that a return to the initial equilibrium levels, $\Delta Y_k = 0$, will result for some large k, provided that $A^k \rightarrow 0$ as $k \rightarrow \infty$. Theil and Boot point out that a necessary and sufficient condition for this result is that all characteristic roots of A are less than one in absolute values. In lieu of these computations, we will present the single shock multipliers in the following section, and the reader can judge that a return to the initial equilibrium would indeed take place.

Shortrun Impact Multipliers: The Shortage Case (Price Endogenous)

The impact multiplier matrix in table 6 shows the immediate effect on the wheat economy when an exogenous variable is changed from a previous level. The effects are computed based on simultaneous solutions for current-year utilization, price, and next year's supply under the assumption that current supply is fixed.

On examining table 6, under the category "U.S. wheat supplies and policy-controlled quantities," one first notices three quantities that are normally thought of as purely exogenous shifts in demand. Exports to centrally planned countries (WXST) are indeed an exogenous demand shifter in our model. Recall, however, that increases in P.L. 480 exports (WX48U) and Government inventories (WHEHH) have counterbalancing downward pressure on demand; increases in the former tend to reduce commercial exports while gains in the latter depress commercial inventories. Hence, Government inventories and food aid exports do not increase wheat prices as much as the fully exogenous demand shift. This tendency is especially dramatic for food aid exports; namely, a 100-million-bushel increase in exogenous exports increases domestic wheat price 27 cents per bushel, but historically the corresponding change in P.L. 480 has only boosted wheat price 10 cents.[11]

Several ramifications are unique to the current inventory specification, which requires that this year's demand and next year's supply be determined simultaneously. For example, the prospect of a severe drought next year could be interpreted as a 20-unit decrease in WHEWC (+1). This would account for increased inventories (25 million bushels) and a 15 cents/bushel price increase for the current year. Table 6 also shows the effects that Government support price announcements have on next year's acreage levels, and hence on this year's demand and price. In particular, a 10 cent/bushel increase in the effective support rate for wheat, WHEPE(+1), expands next year's production by 48.3 million bushels, reduces inventories by 8.738 million bushels, and reduces the current price by $0.033/bushel.

[11] The differences in these price impacts could change with more recent data. For example, farmer-owned reserves and Government stocks could substitute with commercial stocks differently. Also, recent regulations that exert more control over the distribution of U.S. food aid might reduce the substitution between commercial and P.L. 480 exports.

Table 6—Effect of changes in exogenous variables on current-year wheat utilization, following-year supply, and price (price endogenous)

Name	Unit	Change	1975 value
1975 value			
Foreign supplies:			
OWPLDC	Mmt.	1.00	68.8
QWSJ	do.	1.00	1.4
QWSWE	do.	1.00	62.3
QWSCO	do.	1.00	48.4
U.S. wheat supplies and policy-controlled quantities:			
WHEHH	Mil. bu.	10.0	0
WXST	do.	10.0	204.6
WX48U	do.	10.0	117.06
WHEWC(+1)	do.	10.0	80.38
Foreign commodity prices:			
RPWJ	Yen/kg	1000.0	49155.0
PWTH	UOA/mt	10.0	136.5
PCTH	do.	10.0	125.8
AUD	1970 = 100	10.0	104.2
Domestic commodity prices:			
CORPF	Dol./bu.	.10	2.5
SORPF	Dol./cwt	.10	4.2
BARPF	Dol./bu.	.10	2.4
OATPF	Dol./bu.	.10	1.4
COLPF	Dol./cwt	.01	.5
WHEPE(+1)	Dol./bu.	.10	1.9
SORPE(+1)	Dol./cwt	.10	2.3
COLPE(+1)	Dol./cwt	.10	.4
PM	Cents/lb.	1.00	7.0
PFEC(+1)	Dol./cwt	1.00	46.0
PR	Dol./cwt	1.00	17.35
Foreign macro economy:			
YCAP6U	1970 = 1.0	.10	1.14
YCAPWE	1970 = 1.0	.10	1.16
YCAPJ	1970 = 0.01	.001	.012
CPIJ	1970 = 100	10.0	171.2
POPU	Millions	10.0	1195.8
POPWE	do.	10.0	322.2
POPJ	do.	10.0	110.95
U.S. macro economy:			
EXUS	SDR/U.S. $	.10	.817
YCAPUS	1967 = 0.01	.001	.01
WPI	1967 = 100	1.00	174.9
POPUS	Millions	10.0	213.6

Continued—

Table 6—Effect of changes in exogenous variables on current-year wheat utilization, following-year supply, and price (price endogenous)—Continued

Name	Domestic demand			
	WHEDS	WHEHA	WHEDF	WHEDH
	Million bushels			
1975 value	95.0	560.0	86.0	559.0
Foreign supplies:				
QWPLDC	-0.304	4.067	2.161	0
QWSJ	-.839	11.268	5.966	0
QWSWE	-.750	9.787	5.143	0
QWSCO	-.162	2.162	1.150	0
U.S. wheat supplies and policy-controlled quantities:				
WHEHH	.332	-6.042	-2.491	0
WXST	.386	-5.398	-2.899	0
WX48U	.152	-2.283	-1.231	0
WHEWC(+1)	-.805	-12.356	7.512	0
Foreign commodity prices:				
RPWJ	-.068	.903	.481	0
PWTH	-1.294	16.956	8.888	0
PCTH	.957	-13.009	-6.919	0
AUD	.895	-12.226	-6.503	0
Domestic commodity prices:				
CORPF	.307	-4.690	-2.513	0
SORPF	-.070	-2.474	2.304	0
BARPF	-.135	-.462	-1.048	0
OATPF	.009	-.119	-.062	0
COLPF	-.230	.844	-.335	0
WHEPE(+1)	2.329	-8.738	3.374	0
SORPE(+1)	-.342	1.253	-.500	0
COLPE(+1)	-.418	1.529	-.609	0
PM	.285	-4.415	-2.368	0
PFEC(+1)	.070	-1.727	2.132	0
PR	.356	-4.458	-3.331	0
Foreign macro economy:				
YCAP6U	1.074	-14.773	-7.958	0
YCAPWE				
YCAPJ	-.279	3.723	1.979	0
CPIJ	.184	-2.448	-1.305	0
POPU	.397	-5.939	-3.193	0
POPWE	.821	-11.276	-5.999	0
POPJ	.561	-8.097	-4.366	0
U.S. macro economy:				
EXUS	-1.372	18.486	9.751	0
YCAPUS	-.757	9.797	5.187	-18.214
WPI	.264	3.140	1.977	0
POPUS	.965	-13.443	-7.251	24.216

Continued—

Table 6—Effect of changes in exogenous variables on current-year wheat utilization, following-year supply, and price (price endogenous)—Continued

Name	Foreign demand			
	WXT	WXCNS	WXCU	WXCJ
	Million bushels			
1975 value	1155.8	834.2	591.5	113.5
Foreign supplies:				
OWPLDC	-5.924	-5.924	-5.924	0
QWSJ	-16.395	-16.394	4.379	-20.874
QWSWE	-14.179	-14.180	3.948	0
QWSCO	-3.149	-3.150	-2.701	-.469
U.S. wheat supplies and policy-controlled quantities:				
WHEHH	-1.798	-1.798	-1.835	0
WXST	7.909	-2.090	-2.132	0
WX48U	3.363	-6.636	-6.708	0
WHEWC(+1)	5.649	5.649	5.649	0
Foreign commodity prices:				
RPWJ	-1.316	-1.316	.352	-1.676
PWTH	-24.549	-24.549	6.819	0
PCTH	18.971	18.971	-5.417	0
AUD	17.833	17.833	-5.092	0
Domestic commodity prices:				
CORPF	6.896	6.895	6.763	0
SORPF	.241	.240	.240	0
BARPF	1.645	1.644	1.681	0
OATPF	.172	.172	.175	0
COLPF	-.277	-.278	-.277	0
WHEPE(+1)	3.034	3.034	2.802	0
SORPE(+1)	-.412	-.412	-.412	0
COLPE(+1)	-.503	-.503	-.502	0
PM	6.497	6.497	-1.861	0
PFEC(+1)	-.476	-.476	-.740	0
PR	7.432	7.432	7.432	0
Foreign macro economy:				
YCAP6U	21.656	21.655	21.593	0
YCAPWE				
YCAPJ	-5.423	-5.424	1.451	-6.908
CPIJ	3.569	3.569	-.955	4.547
POPU	8.735	8.735	8.544	0
POPWE	16.453	16.453	-4.698	-.01
POPJ	11.902	11.901	-3.210	14.949
U.S. macro economy:				
EXUS	-26.864	-26.865	-27.022	0
YCAPUS	3.988	3.987	3.777	0
WPI	-1.427	-1.427	-1.456	0
POPUS	-5.216	-5.217	-5.325	0

Continued—

Table 6—Effect of changes in exogenous variables on current-year wheat utilization, following-year supply, and price (price endogenous)—Continued

Name	Foreign demand (Continued)			Supply in following year
	WXCWE	QWDWEFE	QWDWFO	WHESP(+1)
	Million bushels	*Million metric tons*		*Million bushels*
1975 value	129.2	11.0	38.3	2096.0
Foreign supplies:				
QWPLDC	0	0	0	-6.310
QWSJ	0	0	0	-17.411
QWSWE	-18.390	0	0	-15.557
QWSCO	0	0	0	-3.357
U.S. wheat supplies and policy-controlled quantities:				
WHEHH	0	0	0	6.884
WXST	0	0	0	8.003
WX48U	0	0	0	3.142
WHEWC(+1)	0	0	0	76.868
Foreign commodity prices:				
RPWJ	0	0	0	-1.404
PWTH	-31.815	-1.730	0	-26.838
PCTH	24.526	1.334	0	19.841
AUD	23.037	1.253	0	18.565
Domestic commodity prices:				
CORPF	0	0	0	6.359
SORPF	0	0	0	-1.453
BARPF	0	0	0	-2.789
OATPF	0	0	0	.190
COLPF	0	0	0	-4.778
WHEPE(+1)	0	0	0	48.300
SORPE(+1)	0	0	0	-7.898
COLPE(+1)	0	0	0	-8.662
PM	8.220	.447	0	5.917
PFEC(+1)	0	0	0	1.446
PR	0	0	0	4.270
Foreign macro economy:				
YCAP6U	.003	0	0	22.270
YCAPWE			0	
YCAPJ	0	0	0	-5.778
CPIJ	0	0	0	3.811
POPU	0.003	0	0	8.231
POPWE	21.233	0	1.155	17.021
POPJ	0	0	0	11.622
U.S. macro economy:				
EXUS	0	0	0	-28.447
YCAPUS	.003	0	0	-15.691
WPI	0	0	0	5.463
POPUS	0	0	0	19.999

Continued—

Table 6—Effect of changes in exogenous variables on current-year wheat utilization, following-year supply, and price (price endogenous)—Continued

Name	Supply in following year			Price
	WHESA(+1)	AWWP(+1)	ASWP(+1)	WHEPF
	Million acres	*1,000 acres*		*Dollars/ bushel*
1975 value	80.1	57.736	22.492	3.52
Foreign supplies:				
QWPLDC	-.232	-191.301	-36.695	-.020
QWSJ	-.641	-528.813	-101.434	-.056
QWSWE	-.591	-476.727	-91.445	-.049
QWSCO	.124	-101.738	-19.516	-.010
U.S. wheat supplies and policy-controlled quantities:				
WHEHH	.259	221.484	42.488	.024
WXST	.301	257.481	49.391	.027
WX48U	.122	110.395	21.176	.012
WHEWC(+1)	-.665	-540.424	-94.852	-.071
Foreign commodity prices:				
RPWJ	-.052	-42.519	-8.159	-.005
PWTH	-1.020	-823.391	-157.938	-.084
PCTH	.780	654.417	125.519	.067
AUD	.731	615.113	117.984	.063
Domestic commodity prices:				
CORPF	.262	238.621	45.766	.025
SORPF	-.049	-91.910	44.348	.024
BARPF	-.105	99.613	-207.625	.010
OATPF	.007	5.813	1.117	.001
COLPF	-.180	-186.766	6.422	.003
WHEPE(+1)	1.830	1042.742	818.824	-.033
SORPE(+1)	-.268	-277.455	9.535	.005
COLPE(+1)	-.327	-338.590	11.641	.006
PM	.245	224.973	43.145	.024
PFEC(+1)	.074	89.641	17.188	.010
PR	.282	240.191	42.154	.032
Foreign macro economy:				
YCAP6U	.830	704.363	135.098	.076
YCAPWE				
YCAPJ	-.213	-175.156	-33.594	-.019
CPIJ	.140	115.383	22.141	-.12
POPU	.317	285.668	54.785	.031
POPWE	.672	567.535	108.848	.058
POPJ	.441	387.898	74.395	.042
U.S. macro economy:				
EXUS	-1.049	-865.539	-166.023	-.092
YCAPUS	-.568	-455.715	-87.430	-.048
WPI	.205	175.781	33.719	.019
POPUS	.751	642.941	123.332	.069

Looking at the sources of competition will help us tell what the magnitude and size of substitute price multipliers should be. Corn and rice directly influence demand only, so an increase in the price of either commodity increases wheat price in the current year and production in the following year. Cotton's influence conforms with recursive models as an increase in cotton's price reduces next year's supply. Finally, sorghum and barley compete with wheat on both the supply and demand side. For both commodities, the demand effect is relatively smaller than the supply effect. Hence, an increase in this year's sorghum or barley price increases this year's price and reduces next year's wheat production. However, the output reductions are relatively small.

Shortrun Impact Multipliers: The Surplus Case (Price Exogenous)

The discussions in chapters 2 and 3 suggested that prices are often fixed near the loan rate during times of surplus. Consequently, shifts in wheat supply or demand result in shifts between Government stockholding and private use at the fixed price. Wheat loan rate changes involve similar substitutions between Government and private sector control of wheat. The table in appendix C contains impact multipliers for all exogenous variables in the wheat model. Table 7 illustrates the operation of the wheat economy under these conditions.

The types of impacts can be distinguished by the origin of the initial disturbance. The first row of table 6 indicates that the prospect of a drought in the United States (ΔWHEWC = −10) reduces next year's production (−86.5), which encourages the private sector to purchase additional inventories. As prices are fixed, however, neither domestic nor foreign demand changes. An expansion in domestic demand (ΔPFEC = +10) results in about a one-for-one substitution between domestic demand (+10.9 million bushels) and Government reserves (−12.68 million bushels). The discrepancy (1.77 million bushels) takes the form of higher commercial inventories, which are held because lower Government reserves enhance the prospects of speculative gains. Similarly, a foreign demand expansion (ΔQWPLDC = 1.0) results in a corresponding reduction in Government inventories, with a modest increase in private stocks. Finally, an increase in the wheat loan rate reduces all forms of current use and increases Government holdings by an equal amount.

Table 7—Selected impact multipliers for the surplus case, price exogenous[1]

Exogenous change	Commercial inventories	Domestic demand	Foreign demand	Following-year production	Government inventories
	Million bushels				
(1) Future supply reduction ΔWHEWC = −10 (71.3)	+26.147	0	0	−86.513	−26.147
(2) Domestic demand expansion ΔPFEC = +10 (21.51)	+1.770	+10.904	0	0	−12.675
(3) Foreign demand expansion ΔQWPLDC = −1.0 (40.141)	+1.225	0	+7.546	0	−8.771
(4) Wheat loan rate increase ΔWHEPF = 0.10 (1.85)	−34.782	−21.594	−5.922	+19.258	+62.298

[1] 1963 = base year.
\+ = increase.
− = decrease.

Dynamics: The Shortage Case

The dynamic properties of the wheat model are considered for the case of a 1-year change in exogenous demand. The effects of this 1-year disturbance (for example, a large Soviet grain deal) are tabulated for subsequent periods following the prescription of equation (6.4a). For convenience, the structural relations were linearized about 1975 values, and production and demand blocks were each reduced to one structural relation. This linearization, expressed in a form amenable to the use of equation (6.4c), is reported in appendix C.

Table 8 contains the period-by-period deviation from initial equilibrium values for 12 periods following the initial disturbance. An examination of

Table 8—Effects of an exogenous demand increase, periods 0 through 12[1]

Endogenous variable	Total demand	Inventory	Following-year production	Price per bushel
	Million bushels			*Dollars*
1975 value	2,455	560	2,096	3.52
Change compared with value in 1975:				
Period 0	-63.572	-36.428	+32.968	+0.2414
1	-1.448	-2.012	+36.299	+.0055
2	+18.814	+15.473	+6.680	-.0714
3	+12.490	+9.663	-9.675	-.0474
4	-.398	+.386	-11.238	+.0015
5	-5.945	-4.907	-1.823	+.0226
6	-3.646	-3.085	+3.943	+.0138
7	+.517	+.342	+3.274	-.0020
8	+1.992	+1.624	-.225	-.0076
9	+.999	+.850	-1.359	-.0038
10	-.294	-.215	-.952	+.0011
11	-.642	-.525	+.033	+.0024
12	-.268	-.232	+.802	+.0010

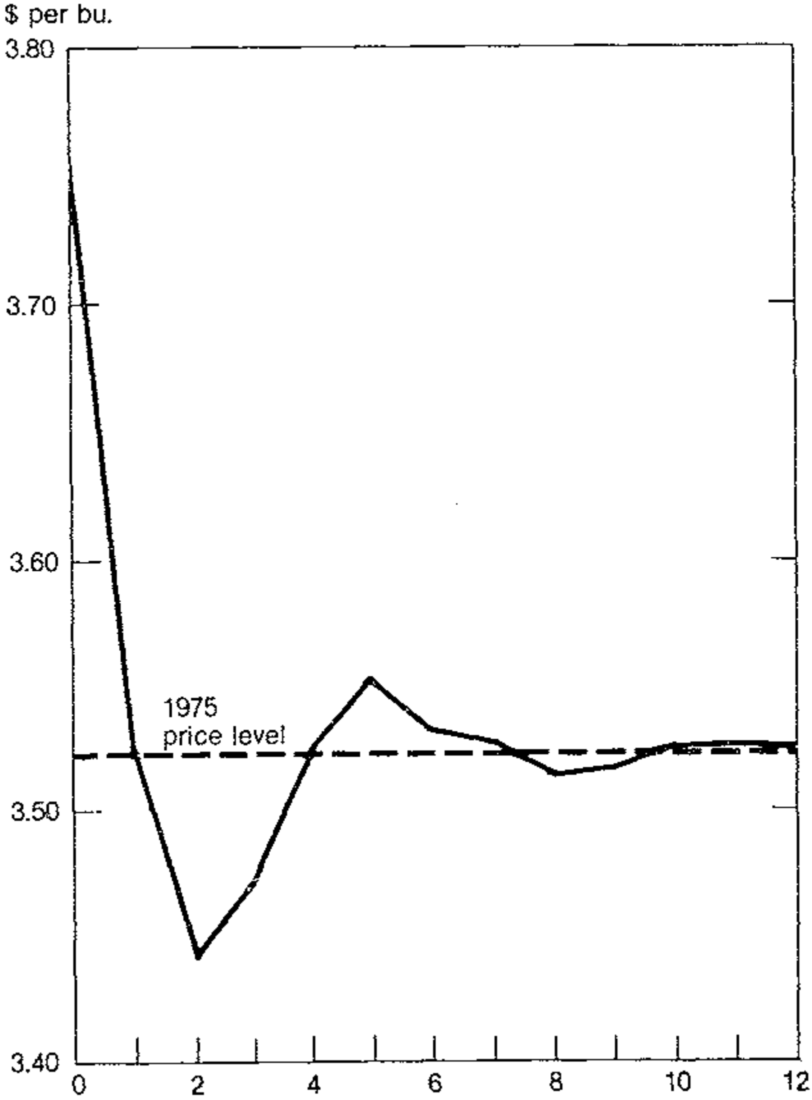
[1] Based on increase of 100 million bushels in period 0.

the column for period 0 shows the initial change; the increase in exogenous demand chokes off price-responsive demand, while higher prices encourage the sale of inventories and an expansion in production for the following year. However, the inventory reduction (−36.428) exceeds the expansion in production (+32.968), so that period 2 supplies are reduced (−3.460) and prices continue higher than the initial value for period 2. Nonetheless, net supplies for subsequent years increase and price reductions eventually occur.

An examination of price behavior over the entire period is instructive since prices indicate the net effects of production and inventory changes over time. In particular, the time path for wheat price indicates: (1) the cyclical properties of this model and (2) whether the system of equations is stable. Accordingly, we show the price level for periods 0 through 12 in figure 12. Wheat prices remain above the initial equilibrium level (3.52) for periods 0 and 1 and drop below it for periods 2 and 3. Subsequent periods indicate 3-year sequences of positive and negative deviations about the initial price level. Hence, the production and inventory relations eventually give rise to a 6-year cycle in wheat prices. Moreover, the system of equations is apparently stable as price fluctuations diminish over time.

Figure 12

Wheat Price Level, Period 0 through 12



Evaluation

We test the relationships of the wheat model as tools that can explain past events and predict future ones. Over the historical period, the magnitude of forecast errors was acceptable, most turning points were correctly predicted, and no evidence of bias in the estimates was found. Exports are the most difficult event to explain. In one application, the model was used as a short-term forecasting tool to forecast 1977 demand and prices before planting and after harvest. The directions of price, consumption, and inventory adjustment were correctly predicted, but price changes were larger and quantity changes smaller than actual behavior.

The model evaluation is conducted over two periods—a historical period and a prediction interval period. However, we estimated the equations over different historical periods. To accommodate the different estimation periods, we defined the historical period from 1962 through 1974. We defined the prediction interval period as 1975-76. Three equations have estimation periods which intrude into the prediction interval period. We estimated winter and spring acreage equations through 1976 and production through 1975. This should be kept in mind when the evaluation results are discussed. For all other equations, the prediction interval fell outside the estimation period.[12]

The historical period *per se* is not of interest. A "good" performance by the model over the historical period does not ensure that it will continue to perform well outside the historical period. However, poor performance over the estimation period would engender little confidence in a model's solution values outside that period.

In the solution procedure we used the solution values for the lagged values of endogenous variables rather than the actual values for those variables. Using solution values is a stricter test of the model and indicates how the model may behave if used for projections over long periods.

Dhrymes and others provide a number of useful nonparametric measures which are commonly employed in the evaluation of models (5, p. 314). The criteria which we used in the evaluation over the historical period are:

1. Mean absolute forecast errors (level and percent),

2. Mean absolute percentage change,

[12] This evaluation exercise was conducted with a single-equation export model, reported in appendix B.

3. Turning point errors, and

4. Test for bias and systematic errors in the forecasts.

The last test is used to determine if the forecasts could be improved by applying Theil's optimal linear correction procedure. The criterion used over the prediction interval is a comparison of the actual percentage change with the estimated percentage change.

The Historical Period: Forecast Errors

Table 9 presents an analysis of the mean absolute forecasting errors for each of the variables considered. Both the level and the percentage error are reported. The percentage error in wheat feed estimates, 32.5 percent, is the largest of all the endogenous variables. The wheat stocks variable had the next largest percentage error—over 30 percent. Among the demand variables, wheat stocks had the largest mean absolute error—nearly 78 million bushels. The exports variable was next with 35.6 million bushels, but a percentage error of only about 13 percent. On the supply side, production had a mean absolute error of 57.8 million bushels, a 3.9-percent error. The

Table 9—Mean absolute errors: Levels and percentage changes

Variable	Unit	Mean absolute error	Mean absolute percentage error	Mean absolute percentage change	
				Actual	Estimate[1]
			Percent		
Seed	Mil. bu.	3.8	5.5	10.4	7.1
Stocks	do.	77.9	30.4	46.0	42.7
Food	do.	5.2	1.0	1.0	.6
Feed	do.	29.1	37.5	76.0	89.2
Exports[2]	do.	35.6	13.3	37.7	23.1
Price	Dol./bu.	.12	6.9	20.9	21.7
Winter acres[3]	1,000 acres	3,097.40	6.9	9.6	6.0
Spring acres[3]	do.	860.10	6.6	13.4	12.0
Total acres[3]	Mil. acres	2.86	4.8	9.5	6.5
Production[3]	Mil. bu.	57.80	3.9	8.9	7.0

[1] Estimate = $[P(t) - P(t-1)]/P(t-1)$, where P_t is predicted value in year t.
[2] Non-centrally planned countries.
[3] For year t + 1.

other variables on both the demand and supply side had percentage errors of less than 7 percent. The very low errors associated with the food variable reflect the highly elastic demand for wheat as food. In fact, food demand is explained solely by income and is not influenced by price.

Table 9 also compares the actual and the estimated percentage change from year to year. Only the price and the feed variables had higher estimated than actual changes. For most variables, the actual and estimated percentage changes were similar. However, the export variable, the winter wheat acreage, and the total acres sown are three variables for which the estimated changes may be expected to underestimate the actual percentage changes.

In table 9, the stocks, the feed wheat, and to a lesser extent the exports variables are subject to the largest forecasting errors. The stocks variable is the most important in size of the error. In percentage changes, the model generally underestimates the absolute values of the year-to-year changes. For demand, the export and the feed variables had the poorest year-to-year change performances. For supply, the forecast percentage changes for winter acres and, consequently, total acres averaged only two-thirds of the actual percentage change.

The Historical Period: Turning Point Errors

Turning points are of interest in evaluating models. Many economic time series are positively autocorrelated, often to a high degree, and may exhibit strong systematic movement. Zarnowitz states, "These observations led to the now widely held idea that it should be rather easy to predict a continuation of the rise or fall in these series; to forecast correctly the end of the current movement or phase appears to mark a more meaningful predictive success" (*40*, p. 15).

There are two types of turning point (TP) errors. The first is that a turning point is predicted but none occurs. The second type is that a turning point occurs but none was predicted. Similarly there are two types of correct predictions. One is when a turning point is predicted and it does occur; the other, when no turning point is predicted and none occurs. These four possibilities may be arranged in a 2 x 2 table (N refers to the absence, T to the presence of a turning point). The first letter refers to actual values, the second to predictions:

Actual	Predictions: No TP	Predictions: TP
No TP	NN	NT
TP	TN	TT

The number of correct predictions is NN + TT. False signals are represented by NT and missed turns by TN.

Researchers commonly determine turning point errors by examining a plot of actual and predicted values and counting the instances when false signals or missed turns have occurred. Zarnowitz, however, states that the prediction for any future period is based on the estimate of the current value of the series, not on the past prediction that has already been superseded by the intervening information (*40*, p. 52). Therefore, to determine whether a turning point has been predicted, one should compare the forecasting change with the preceding actual change and not with the preceding forecasting change. In this study, however, because we solved the model by allowing the generated lagged values of endogenous variables to be used, not the actual values, we determined the turning points by considering the sequence of predicted changes and the sequence of actual changes to maintain consistency. That is, we used the sequence $P_t - P_{t-1}$ (predicted) and the sequence $A_t - A_{t-1}$ (actual) and not the sequence, $P_t - A_{t-1}$, suggested by Zarnowitz.

Because we are dealing with a sequence of signs, we define a turning point error as: (a) being associated with changes in the sign of either the actual or predicted change or both, and therefore, (b) resulting in a directional disagreement between the actual and the predicted changes. The definition excludes: (1) repeated directional errors (which do not follow directly upon any sign changes) and (2) the "corrective" directional changes (which result in an agreement of signs). For example, consider the following sequences:

Period	1	2	3	4	5
Sign of actual change	+	+	+	+	–
Sign of predicted change	+	–	–	+	+

There is a turning point error of the false signal type in period 2. In period 3 there is a repeated directional error, but no new turning point error. In period 4 the sign of the forecast sequence changes again and conforms with the actual change. This situation, however, corrects the previous error and is not a new turning point error. In the last period, there is a turning point error of the missed turn type.

Table 10 presents the results of the turning point analysis for the variables under consideration. The turning points which have been excluded from the count are those that correct previous turning point errors and that result in directional agreement between the two sequences. The number of repeated directional errors are also listed separately.

The model performs well with a high proportion of correctly predicted turning points and with very few missed. The food variable had one missed turning point and the export equation had two such points. It was more common for the model to falsely predict turning points, although the incidence was relatively low overall. Again, the principal "offenders" were the food and export variables. *In only one instance was a price change falsely predicted.* Two variables had repeated directional errors. The more important of the two was the winter wheat acreage sown. The model's performance might be improved by introducing regional factors that influence exports and by refining the analysis of winter wheat acreage response.

The Historical Period: A Test For Bias And Specification Error

Theil (*34*, p. 35) has demonstrated that if a linear relationship exists between the predicted (P_t) and the actual (A_t) values, one can improve the forecasts by applying a linear correction of the form $P_t^* = a + bP_t$. The procedure is termed the optional linear correction of the forecasts. Consider the relation:

$$A_t = a + bP_t + e_t \,.$$

The mean square error, $M_p^2 = \frac{1}{n} \sum_{i=1}^{n} (P_t - A_t)^2$, may be decomposed into three parts, namely:

$$M_p^2 = (\overline{P} - \overline{A})^2 + (1 - b)\, s_p^2 + s_u^2$$

Table 10—Frequency of turning points and errors

Variable	Number of turning points counted[1]					Number of turning points excluded[2]		Number of repeated directional errors[3]
	Actual	Predicted	Correctly predicted	Missed	Falsely predicted	Actual	Predicted	
	(TT + TN)	(TT + NT)	TT	TN	NT			
Seed	4	5	4	0	1	0	1	0
Stocks	4	5	4	0	1	1	1	0
Food	1	4	1	1	3	3	1	1
Feed	4	5	4	0	1	1	1	0
Exports[4]	6	7	4	[5] 2	[5] 3	1	1	0
Price	4	5	4	0	1	0	1	0
Winter acres[6]	3	5	3	0	2	1	1	1
Spring acres[6]	7	6	6	1	0	0	2	0
Total acres[6]	4	5	4	0	1	0	1	0
Production[6]	5	4	4	1	0	1	0	0

[1] Excludes the turning points in the last three columns.
[2] Directional changes that correct previous turning-point errors.
[3] Includes instances of divergent signs that have not changed from the preceding period.
[4] Non-centrally planned countries.
[5] Includes two instances of opposite sequence of signs in the actual and predicted series.
[6] For year t + 1.

where $(\overline{P} - \overline{A})^2$ is the squared mean error and equals zero if the predictions are unbiased $(\overline{P} = \overline{A})$; s_p^2 is the variance of the predictions, and this component is positive unless $b = 1$; s_u^2 is the variance of the disturbance term. The three components are the error due to bias, the systematic error, and the random error. If a relationship exists between A_t and P_t, then the optimal linear correction procedure will reduce the prediction error to the random component only. Corrections of this kind are useful when it is believed the forecaster will continue to make the same kind of systematic error.

In a finite sample, a statistical test is required to determine if the differences estimated between a and zero and b and one may be ascribed to chance. Regression coefficients and t values for tests of the null hypotheses, $a = 0$ and $b = 1$, are presented in table 11.[13] No variable has a t value for either a or b that exceeds the critical value of 2.201. Therefore, the hypothesis that $a = 0$ and $b = 1$ is accepted. Consequently, no advantage is to be gained by adjusting the predicted values of the endogenous variables. The model solutions are neither systematically underestimating nor overestimating the actual values.

The Historical Period: An Overview

Our subjective evaluation is that the model performs well over the historical period. The turning point analysis revealed that the export equation performed worst in missing turning points or falsely predicting them. Exports were suspect in the absolute percentage change evaluation and, to a

[13] Not strictly appropriate, as t statistics test the hypotheses that the estimates are independently equal to zero and one for a and b, respectively. The test required is a simultaneous one:

$$H_1: \quad \beta = \beta_0 \text{ versus } H_0: \beta \neq \beta_0,$$

$$\text{where } \beta = \begin{pmatrix} a \\ b \end{pmatrix} \text{ and } \beta_0 = \begin{pmatrix} 0 \\ 1 \end{pmatrix}.$$

The appropriate test statistic is:

$$\frac{(\hat{\beta} - \beta_0)X'X(\hat{\beta} - \beta_0)}{2s^2}$$

which has an F distribution under the null hypothesis.

lesser extent, in the mean absolute percentage error. The stocks and feed variables performed worst on the mean absolute percentage error test. The magnitude of feed use, however, in the overall utilization was not large. Neither evidence of bias in the predictions nor of systematic error was found.

Having evaluated the model over the historical period under the stringent test of causing it to use the solution values of the lagged dependent variables instead of the actual values, we now examine the model's performance in the prediction interval 1975 and 1976.

The Prediction Interval

To simulate the way the model is actually used, as a short-term forecasting tool, we consider two information states. The first state represents the situation prior to sowing when acreage and production predictions are available for the coming crop. In the model, these variables are predetermined based on estimates in the previous period. This estimated supply information is used in the simultaneous demand block to predict wheat use and price in the current year. A set of supply estimates for the next year's crop (t + 1) is simultaneously generated. The second state represents

Table 11—Test for linear relationship between predicted and actual values of endogenous variables

Variable	$\hat{a}$	t value[1]	$\hat{b}$	t value[2]
Seed	−14.529	−1.211	1.217	1.239
Stocks	−21.336	−0.259	1.036	.162
Food	−271.604	−1.372	1.520	1.363
Feed	9.662	.464	.915	−.585
Exports[3]	1.272	.045	.974	−.434
Price	−.084	−.737	1.058	1.041
Winter acres[4]	−1833.463	−.121	1.049	.145
Spring acres[4]	−63.317	−.034	1.014	.099
Total acres[4]	−8.963	−.809	1.158	.838
Production[4]	−158.192	−1.066	1.100	1.035

[1] Test for a = 0, critical value, 5-percent level (11 degrees of freedom (d.f.)) is 2.201.
[2] Test for b = 1, critical value, 5-percent level (11 d.f.) is 2.201.
[3] Non-centrally planned countries.
[4] For year t + 1.

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the situation at post-harvest. The actual acreages and production are known and these data can be fed into the demand block to predict wheat utilization and price in the current year. Again a set of supply estimates for next year's crop ($t + 1$) is generated.

For a given solution year, therefore, there are two predictions for the next year's supply (just as there are two utilization predictions) conditional on the information state. As we attempt to simulate the actual use of the model, we do not consider the next year's supply estimates made prior to the sowing of the current year's crop. Instead, we use the supply estimates obtained under a post-harvest information state. These estimates are available prior to sowing in the following year.

Table 12 presents the actual and the predicted percentage change from the previous year for the endogenous variables. The predictions are presented as they would be available at the prior-to-sowing and the post-harvest times of the year. The table presents the supply predictions for the current year, but as already discussed, the predictions were obtained from the previous year's model solution. The data were not available for predicting the 1976 use and price.

Table 12—Prediction interval test: Percentage change from previous year[1]

Endogenous variable	1975			1976		
	Actual	Prior to sowing	Post-harvest	Actual	Prior to sowing	Post-harvest
Seed	2.56	1.00	0.31			
Stocks	71.63	84.23	92.13			
Food	6.50	1.55	1.31			
Feed	38.83	102.10	102.59			
Exports	5.42	−4.95	−3.76			
Price	−13.94	−20.84	−22.18			
Winter acres	7.28	9.57	[2]	2.82	−1.01	[2]
Spring acres	−.36	−.08	[2]	18.80	16.97	[2]
Total acres	5.24	7.00	[2]	6.67	3.52	[2]
Production	18.81	17.47	[2]	−1.78	−2.74	[2]

[1] Predicted change = $(P_t - A_{t-1})/A_{t-1}$.
[2] Actual values known.

In 1975, all pre-sowing predictions had the correct sign, except the exports variable. A nearly 5-percent decline in exports was predicted, whereas a more than 5-percent increase actually occurred. The exports variable still had an incorrect sign under the post-harvest information state, but the magnitude had slightly decreased. In both information states, feed demand was predicted to increase more than 100 percent. The actual increase was slightly less than 40 percent. Again, the magnitude of actual feed use in overall utilization is not large. In both information states, a large increase in ending commercial stocks was predicted—which actually occurred. The nearly 72-percent actual increase was growth from 234 million bushels to 559 million bushels. In both information states, a decrease in season-average price in excess of 20 percent was predicted, and a price decline did occur; however, it was less than predicted. Except for the stocks variable, little difference exists between the two information state predictions. The actual changes in the supply variables seem to have been closely predicted.

For 1976, the increase in spring acres was closely predicted and so was the decline in production. (Production may decline because of weather and because of lower fertilizer use.) Winter acres were predicted to decline 1 percent (just over a half-million acres), but instead increased nearly 3 percent.

Concluding Remarks

The evaluation procedure was conducted over the historical period and a prediction interval period. The evaluation criteria used were those listed by Dhrymes and others (*5*, p. 314) as being commonly used to evaluate models. Furthermore, the actual values for the endogenous variables were regressed on the predicted values to determine if Theil's optimal linear correction procedure should be applied to the forecasts.

We evaluated the prediction interval period in a manner designed to simulate the actual use of the model, and we identified two information states corresponding to a prior-to-sowing and post-harvest situation.

The model performed well over the historical period, and it appeared to forecast well outside this period. Chen recently stated, "The most neglected aspect of model research is in forecasting evaluation, which is the best means for pinpointing biases and for improving forecast performance" (*2*). Our evaluation is a step towards ending this neglect.

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Appendix A: Data For The Econometric Wheat Model, 1950-75

Year	EWHESA	EAWWP	EASWP	EWHESP	WHEDH	WHEDF	WHEDS	WXT	WXCNS	WXCU
1950	78.524	56145	18808	988.161	492.812	109.440	87.904	—	—	—
1951	78.645	56997	21684	1306.440	496.825	103.590	88.195	—	—	—
1952	78.931	57087	21844	1173.071	488.171	83.714	89.091	—	—	—
1953	62.539	46617	15922	983.900	487.468	76.938	69.478	—	—	—
1954	58.246	44297	13949	937.094	486.344	60.256	64.788	—	—	—
1955	60.655	44418	16237	1005.396	481.27	54.43	68.056	—	—	—
1956	49.843	37420	12423	955.74	481.218	49.427	57.995	—	—	—
1957	56.017	43674	12343	1457.435	486.605	42.106	62.960	—	—	—
1958	56.706	43615	13091	1117.735	497.558	46.753	64.287	—	—	—
1959	54.906	42725	12181	1354.709	497.288	36.806	62.798	—	—	—
1960	55.707	43489	12218	1232.358	497.162	42.017	64.229	659.566	189.066	48.639
1961	49.274	38895	10379	1091.958	501.543	50.146	56.353	723.198	222.175	60.281
1962	53.364	42289	11075	1146.821	500.353	18.515	61.440	635.881	143.849	62.267
1963	55.672	43632	12040	1283.371	503.287	20.217	64.963	848.879	267.302	80.370
1964	57.361	45412	12219	1315.603	509.218	68.897	65.572	710.897	162.502	59.798
1965	54.105	42974	11421	1304.888	515.425	154.38	61.466	858.657	327.346	133.882
1966	67.164	54127	13669	1507.597	501.936	93.81	77.358	734.082	424.403	244.709
1967	61.86	49267	13219	1556.635	519.155	42.879	71.283	742.156	347.834	192.171
1968	53.45	43094	11185	1442.678	519.731	154.8	60.883	539.892	297.721	147.348
1969	48.739	37623	11116	1351.557	520.604	195.448	55.573	606.713	337.432	167.818
1970	53.822	38072	15750	1618.636	519.538	186.942	62.046	728.297	462.849	207.788
1971	54.913	42183	12730	1546.209	525.931	266.254	63.182	621.228	392.202	231.538
1972	59.254	43501	15753	1710.787	527.698	190.896	67.380	1167.488	616.224	358.696
1973	71.094	52023	19021	1781.918	527.958	145.993	83.100	1141.186	835.736	607.125
1974	74.786	56881	18905	2122.459	524.866	50.147	90.446	1030.073	818.051	610.224
1975	80.202	57668	22534	2142.362	559.132	98.9	95.321	1158.235	855.483	581.083

See note at end of table.

Continued—

Appendix A: Data For The Econometric Wheat Model, 1950-75 — Continued

Year	WXCJ	WXCWE	WICWE	QWDWEFE	QWDWEFO	WHEHA	WHEPF	WHEPE	COLPE	SORPE	WHEPDW
1950	—	—	—	—	—	203.471	2.00	1.75	0.277	1.87	0
1951	—	—	—	—	—	112.678	2.11	1.91	.324	2.17	0
1952	—	—	—	—	—	135.543	2.09	2.2	.324	2.38	0
1953	—	—	—	—	—	158.906	2.04	2.21	.335	2.43	0
1954	—	—	—	—	—	60.278	2.12	1.76	.259	2.28	0
1955	—	—	—	—	—	82.787	1.98	1.45	.247	1.78	0
1956	—	—	—	—	—	84.93	1.97	1.4	.225	1.97	0
1957	—	—	—	—	—	46.473	1.93	1.4	.224	1.86	.8
1958	—	—	—	—	—	148.466	1.75	1.27	.243	1.83	.59
1959	—	—	—	—	—	118.05	1.76	1.26	.253	1.52	0
1960	32.1784	108.25	11.677	8.573	37.986	168.839	1.74	1.24	.241	1.52	0
1961	36.8726	125.12	11.927	6.084	39.426	225.406	1.83	1.25	.241	1.35	0
1962	36.8073	44.774	8.974	9.045	38.448	112.723	2.04	1.18	.232	1.35	.25
1963	74.798	112.134	9.159	8.174	37.998	72.486	1.85	1.28	.208	1.4	.19
1964	60.762	42.942	8.171	9.052	37.151	209.555	1.37	1.09	.158	1.3	.04
1965	71.379	122.085	9.373	9.807	38.334	273.073	1.35	1.53	.153	1.3	.08
1966	78.465	101.23	9.016	9.577	37.555	300.814	1.63	1.63	.111	.99	.16
1967	81.763	73.926	6.544	10.304	38.51	436.247	1.39	1.66	.107	1.29	0
1968	67.574	82.799	7.21	11.728	37.573	653.959	1.24	1.67	.107	1.05	0
1969	87.521	82.094	7.253	13.65	37.588	583.673	1.25	1.67	.225	1.05	.2
1970	105.742	149.319	10.489	14.254	37.496	361.578	1.33	1.48	.238	1.05	.18
1971	80.649	80.015	7.535	13.881	38.008	495.853	1.34	1.66	.225	1.73	0
1972	124.819	132.709	6.938	16.067	37.076	294.401	1.76	1.59	.225	1.52	0
1973	112.149	116.462	4.12	12.6	36.789	228.856	3.95	1.42	.225	1.43	.207
1974	113.134	94.693	3.238	13.373	38.127	325.689	4.09	1.85	.378	2.34	0
1975	122.871	151.529	7.699	10.376	38.323	674.000	3.56	1.85	.38	2.34	0

See note at end of table.

Continued—

Appendix A: Data For The Econometric Wheat Model, 1950-75 — Continued

Year	COLPF	SORPF	WHEPDS	BARPF	WHEPPF	WHEWC	POPUS	YCAPUS	PFEC	WX48U
1950	0.401	1.88	0	1.19	96.17	0	152.271	0.007086	27.88	—
1951	.379	2.36	0	1.26	96.42	0	154.878	.006964	34.18	—
1952	.346	2.82	0	1.37	101.00	0	157.553	.007023	31.04	—
1953	.322	2.36	0	1.17	102.92	68.294	160.184	.007254	21.91	—
1954	.336	2.25	0	1.09	102.08	65.968	163.026	.007281	22.67	—
1955	.323	1.75	0	.92	108.83	65.59	165.931	.007725	21.39	—
1956	.317	2.05	0	.99	98.83	51.221	168.903	.00784	20.15	—
1957	.296	1.74	.8	.887	98.67	80.98	171.984	.007837	22.07	—
1958	.332	1.78	.59	.9	100.5	87.712	174.882	.007746	25.59	—
1959	.317	1.53	0	.86	99.75	81.301	177.83	.008112	26.11	—
1960	.302	1.49	0	.84	99.42	83.433	180.671	.008215	24.27	371.171
1961	.329	1.8	0	.979	100.17	83.554	183.691	.008248	23.17	416.202
1962	.319	1.82	.25	.915	100.33	81.911	186.538	.008516	25.45	419.36
1963	.322	1.74	.19	.897	99.67	70.71	189.242	.008747	22.7	444.035
1964	.298	1.88	.04	.953	99.33	71.317	191.889	.009101	21.51	494.023
1965	.281	1.76	.08	1.02	99.67	81.835	194.303	.009494	24.33	470.534
1966	.208	1.82	.16	1.06	99.67	74.123	196.56	.009858	25.27	291.007
1967	.256	1.77	0	1.01	100	74.545	198.712	.01	24.88	381.773
1968	.221	1.69	0	.921	99	80.411	200.706	.010383	26.42	241.222
1969	.209	1.91	.2	.885	95	82.435	202.677	.010556	29.24	268.724
1970	.224	2.04	.18	.973	94	74.713	204.878	.010523	29.02	232.681
1971	.215	1.88	0	.993	99	74.314	107.053	.01078	32.03	227.525
1972	.272	2.45	.175	1.21	101	80.12	208.846	.01135	35.49	138.915
1973	.444	3.82	0	2.14	106.66	83.707	210.41	.011717	44.54	56.788
1974	.429	4.95	0	2.81	137.33	73.409	211.901	.01129	41.89	116.549
1975	.513	4.23	0	2.42	120	80.384	213.559	.011456	44.61	124.141

See note at end of table.

Continued—

Appendix A: Data For The Econometric Wheat Model, 1950-75 — Continued

Year	WX48D	WXST	POPU	SW	PFG	CORPF	OATPF	PR	SR	YCAP6U	EXUS
1950	—	—	—	—	—	1.52	0.788	—	—	—	—
1951	—	—	—	—	—	1.66	.820	—	—	—	—
1952	—	—	—	—	—	1.52	.789	—	—	—	—
1953	—	—	—	—	—	1.48	.742	—	—	—	—
1954	—	—	—	—	—	1.43	.714	—	—	—	—
1955	—	—	—	—	—	1.35	.600	—	—	—	—
1956	—	—	—	—	—	1.29	.686	—	—	—	—
1957	—	—	—	—	—	1.11	.605	—	—	—	—
1958	—	—	—	—	—	1.12	.578	—	—	—	—
1959	—	—	—	—	—	1.05	.646	—	—	—	—
1960	42.293	57.035	829.99	0.500	0.844	1.00	.599	8.20	3.35	0.929	1.000
1961	28.646	56.076	850.75	.550	.960	1.10	.642	9.40	2.85	.981	1.000
1962	7.179	65.603	873.12	.600	.962	1.12	.624	9.30	2.30	1.041	1.000
1963	10.103	127.439	895.66	.470	.942	1.11	.622	8.80	2.37	1.075	1.000
1964	8.897	44.697	917.56	.210	1.000	1.17	.631	8.35	2.23	1.069	1.000
1965	3.348	57.414	940.01	.460	.989	1.16	.622	8.15	1.30	1.051	1.000
1966	1.129	17.532	963.37	.140	1.044	1.24	.666	8.35	.61	1.084	1.000
1967	.549	11.974	986.86	.008	.926	1.03	.659	8.65	0	1.099	1.000
1968	.415	.520	1011.10	.123	.926	1.08	.598	8.50	0	1.153	1.000
1969	.171	.374	1036.20	.121	.990	1.16	.584	8.65	.78	1.223	1.000
1970	.169	32.573	1063.30	.110	1.108	1.33	.623	8.90	.97	1	1.000
1971	.139	1.339	1089.60	.064	.959	1.08	.605	9.15	1.97	1.015	.941
1972	.098	412.217	1115.40	.040	1.323	1.57	.724	13.55	.79	1.048	.875
1973	0	248.626	1141.60	0	2.153	2.55	1.180	27.40	0	1.097	.829
1974	0	95.473	1168.30	0	2.663	3.02	1.530	19.90	0	1.109	.817
1975	0	178.611	1195.75	0	2.246	2.54	1.460	17.35	0	1.144	.863

See note at end of table.

Continued—

Appendix A: Data For The Econometric Wheat Model, 1950-75 — Continued

Year	QWPU	QWSCO	POPJ	RPWJ	CPIJ	YCAPJ	QWSJ	WXTWE	BSWWE
1950	—	—	—	—	—	—	—	—	—
1951	—	—	—	—	—	—	—	—	—
1952	—	—	—	—	—	—	—	—	—
1953	—	—	—	—	—	—	—	—	—
1954	—	—	—	—	—	—	—	—	—
1955	—	—	—	—	—	—	—	—	—
1956	—	—	—	—	—	—	—	—	—
1957	—	—	—	—	—	—	—	—	—
1958	—	—	—	—	—	—	—	—	—
1959	—	—	—	—	—	—	—	—	—
1960	36.651	44.680	94.10	35910	56.7	0.004754	2.181	1.552	9.131
1961	36.134	38.149	94.95	35450	59.7	.005126	2.556	1.952	9.722
1962	40.972	40.814	95.83	35200	63.7	.005533	2.711	3.068	9.295
1963	40.141	51.954	96.81	35200	68.7	.005952	1.616	2.923	11.956
1964	38.731	52.918	97.83	35200	71.5	.006593	2.244	4.830	9.639
1965	43.212	48.786	98.88	35200	76.7	.006861	2.287	4.494	9.347
1966	38.967	53.52	99.79	34920	80.4	.007389	1.999	3.893	11.819
1967	44.227	48.911	100.83	34640	83.7	.008038	2.212	4.000	10.018
1968	53.654	59.283	101.96	34650	88.3	.008707	2.062	3.927	10.216
1969	54.514	67.452	103.17	34460	93.3	.009374	1.758	5.218	12.020
1970	57.056	57.611	104.33	34460	100.0	.010000	1.334	2.777	8.032
1971	62.166	53.018	105.60	34530	106.3	.010557	1.390	4.177	7.760
1972	67.030	45.845	106.96	33690	111.4	.011383	1.284	6.346	10.113
1973	61.777	45.485	108.35	33690	124.5	.012079	1.372	4.759	8.626
1974	63.345	43.719	109.67	45760	152.7	.011994	1.342	5.382	10.923
1975	68.088	48.170	110.95	45250	171.2	.012443	1.391	9.712	13.414

See note at end of table.

Continued—

Appendix A: Data For The Econometric Wheat Model, 1950-75 — Continued

Year	QWSWE	AUD	PWTH	SWEEC	PCTH	PM	POPWE	YCAPWE	WHEHH	WPI
1950	—	—	—	—	—	—	—	—	196.4	81.8
1951	—	—	—	—	—	—	—	—	143.3	91.1
1952	—	—	—	—	—	—	—	—	470.0	88.6
1953	—	—	—	—	—	—	—	—	774.6	87.4
1954	—	—	—	—	—	—	—	—	975.9	87.6
1955	—	—	—	—	—	—	—	—	950.7	87.8
1956	—	—	—	—	—	—	—	—	823.9	90.7
1957	—	—	—	—	—	—	—	—	834.9	93.3
1958	—	—	—	—	—	—	—	—	1146.6	94.6
1959	—	—	—	—	—	—	—	—	1195.4	94.8
1960	45.137	81.032	0	0	0	3.03	287.49	0.669	1242.5	94.9
1961	44.163	84.606	0	0	0	3.18	290.26	.702	1096.6	94.5
1962	53.547	83.932	108.529	15.43	73.92	3.57	293.30	.730	1082.5	94.8
1963	49.351	82.412	107.785	14.74	76.48	3.55	296.75	.766	828.9	94.5
1964	52.796	84.974	108.604	14.86	80.75	3.51	299.14	.792	607.7	94.7
1965	55.045	87.698	108.870	14.47	80.86	4.02	301.69	.819	262.1	96.6
1966	51.748	89.633	109.082	14.09	85.13	3.94	303.91	.850	123.6	99.8
1967	57.373	91.870	104.380	13.36	88.67	3.84	305.83	.876	102.3	100.0
1968	57.677	93.515	104.380	13.47	93.18	3.70	307.68	.911	162.7	102.5
1969	57.264	96.076	104.380	16.73	94.33	3.92	309.87	.957	301.2	106.5
1970	51.830	97.416	104.38	13.21	95.59	3.92	312.04	1.000	369.9	110.4
1971	58.901	96.986	107.25	11.23	96.58	4.51	314.34	1.032	367.4	113.9
1972	61.469	99.03	111.60	11.84	101.79	11.45	316.56	1.083	144.1	119.1
1973	59.391	103.542	112.80	2.82	103.56	7.32	318.56	1.132	18.9	134.7
1974	67.619	104.365	119.00	0	115.37	6.561	320.38	1.146	1.3	160.1
1975	61.923	103.153	136.45	0	125.75	7.199	322.21	1.159	0	174.9

See note at end of table.

Continued—

Appendix A: Data For The Econometric Wheat Model, 1950-75 — Continued

Year	WX48T	YPOPW	QWSW	DV6467	DV73	TIME	DV6272	DV6266	DV7274	DSTRIKE
1950	—	—	—	0	0	50	0	—	—	—
1951	—	—	—	0	0	51	0	—	—	—
1952	—	—	—	0	0	52	0	—	—	—
1953	—	—	—	0	0	53	0	—	—	—
1954	—	—	—	0	0	54	0	—	—	—
1955	—	—	—	0	0	55	0	—	—	—
1956	—	—	—	0	0	56	0	—	—	—
1957	—	—	—	0	0	57	0	—	—	—
1958	—	—	—	0	0	58	0	—	—	—
1959	—	—	—	0	0	59	0	—	—	—
1960	473.0847	1211.580	128.649	0	0	60	0	1	0	0
1961	503.7470	1235.960	121.002	0	0	61	0	1	0	0
1962	493.3229	1262.250	1[illegible]8.044	0	0	62	1	1	0	.5
1963	485.2309	1289.219	143.062	0	0	63	1	1	0	−.5
1964	555.7464	1314.530	146.689	1	0	64	1	1	0	1
1965	529.5303	1340.580	149.33	0	0	65	1	1	0	−1
1966	298.7440	1367.070	146.234	0	0	66	1	1	0	0
1967	382.9839	1393.520	152.723	1	0	67	1	0	0	0
1968	242.1139	1420.740	172.676	0	0	68	1	0	0	1
1969	269.2416	1449.240	180.988	0	0	69	1	0	0	−1
1970	233.0601	1479.670	167.831	0	0	70	1	0	0	0
1971	227.6866	1509.540	175.475	0	0	71	1	0	0	2
1972	139.0470	1538.919	175.628	0	0	72	1	0	1	−2
1973	56.8240	1568.510	168.025	0	1	73	0	0	1	0
1974	116.5490	1598.350	176.025	0	0	74	0	0	1	0
1975	124.1410	1628.909	179.572	0	0	75	0	0	1	0

— = Not applicable.

Appendix B: Single-Equation Export Model

Our objectives in this single-equation model of U.S. wheat export demand are modest. We have limited our attention to the major determinants of commercial exports, emphasizing the relation between world wheat prices and exports. Thus, this aggregate approach, combined with information from the more detailed regional study of chapter 5, is adequate for solving many forecasting and policy analysis problems.

Less developed countries (LDC's) provide the most important foreign outlet for U.S. wheat. Accordingly, one should consider their specific market characteristics and institutions. Of course, LDC imports depend principally on the balance between increasing demands of growing populations and the ability of these countries to provide corresponding boosts in supply. Historically, surplus U.S. wheat in the form of food aid partially offset the pressures of increasing populations. More recently, though, reductions in food aid have been matched by expansions in LDC purchases of foreign wheat. Any analysis of the commercial export market must emphasize both the food-aid-dominated period in the sixties and the commercial demands of the seventies. To understand the sixties, one must recognize that food aid exports are interpreted as an exogenous increase in LDC supplies. Taking the competition between wheat and other food grains into account contributes to an analysis of the seventies.

Excess demand theory provides theoretical justification for the commercial export relationship. In practice, this approach requires measuring those factors influencing foreign supply and demand conditions. The supply side is simplified by taking non-U.S. production and beginning stocks (QWSW) as given.[1] The quantity exported under P.L. 480 (WX48T) is also included as a foreign supply measure. The demand specification emphasizes the role of world food-grain prices in allocating exports within this commodity group. Thus, we assume that foreign demand depends on subsidy-adjusted U.S. prices of wheat (WHEPF-SW) and rice (PR-SR). Feed-grain prices (PFG) are also included, as 90 percent of LDC coarse grain supplies are used for human consumption. Finally, all quantity variables are expressed in per capita terms (deflated by POPW), as this is a convenient method of accounting for world population growth.

[1] World supply (QWSW) and population (POPW) are defined to *exclude* the Soviet Union, the People's Republic of China, and Eastern Europe.

The following single-equation model represents the results:

$$
\begin{array}{rllll}
WXCNS/POPW = & 0.8512 & - 5.4423 & QWSW/POPW & \\
 & (3.05) & (-2.47) & & \\
 & - 0.5458 & & WX48T/POPW - 0.1067 & WHEPF-SW \\
 & (-4.03) & & \qquad\qquad (-1.79) & \\
 & + 0.0096 & & PR-SR + 0.2055 & PFG \\
 & (1.76) & & \qquad (2.44) &
\end{array}
$$

R-SQUARED(CORR.): 0.916
SEE: 0.36832E-01
DW: 2.50

ELASTICITIES:
E(WXCNS.QWSW) = -2.18
E(WXCNSxWX48T) = -0.47
E(WXCNS.POPW) = 1.00

E(WXCNS.WHEPF) = -0.72
E(WXCNS.PR) = 0.38
E(WXCNS.CORPF) = 0.51

E(WXCNS.SORPF) = 0.22
E(WXCNS.BARPF) = 0.14

PERIOD OF FIT: 1960-74

Appendix C: Multiplier Computations

We obtained the linearization supporting the results of table 11 by converting the structural relations of chapters 4 and 5 (on pp. 32-67) into first differences. Valu.s of exogenous variables were held at 1975 levels. By substituting the relations of the production block and aggregating demand categories, one obtains the following four-equation system:

Production:
$$\Delta QP_{t+1} = 136.5314\ \Delta P_t + 147.258\ \Delta P_{t-1} + 64.72988\ \Delta P_{t-2} + 28.81452\ \Delta P_{t-3} \quad (1)$$

Demand:
$$\Delta D_t = -\ 263.277\ \Delta P_t \quad (2)$$

Inventories:
$$\Delta I_t = -\ 114.81676\ \Delta P_t + 0.2488\ \Delta QP_t - 0.2640\ \Delta QP_{t+1} \quad (3)$$

Identity:
$$\Delta QP_t + \Delta I_{t-1} = \Delta D_t + \Delta I_t + \Delta D_t^* \quad (4)$$

current endogenous: QP_{t+1}, D_t, I_t, P_t

lagged endogenous: I_{t-1}, QP_t, P_{t-1}, P_{t-2}, P_{t-3}

where Δ indicates first differences of a variable and

QP_{t+1} = year t + 1 production, in million bushels;

D_t = year t endogenous demand, in million bushels;

D_t^* = year t exogenous demand, in million bushels; and

P_t = year t price, in dollars per bushel.

Appendix C

Equations (1) through (4) can be converted to levels by assuming that first differences apply to deviations about 1975 values. When rearranged, this block of equations can be expressed in matrix form as:

$$\Gamma Y_t = B_1 Y_{t-1} + B_2 Y_{t-2} + B_3 Y_{t-3} + \phi X_t$$

where:

$$\Gamma = \begin{bmatrix} 0 & 0 & 1 & -136.5314 \\ 1 & 0 & 0 & 263.277 \\ 0 & 1 & .264 & 114.8168 \\ -1 & -1 & 0 & 0 \end{bmatrix}$$

$$B_1 = \begin{bmatrix} 0 & 0 & 0 & 147.258 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & .2488 & 0 \\ 0 & -1 & -1 & 0 \end{bmatrix}$$

$$B_2 = \begin{bmatrix} 0 & 0 & 0 & 64.72988 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$B_3 = \begin{bmatrix} 0 & 0 & 0 & 28.8145 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\phi = \begin{bmatrix} k_1 & 0 \\ k_2 & 0 \\ k_3 & 0 \\ 0 & 1 \end{bmatrix}$$

$$Y_t = \begin{bmatrix} D_t \\ I_t \\ QP_{t+1} \\ P_t \end{bmatrix} \qquad X_t = \begin{bmatrix} 1 \\ D_t^* \end{bmatrix}$$

The following reduced form equation results upon inversion and suitable matrix manipulations:

$$Y_t = \Gamma^{-1}B_1Y_{t-1} + \Gamma^{-1}B_2Y_{t-2} + \Gamma^{-1}B_3Y_{t-3} + \Gamma^{-1}\phi X_t \tag{5}$$

For the coefficients given above, the following matrices result:

$$\Gamma^{-1} = \begin{bmatrix} .16783 & .36428 & -.63572 & -.63572 \\ -.16783 & -.36428 & .63572 & -.36428 \\ .91296 & .32968 & .32968 & .32968 \\ -6.3476 \times 10^{4} & .002414 & .002414 & .002414 \end{bmatrix}$$

$$A_1 = \Gamma^{-1}B_1 = \begin{bmatrix} 0 & .63572 & .47756 & 24.71431 \\ 0 & .36428 & .52245 & -24.71431 \\ 0 & -.32968 & -.24766 & 134.44066 \\ 0 & -.002414 & -.001813 & -.09386225 \end{bmatrix}$$

$$A_2 = \Gamma^{-1}B_2 = \begin{bmatrix} 0 & 0 & 0 & 10.86362 \\ 0 & 0 & 0 & -10.86362 \\ 0 & 0 & 0 & 59.09579 \\ 0 & 0 & 0 & -.041036 \end{bmatrix}$$

$$A_3 = \Gamma^{-1}B_3 = \begin{bmatrix} 0 & 0 & 0 & 4.83594 \\ 0 & 0 & 0 & -4.83594 \\ 0 & 0 & 0 & 26.30650 \\ 0 & 0 & 0 & -.018368 \end{bmatrix}$$

$$B^* = \Gamma^{-1}\phi = \Gamma^{-1} = \begin{bmatrix} k_1^* & 0 \\ k_2^* & 0 \\ k_3^* & 0 \\ 0 & 1 \end{bmatrix}$$

Matrix equation (5) can also be expressed in a form amenable to the analysis of Theil and Boot:

$$Y_t^* = AY_{t-1} + BX_t \text{, that is,}$$

$$\begin{bmatrix} Y_t \\ Y_{t-1} \\ Y_{t-2} \end{bmatrix} = \begin{bmatrix} A_1 & A_2 & A_3 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ Y_{t-2} \\ Y_{t-3} \end{bmatrix} + \begin{bmatrix} B^* \\ 0 \\ 0 \end{bmatrix} X_t$$

The analysis of a single-period shock in exogenous demand is cast as:

$$\Delta X_0 = \begin{bmatrix} 0 \\ 100 \end{bmatrix}$$

Then the period 0 change can be written as:

$$B\Delta X_0 = \begin{bmatrix} -63.572 \\ -36.428 \\ 32.968 \\ .2414 \\ \hline 0 \\ 0 \end{bmatrix}$$

The change for the subsequent period is obtained by premultiplying $B\Delta X_0$ by the "A" matrix:

$$
A = \left[\begin{array}{cccc|cccc|cccc}
0 & .63572 & .47756 & 24.71431 & 0 & 0 & 0 & 10.86362 & 0 & 0 & 0 & 4.83594 \\
0 & .36428 & .52245 & -24.71431 & 0 & 0 & 0 & -10.86362 & 0 & 0 & 0 & -4.83594 \\
0 & -.32968 & -.24766 & 134.44066 & 0 & 0 & 0 & 59.09579 & 0 & 0 & 0 & 26.30650 \\
0 & -.002414 & -.001813 & -.09386225 & 0 & 0 & 0 & -.041036 & 0 & 0 & 0 & -.018368 \\
\hline
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\hline
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{array}\right]
$$

$$12 \times 12$$

Appendix D: Impact Multipliers: Surplus

Effect of changes in exogenous variables on current-year wheat utilization, stocks, and following-year supply (price exogenous)

Name	Unit	Change	1963 value
1963 value			
Foreign supplies:			
QWPLDC	Mmt.	1.0	40.141
QWSJ	do.	1.0	1.616
QWSWE	do.	1.0	49.351
QWSCO	do.	1.0	51.954
U.S. policy-controlled quantities:			
WXST	Mil. bu.	10	31.093
WX48U	Mil. bu.	10	444.035
Foreign commodity prices:			
RPWJ	Yen/kg	1,000	35,200.0
PWTH	UOA/mt	10	107.785
PCTH	UOA/mt	10	76.480
AUD	1967 = 100	10	82.412
Domestic commodity prices:			
WHEPF	Dol./bu.	.10	1.85
CORPF	do.	.10	1.11
SORPF	Dol./cwt	.10	1.74
BARPF	do.	.10	.897
OATPF	Dol./bu.	.10	.622
COLPF	Dol./cwt	.01	.322
PR	do.	1.0	8.8
WHEPE(+1)	Dol./bu.	.10	1.09
SORPE(+1)	Dol./cwt	.10	1.30
COLPE(+1)	do.	.10	.158
PM	Cents/lb.	1.0	3.55
PFEC(+1)	Dol./cwt	1.0	21.51
Foreign macro economy:			
YCAP6U	1970 = 1.0	.10	1.075
YCAPWE	do.	.10	.766
YCAPJ	1970 = 0.01	.001	.006
CPIJ	1970 = 100	10.0	68.7
POPU	Millions	10.0	895.660
POPWE	do.	10.0	296.750
POPJ	do.	10.0	96.81
U.S. macro economy:			
EXUS	SDR/U.S. dol.	.1	1
YCAPUS	1967 = 0.01	.001	.009
WPI	1967 = 100	1	94.5
POPUS	Millions	10	189.2
WHEPPF(+1)	1967 = 100	10	99.33

Continued—

Appendix D: Impact Multipliers: Surplus—Continued

Effect of changes in exogenous variables on current-year wheat utilization, stocks, and following-year supply (price exogenous)

Name	Domestic demand			
	WHEDS	WHEHA1	WHEDF	WHEDH
	Million bushels			
1963 value	64.963	72.486	20.217	503.287
Foreign supplies:				
QWPLDC	0	−1.225	0	0
QWSJ	0	−3.389	0	0
QWSWE	0	−10.988	0	0
QWSCO	0	−.651	0	0
U.S. policy-controlled quantities:				
WXST	0	1.623	0	0
WX48U	0	.683	0	0
Foreign commodity prices:				
RPWJ	0	−.592	0	0
PWTH	0	−18.976	0	0
PCTH	0	14.676	0	0
AUD	0	13.786	0	0
Domestic commodity prices:				
WHEPF	1.607	−34.782	−23.201	0
CORPF	0	.970	0	0
SORPF	−.320	3.127	10.561	0
BARPF	−.232	1.141	0	0
OATPF	0	.015	0	0
COLPF	−.634	2.192	0	0
PR	0	1.209	0	0
WHEPE(+1)	2.631	−9.095	0	0
SORPE(+1)	−.350	1.209	0	0
COLPE(+1)	−.548	1.896	0	0
PM	0	4.912	0	0
PFEC(+1)	0	1.770	10.904	0
Foreign macro economy:				
YCAP6U	0	2.726	0	0
YCAPWE	0	−10.103	0	0
YCAPJ	0	−.979	0	0
CPIJ	0	2.647	0	0
POPU	0	1.451	0	0
POPWE	0	14.047	0	0
POPJ	0	2.195	0	0
U.S. macro economy:				
EXUS	0	−2.664	0	0
YCAPUS	0	−2.620	0	−16.138
WPI	0	7.937	0	0
POPUS	0	4.407	0	27.148
WHEPPF(+1)	0	7.927	0	0

Continued—

Appendix D: Impact Multipliers: Surplus—Continued

Effect of changes in exogenous variables on current-year wheat utilization, stocks, and following-year supply (price exogenous)

Name	Foreign demand			
	WXT1	WXCNS	WXCU	WXCJ
	Million bushels			
1963 value	546.113	267.302	80.370	74.798
Foreign supplies:				
QWPLDC	-7.546	-7.546	-7.546	0
QWSJ	-20.876	-20.876	0	-20.876
QWSWE	-67.731	-67.731	0	0
QWSCO	-4.013	-4.013	-3.544	-.469
U.S. policy-controlled quantities:				
WXST	10.0	0	0	0
WX48U	4.206	-5.794	-5.794	0
Foreign commodity prices:				
RPWJ	-3.645	-3.645	0	-3.645
PWTH	-117.179	-117.179	0	0
PCTH	90.354	90.354	0	0
AUD	84.868	84.868	0	0
Domestic commodity prices:				
WHEPF	-5.922	-5.922	-5.922	0
CORPF	5.977	5.977	5.977	0
SORPF	1.888	1.888	1.888	0
BARPF	2.102	2.102	2.102	0
OATPF	.093	.093	.093	0
COLPF	0	0	0	0
PR	7.447	7.447	7.447	0
WHEPE(+1)	0	0	0	0
SORPE(+1)	0	0	0	0
COLPE(+1)	0	0	0	0
PM	30.276	30.276	0	0
PFEC(+1)	0	0	0	0
Foreign macro economy:				
YCAP6U	16.793	16.793	16.793	0
YCAPWE	-62.272	-62.272	-62.272	0
YCAPJ	-6.029	-6.029	0	-6.029
CPIJ	16.305	16.305	0	16.305
POPU	8.937	8.937	8.937	0
POPWE	86.473	86.473	0	0
POPJ	13.520	13.520	0	13.520
U.S. macro economy:				
EXUS	-16.409	-16.409	-16.409	0
YCAPUS	0	0	0	0
WPI	0	0	0	0
POPUS	0	0	0	0
WHEPPF(+1)	0	0	0	0

Continued—

Appendix D: Impact Multipliers: Surplus—Continued

Effect of changes in exogenous variables on current-year wheat utilization, stocks, and following-year supply (price exogenous)

Name	Foreign demand—Continued			
	WXCWE	WICWE	QWDWEFE	QWDWEFO
	Million metric tons			
1963 value	112.134		8.174	37.998
Foreign supplies:				
QWPLDC	0	0	0	0
QWSJ	0	0	0	0
QWSWE	-67.731	-1.0	0	0
QWSCO	0	0	0	0
U.S. policy-controlled quantities:				
WXST	0	0	0	0
WX48U	0	0	0	0
Foreign commodity prices:				
RPWJ	0	0	0	0
PWTH	-117 179	-1.730	-1.730	0
PCTH	90.354	1.334	1.334	0
AUD	84.868	1.253	-1.253	0
Domestic commodity prices:				
WHEPF	0	0	0	0
CORPF	0	0	0	0
SORPF	0	0	0	0
BARPF	0	0	0	0
OATPF	0	0	0	0
COLPF	0	0	0	0
PR	0	0	0	0
WHEPE(+1)	0	0	0	0
SORPE(+1)	0	0	0	0
COLPE(+1)	0	0	0	0
PM	30.276	.447	.447	0
PFEC(+1)	0	0	0	0
Foreign macro economy:				
YCAP6U	0	0	0	0
YCAPWE	0	- .919	- .919	0
YCAPJ	0	0	0	0
CPIJ	0	0	0	0
POPU	0	0	0	0
POPWE	86.473	1.277	0	1.277
POPJ	0	0	0	0
U.S. macro economy:				
EXUS	0	0	0	0
YCAPUS	0	0	0	0
WPI	0	0	0	0
POPUS	0	0	0	0
WHEPPF(+1)	0	0	0	0

Continued—

Appendix D: Impact Multipliers: Surplus—Continued

Effect of changes in exogenous variables on current-year wheat utilization, stocks, and following-year supply (price exogenous)

Name	Supply in following year		
	WHESP(+1)	WHESA(+1)	AWWP(+1)
	Million bushels	*Million acres*	*1,000 acres*
1963 value	1,283.371	55.672	43,632.0
Foreign supplies:			
QWPLDC	0	0	0
QWSJ	0	0	0
QWSWE	0	0	0
QWSCO	0	0	0
U.S. policy-controlled quantities:			
WXST	0	0	0
WX48U	0	0	0
Foreign commodity prices:			
RPWJ	0	0	0
PWTH	0	0	0
PCTH	0	0	0
AUD	0	0	0
Domestic commodity prices:			
WHEPF	19.258	1.274	1,140.766
CORPF	0	0	0
SORPF	−3.883	−.253	−253.439
BARPF	−2.775	−.183	0
OATPF	0	0	0
COLPF	−7.598	−.502	−502.395
PR	0	0	0
WHEPE(+1)	31.527	2.085	1163.405
SORPE(+1)	−4.192	−.277	−277.143
COLPE(+1)	−6.574	−.435	−434.650
PM	0	0	0
PFEC(+1)	0	0	0
Foreign macro economy:			
YCAP6U	0	0	0
YCAPWE	0	0	0
YCAPJ	0	0	0
CPIJ	0	0	0
POPU	0	0	0
POPWE	0	0	0
POPJ	0	0	0
U.S. macro economy:			
EXUS	0	0	0
YCAPUS	0	0	0
WPI	0	0	0
POPUS	0	0	0
WHEPPF(+1)	−26.229	0	0

Continued—

Appendix D: Impact Multipliers: Surplus—Continued

Effect of changes in exogenous variables on current-year wheat utilization, stocks, and following-year supply (price exogenous)

Name	Supply	Government stocks
	ASWP(+1)	WHEHH
	1,000 acres	*Million bushels*
1963 value	12,040.0	828.9
Foreign supplies:		
QWPLDC	0	8.771
QWSJ	0	24.265
QWSWE	0	78.719
QWSCO	0	4.664
U.S. policy-controlled quantities:		
WXST	0	-11.623
WX48U	0	-4.888
Foreign commodity prices:		
RPWJ	0	4.237
PWTH	0	136.156
PCTH	0	-105.030
AUD	0	-98.654
Domestic commodity prices:		
WHEPF	132.770	62.298
CORPF	0	-6.947
SORPF	0	-15.256
BARPF	-183.472	-3.011
OATPF	0	-.108
COLPF	0	-1.558
PR	0	-8.656
WHEPE(+1)	921.146	6.465
SORPE(+1)	0	-.359
COLPE(+1)	0	-1.348
PM	0	-35.187
PFEC(+1)	0	-12.675
Foreign macro economy:		
YCAP6U	0	-19.519
YCAPWE	0	72.375
YCAPJ	0	7.007
CPIJ	0	-18.952
POPU	0	-10.388
POPWE	0	-100.520
POPJ	0	-15.715
U.S. macro economy:		
EXUS	0	19.074
YCAPUS	0	18.758
WPI	0	-7.937
POPUS	0	-31.556
WHEPPF(+1)	0	-7.927

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