Price Determination for Corn and Wheat: The Role of Market Factors and Government Programs. By Paul C. Westcott and Linwood A. Hoffman, Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1878.

Abstract

Annual models for U.S. farm prices for corn and wheat are developed based on market factors as well as government agricultural commodity programs. The pricing relationships utilize a stocks-to-use modeling framework to capture the effects of market supply and demand factors on price determination. This formulation is augmented by factors that represent the changing role of agricultural policies, particularly government price support and stockholding programs. For wheat, international market effects as well as wheat feed use and related cross-commodity pricing considerations also are included. Model properties and model performance measures are presented. Additionally, recent price-forecasting applications of the models are discussed. The relatively simple structure of the estimated price models and their small data requirements lend themselves to use in price-forecasting applications in conjunction with market analysis of supply and demand conditions. In particular, the models have been implemented into USDA's short-term market analysis and long-term baseline projections. In these applications, the models provide an analytical framework to forecast prices and a vehicle for making consistency checks among the Department's supply, demand, and price forecasts.

Keywords: Corn, wheat, farm price, price determination, stocks-to-use ratio, price supports, commodity programs, forecasts.

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Contents

Summary iii

Introduction 1

Price Determination Factors for Corn and Wheat 3
Supply Factors for Corn and Wheat 3
Demand Factors for Corn and Wheat 5
Carryover Stocks 7
Agricultural Policies: Price Support and
Commodity Storage Programs, 1975 to 1996 8

Previous Price Modeling Research 11

A Pricing Model 12
Adjustments to the Basic Model 12
Additional Considerations for the Wheat Price Model 12

Model Implementation 14

Model Results and Properties 17
Corn Equation 17
Wheat Equation 18

Evaluation of the Price Models 21

Price Forecasting Applications 23
Corn 23
Wheat 23
Confidence Intervals 23

Conclusions 25

References 26

Summary

Corn and wheat crops have prominent roles in the U.S. agricultural sector as important sources of cash receipts and farm income to producers, in linkages within the agricultural sector among various crops and between crops and livestock, and as major crops in U.S. and global agricultural trade. Information affecting market conditions and prices for corn and wheat is particularly important as the sector has become more market oriented under agricultural policy changes of the last 10-15 years. Consequently, corn and wheat prices are carefully watched throughout much of the agricultural sector.

This technical bulletin examines some of the factors that affect U.S. farm-level prices for corn and wheat. Price determination models are developed for these crops using an annual framework. The models build on two types of factors that influence prices—market supply and demand conditions, and government policy variables.

A stocks-to-use ratio formulation is used to capture the effects of market supply and demand factors on price determination. This formulation is augmented by factors that represent the changing role of agricultural policies, particularly government price support and stockholding programs. The wheat price model also reflects the influence of international market conditions, represented by the stocks-to-use ratio for four major competitors. Additionally, the role of wheat feeding and competition with corn for feed use in the summer quarter affects the pricing of wheat.

Model properties are shown to indicate the relative sensitivity of prices to changes in the different independent variables. Additionally, model performance measures are presented and recent price-forecasting applications are discussed. Statistical evaluation measures indicate good performance for the price models. This is particularly the case given the large range of corn and wheat prices over the sample period used to estimate the model (1975-96) as well as the changing nature of the influence of government programs on price determination.

The relatively simple structure of the estimated price models and their small data requirements lend themselves to use in price-forecasting applications in conjunction with market analysis of supply and demand conditions. In particular, the models have been implemented into USDA's short-term market analysis and long-term baseline projections activities. In these applications, the models provide an analytical framework for forecasting prices and a vehicle for making consistency checks among the Department's supply, demand, and price forecasts.

Price Determination for Corn and Wheat
The Role of Market Factors and Government Programs

Paul C. Westcott and Linwood A. Hoffman

Introduction

Corn and wheat crops play major roles in the U.S. agricultural sector. As sources of income to farmers, corn cash receipts are the largest among crops, while wheat ranks third. Together, cash receipts for these two grains averaged nearly $24 billion annually during 1990-96, accounting for over one-fourth of total crop cash receipts.

Corn and wheat have important roles in linkages within the agricultural sector among various crops and between crops and livestock. Each competes with other crops for land in farmers' production decisions, such as corn with soybeans in the Corn Belt and wheat with barley in the Northern Plains. Corn is also the largest feed grain used by the livestock sector. Some wheat is also used for feed, particularly in the summer prior to harvest of major feed grain crops. Further, the United States is the largest exporter of corn and wheat, accounting for over 70 percent of global corn trade and over 30 percent of wheat trade in 1990-96. Consequently, events that affect market conditions for corn and wheat—and prices for those crops—are carefully watched throughout much of the agricultural sector.

The Federal Agriculture Improvement and Reform Act of 1996 (1996 Farm Act) fundamentally changed the nature of farm commodity programs in the United States, furthering trends toward market orientation in the sector. In particular, changes in the income support program for wheat, corn, grain sorghum, barley, oats, rice, and upland cotton shifted much of the risk of price volatility for those crops from the Government to producers (Young and Westcott, 1996). As a result, market information affecting corn and wheat prices is particularly important under the 1996 Farm Act as farmers seek to make informed farm management decisions to manage risk and other market participants work within a more market-oriented agricultural sector.

Each month the U.S. Department of Agriculture (USDA) analyzes major agricultural commodity markets and publishes annual supply, demand, and price projections for the current year to provide market information regarding the agricultural sector. Additionally, once a year, USDA publishes longer term, 10-year baseline projections for the agricultural sector that include commodity supply, demand, and prices.

This technical bulletin examines some of the factors that affect U.S. farm-level prices for corn and wheat. An annual framework is employed to develop pricing models for use in USDA's projections, in conjunction with ongoing commodity market analysis of supply and demand factors. As such, the models provide an analytical framework for forecasting prices as well as a vehicle for making consistency checks among supply, demand, and price forecasts. The models build on two types of factors that influence prices—market supply and demand conditions, and government policy variables.

Market forces, as measured by supply and demand, influence prices. Year-ending stocks of an annually produced commodity, such as corn or wheat, summarize the effects of both supply and demand factors during the year and are a useful indicator of price movements for the commodity. Annual prices for corn and wheat tend to have a strong negative correlation with their ending stocks. High stocks typically result in lower prices, while low stocks tend to push prices up.

Government programs have also been important in influencing farm-level prices of corn and wheat. However, changes in policies historically have altered the role of farm programs in price determination. Some programs, such as acreage reduction and set-aside programs, have influenced prices indirectly by placing restrictions on the use of land for agricultural production, thereby affecting the supply of agricultural commodities. The 1996 Farm Act terminated supply management programs. Government price support and commodity stockholding programs have also influenced prices for corn and wheat. The nonrecourse commodity

loan program directly affected prices in some periods, providing support to farm-level prices and affecting market equilibrium by influencing private stockholding. However, the role of the loan rate in influencing prices has differed historically as the nature of the commodity loan program has changed under different farm legislation. With marketing assistance loans of current policy, commodity loan rates no longer provide a floor for market prices. Thus, one of the key policy variables used in the price models presented here is the commodity loan rate in periods when it affected market prices. Additionally, agricultural programs that have resulted in public stockholding by the Government have affected prices for corn and wheat, and this policy effect is also represented in the models.

Price Determination Factors for Corn and Wheat

Prices are determined by the interaction of the supply and demand functions, which historically have been influenced by government agricultural policies. This section provides information regarding supply and demand factors for the corn and wheat markets. Selected agricultural policies are also discussed because they, too, can affect the supply, demand, and pricing of commodities. Some policies have affected supply or demand factors and thus have influenced prices indirectly. Such policies include, for example, acreage reduction programs that affected supplies of corn and wheat, and export programs that affected demand. The price effects of these policies are usually embedded in the supply and demand data and thus do not need to be modeled separately. These policies are discussed within the context of the relevant supply and demand factors.

Other policies have affected the pricing of corn and wheat more directly, beyond the effects on supply and demand and, therefore, need to be considered separately in pricing models. In particular, governmental price support and commodity storage programs have affected market prices for corn and wheat in certain periods. And public stockholding by the Government has influenced prices. These programs are discussed in a separate policy section.

Supply Factors for Corn and Wheat

The components of supply are beginning stocks, imports, and production. Corn is the largest feed grain domestically and globally. Corn accounts for over 85 percent of total U.S. feed grain production. The United States is the largest producer of corn in the world, averaging 210 million metric tons in 1990-96, representing about 40 percent of global production. U.S. farmers' cash receipts from corn averaged nearly $16 billion in 1990-96, the largest of all field crops.

Wheat is the principal food grain in the United States and throughout much of the world. The United States is the third largest producer of wheat in the world, averaging 63.6 million metric tons in 1990-96, accounting for about 11 percent of world production. Cash receipts for wheat in the United States averaged almost $8 billion in 1990-96, the third largest of all field crops (soybeans ranked second).

Beginning Stocks

Carryover stocks from the previous year become the current year's beginning stocks and augment current production in determining total supply. Large stocks can provide additional supplies in a low production year while small stocks provide less cushion.

Imports

Corn and wheat imports have been fairly insignificant relative to total supply for many years. U.S. corn imports continue to have little impact on domestic supply as they averaged 15 million bushels during 1990-96, less than 1 percent of supply. Imports of seed and trade with Canada account for most U.S. corn imports. Wheat imports were an insignificant factor for the U.S. wheat supply for many years, representing less than 1 percent of domestic wheat supply between 1960 and 1989. However, imports of wheat (including wheat products) from Canada in the 1993/94 marketing year pushed total wheat imports to 109 million bushels, or 4 percent of supply. Wheat imports have since declined to about 3 percent of supply, but the United States remains an attractive market for Canadian wheat.

Production

Production is the major component of supply and is determined by the amount of acreage harvested for grain and the yield per acre.

Acreage. Acreage planted generally reflects producer net returns per acre for a given commodity compared with returns for competing crops. Government policy and agronomic considerations, such as crop rotations, can also influence plantings. Income support and supply management/production control programs were important in affecting land use from 1974 through 1995. Income support policies may have provided economic incentives to increase acreage during those years, but supply management policies, such as acreage reduction programs, could be offsetting.

In an effort to influence production, support farm income, and limit government costs, various acreage limitation programs have been employed, such as the acreage reduction program, paid land diversions, and

the voluntary 0,50/85-92 programs.[1, 2] In addition, the long-term Conservation Reserve Program (CRP) affected acreage available for production.[3]

Income support through the target price/deficiency payment system provided economic incentives for producers to participate in annual farm programs, thereby influencing farmers' planting decisions. For an individual farmer, program benefits would be compared with costs of participating in the programs, such as complying with any requirement to idle land under a supply management program. Planting choices were also affected by program rules for determining crop-specific acreage bases to maintain eligibility for future farm program benefits. The 1996 Farm Act replaced deficiency payments with annual production flexibility contract payments, eliminated annual supply control programs, and decoupled planting decisions from program parameters. Thus, planting decisions now are mostly based on market prices rather than farm programs.

[1] Acreage reduction programs (ARP's) began in the early 1980's, replacing set-aside programs of the late 1970's. If supplies were estimated by USDA to be excessive, ARP's were required and paid land-diversion programs (PLD's) were permitted. To participate in the annual farm programs and be eligible for program benefits, farmers were required to idle a crop-specific percentage of their acreage base, as specified by the ARP. No payments were made for idled ARP land. Some PLD's were optional and some were required for program participation.

[2] 0,50/85-92 programs are the 50/85 and 50/92 provisions for rice and cotton and the 50/92, 0/92, and 0/85 provisions for wheat and feed grains that were in effect in various forms from 1986 through 1995. Under these provisions, farmers could idle all or part of their permitted acreage, putting the land in a conserving use, and receive deficiency payments for part of the acreage. A minimum planting requirement of 50 percent of maximum payment acreage applied for rice and cotton for all years during that period, and applied for feed grains and wheat in 1986 and 1987. For feed grains and wheat in 1991 through 1995, producers could plant acreage in this program to selected alternative crops (minor oilseeds, sesame, crambe, or "industrial and other crops") instead of idling the land.

[3] The CRP was created by the Food Security Act of 1985 to reduce erosion and protect water quality, initially on up to 45 million acres of farmland. Under the program, landowners who sign contracts agree to convert environmentally sensitive land to approved permanent conserving uses for 10 to 15 years. In exchange, the landowner receives an annual rental payment and an initial payment of up to 50 percent of the cost of establishing permanent vegetative cover. The 1996 Farm Act caps CRP acreage at 36.4 million acres. Over 40 percent of current CRP enrollments come from wheat and corn cropland.

Corn area planted and harvested for grain averaged 76.0 and 68.7 million acres, respectively, for 1990-96, compared with averages of 66.5 and 56.8 million acres in 1965-70. Wheat plantings and area harvested averaged 72.3 and 62.6 million acres, respectively, for 1990-96, compared with averages of 57.1 and 50.5 million acres in 1965-70.

The proportion of corn planted area that is harvested for grain has been trending upward during the last 20 to 25 years. Low harvest-to-planting ratios for corn typically occur in years of weather-related production and yield shortfalls. For wheat, the relationship between area planted and harvested for grain can vary by region, but at the national level, the harvest-to-planting ratio has been more stable. Typically, the harvest-to-planting ratio for wheat reflects the yield and quality of the crop, market prices, farm program provisions, and, in some regions, the relative grazing value.

Acreage for both corn and wheat in the future is expected to reflect relative net returns from the marketplace as farmers use full planting flexibility provided by the 1996 Farm Act to respond to changes in domestic and international demand.

Yields. Many factors affect U.S. yields for corn and wheat, including climatic conditions, weather, farm management practices, crop variety, and soil type. Trend yields are a good composite indicator of gains related to productivity from production practices, management skills, technology, and input use. In any given year, weather events are crucial and can push yields above or below trends. Major deviations from trend yields may have a significant impact on prices.

Corn yields increased from 74.1 bushels per acre in 1965 to 127.1 bushels per acre in 1996, a 72-percent increase. Corn yields trended upward by 1.5 to 2 bushels per acre per year from 1965 to 1997. Yields are expected to continue to increase, assuming producers adopt favorable production practices developed through research and select hybrids with high yield potential.

Average U.S. wheat yields rose from around 30 bushels per acre in the mid-1970's to 37 bushels per acre in 1990-96. The current yield trend for wheat is about 0.2 to 0.3 bushel per acre per year.

Demand Factors for Corn and Wheat

Major components of demand for corn and wheat include food, seed, industrial, feed and residual, exports, and carryover stocks. Domestic use is a growing component of total U.S. consumption for both corn and wheat. Domestic corn use averaged 79 percent of total disappearance in 1990-96 compared with 69 percent in 1975-80. Increased production of alcohol fuels and corn sweeteners contributed significantly to this growth. Domestic consumption of U.S. wheat accounts for about 50 percent of total wheat disappearance, up from an average 39 percent during 1975-80, with much of this gain reflecting increased wheat flour consumption.

Food, Seed, and Industrial Use

Food, seed, and industrial (FSI) use is a growing component of total demand for both corn and wheat, with its relative share rising. Such a situation strengthens prices at the farm level. FSI use for corn represented an average of 19 percent of total use in 1990-96, up from an average of 9 percent in 1975-80. Food and seed uses for wheat accounted for 39 percent of total wheat disappearance in 1990-96, compared with 34 percent in 1975-80.

Food use. Consumption of corn or wheat for food purposes usually follows a trend because gains are largely related to population growth. Changes in tastes or preferences may at times alter consumption trends. Annual growth for food-use items also depends on whether the market is new and developing, with relatively strong growth, or has reached a stage of mature or stable growth. Food uses of corn and wheat are relatively unresponsive (inelastic) to farm-level prices since the farm value of grain in consumer food items is small.

Food use of corn, consisting of cereals and other products, starch, beverage alcohol, and corn sweeteners, has grown sharply over the past 20 years. Demand for corn-based cereals, snack foods, and baked goods is expected to increase near the rate of population growth. Use of corn starch as a thickening agent for food also is expected to grow in line with population gains. Demand for corn sweeteners has been stimulated indirectly by the sugar program. The U.S. sugar program has kept the price of domestically refined sugar high, thereby stimulating consumption of high-fructose corn syrup, an alternative sweetener. Future growth in demand for corn sweeteners is expected to exceed population growth, but will likely be much less than the sharp gains in the early to mid-1980's.

Wheat food use has been the largest and most stable component of domestic wheat use and is characterized by a steady growth rate, closely tied to population, tastes, and preferences. Wheat food use accounted for an average of 35 percent of total wheat disappearance in 1990-96, compared with an average of 30 percent in 1975-80. Wheat is unique because it is the only cereal grain with sufficient gluten to produce bread without requiring mixing with another grain.

Understanding the different classes of wheat, their uses, and their degree of substitutability is an important demand consideration. Hard red winter wheat, possessing a typical protein content of 9 to 14 percent, is generally used for making white breads and rolls. Hard red spring wheat, typically consisting of 11.5 to 18 percent protein, is used for making whole-wheat and hearth breads. Soft red winter wheat has a protein content from 8.25 to 11.75 percent and is generally used to produce cakes, cookies, crackers, or pastries with a tender, flaky, or crisp texture. Soft white wheat has a protein content ranging from about 6.75 to 10.5 percent and is used to produce cookies, cakes, pastries, and cereal. New hard white wheat varieties are being developed with milling and end-use characteristics superior to hard red winter wheat. Finally, durum wheat is primarily used for spaghetti, macaroni, and other pastas. The amount of potential substitution among the different wheat classes depends on the end use. Thus, the greatest degree of substitutability is between hard red winter and hard red spring wheats. This substitutability allows blending of these two varieties to achieve minimum protein requirements in various end uses if protein content of either variety is low. Additional substitution potential exists between the hard red wheats and new hard white varieties.

Seed use. Seed use is a relatively small component of total demand for corn and wheat. Seed use reflects the amount of land planted to the crop and the per-acre seeding rates. Seeding rates for corn and wheat vary across States due to differences in soil types and production practices, and change slowly over time as production practices evolve. As a result, national average seeding rates for these crops tend to be fairly stable. Thus, variations in total seed use for corn and wheat are

mostly due to changes in acreage, which historically have reflected provisions of annual supply management programs.

Industrial use. Industrial use of corn reflects the production of starch and alcohol. Corn starch is used in the paper industry for coating paper and in the construction industry as an ingredient for wallboard construction. Corn used in starch production follows the growth rate of population and the general economy. Corn use for fuel alcohol depends on government incentives and policies, technology, corn prices, prices of production byproducts, and prices of energy substitutes. Fuel alcohol use of corn, which began in the late 1970's, averaged about 425 million bushels in 1990-96.

Feed and Residual

Feed and residual use is a major demand component for corn, but represents a relatively smaller component of total demand for wheat. Despite corn's rising levels of feed use, its share of total disappearance remained fairly constant between 1975 and 1996. In contrast, the share of wheat feed use of total wheat disappearance is more variable, reflecting both feed wheat's small share of total wheat use and wheat's primary use as a food grain. The reported data for the category "feed and residual" are derived by subtracting other domestic uses (food, seed, and industrial uses), exports, and ending stocks from total supply. As a result, some variation in this category reflects unaccounted statistical measurement errors in other categories of supply and demand.

Feed use of corn is related to the number of animals on feed, the price of corn, and prices of competing feed grains and feed wheat. Feed and residual use for corn averaged 5.0 billion bushels during 1990-96, about 60 percent of total disappearance for corn. This compares with an average corn feed and residual use of 4.0 billion bushels during 1975-80, again about 60 percent of total corn use. Corn feed use may vary annually, reflecting changes in the numbers of animals fed and adjustments in rations made by feeders in response to relative prices and availability of corn and competing feed ingredients.

Feed use for wheat is more variable than food use and is related to wheat prices, feed grain prices, and wheat crop quality. Feed and residual use for wheat accounted for 18-20 percent of total disappearance in the 1986 and 1990 crop years, years of lower wheat prices, compared with about 6 percent in 1988 and 1995, years of higher wheat prices. Typically, most feed use of wheat occurs in the summer, when wheat prices are seasonally low following the wheat harvest but before new crops of corn and sorghum are harvested.

Exports

Exports are important to both the corn and wheat market. Crop developments in other countries and U.S. agricultural policies (such as EEP[4] and P.L. 480 programs[5]) can affect the demand for U.S. exports and, consequently, the U.S. price. A crop shortfall in a major producing foreign country can increase the demand for U.S. exports, strengthening U.S. prices. Or an abundant crop in an importing country can reduce U.S. export demand, lowering U.S. prices. One expected result of global trade liberalization is that export demand for U.S. corn and wheat will become more responsive to price changes (more price-elastic) as foreign import demand and export supply become more elastic.

Corn exports averaged 21 percent of total U.S. corn consumption in 1990-96, compared with an average of 31 percent in 1975-80. In fiscal 1996, corn exports accounted for 14 percent of the total value of U.S. agricultural exports, or $8.4 billion. The United States is the world's largest exporter of corn, with a world market share averaging over 70 percent in 1990-96.

[4] The Export Enhancement Program (EEP) was initiated in May 1985 under the Commodity Credit Corporation Charter Act to help U.S. exporters meet competitors' subsidized prices in targeted markets. The program was later authorized by the Food Security Act of 1985 and has continued under subsequent legislation. Under the EEP, exporters are awarded cash payments to enable the sale of certain commodities to specified countries at competitive prices. The 1996 Farm Act caps EEP program levels annually through 2002 and allows the Secretary to target up to $100 million annually (under certain conditions) for the sale of intermediate-value products.

[5] Public Law 480 (P.L. 480), the common name for the Agricultural Trade Development and Assistance Act of 1954, seeks to expand foreign markets for U.S. agricultural products, combat hunger, and encourage economic development in developing countries. P.L. 480 is also referred to as the Food for Peace Program. Title I of P.L. 480 makes U.S. agricultural commodities available by financing export sales on concessional terms, such as using low interest rates for up to 30 years. Donations for emergency food relief and nonemergency humanitarian assistance are provided under Title II. Title III authorizes a Food for Development program that provides government-to-government grant food assistance to least developed countries. The 1996 Farm Act extends the authority to enter into new P.L. 480 agreements through fiscal year 2002.

U.S. exports of wheat are very important to the U.S. wheat market. Wheat exports averaged 49 percent of total disappearance in 1990-96, compared with an average of 61 percent in 1975-80. In fiscal 1996, wheat exports accounted for 12 percent of the total value of U.S. agricultural exports, or $7.0 billion. Although the United States is the world's largest exporter of wheat, it has a smaller world-market share than for corn, averaging slightly over 30 percent of global wheat trade in 1990-96. Since wheat can be grown in more different climates than corn, relatively greater production occurs in other countries. Consequently, the United States has a less dominant role in the international wheat market than it does in the global corn market. Major wheat trade competitors include the European Union (EU), Canada, Australia, and Argentina.

U.S. wheat exports have been boosted by a variety of agricultural export programs, including food aid, export credit guarantees, export enhancement programs, and market development and market promotion programs. Between 1986 and 1994, over half of U.S. wheat exports received EEP subsidies. Although the EEP has not been used for U.S. wheat exports since July 1995, the 1996 Farm Act continues the program, but annual funding is limited by the 1996 Act and by WTO (World Trade Organization) export subsidy commitments.

Carryover Stocks

In general, changes in carryover stocks are inversely related to the marketing year price. If total use rises relative to supply, ending stocks decline and farm prices tend to rise. On the other hand, if supply rises relative to total use, prices tend to decline as ending stocks build. For corn and wheat, government programs historically have influenced the holding of stocks, either through direct government (public) ownership of stocks or through programs that influence stockholding by the private sector.

Government programs led to a large buildup of stocks in the early to mid-1980's. Total ending stocks for corn exceeded 4 billion bushels from 1985 through 1987, an average of 61 percent of annual use. Wheat carryover stocks reached levels greater than 1 billion bushels between 1981 and 1987, with ending stocks representing an average of 62 percent of annual use. Many of these stocks were in the Farmer-Owned Reserve (FOR) or held by the Commodity Credit Corporation (CCC). However, as 1985 and 1990 farm legislation steered the sector toward greater market orientation, grain stocks declined. Year-ending stocks of corn averaged about 1.2 billion bushels (14.5 percent of use) in 1990-96, while wheat carryover stocks averaged about 540 million bushels (22 percent of use).

Publicly held stocks owned by the Government (CCC) represent stocks acquired through loan defaults or market purchases. Stocks owned by the Government have historically influenced corn and wheat prices because these stocks have generally not been readily accessible to the marketplace. This reflects CCC sales price restrictions, which, until removed in the 1996 Farm Act, prohibited the Government from selling commodities it owned unless prices reached specified levels. Government-owned stocks of corn and wheat were high in the early to mid-1980's, but have fallen in recent years with more market-oriented stockholding policies. At the end of the 1996 crop year, the CCC held only 2 million bushels of corn and 93 million bushels of wheat.

For wheat, government-owned stocks have included those held in the Food Security Wheat Reserve (FSWR). The FSWR was created in the 1980/81 marketing year to provide a government-held reserve of up to 4 million metric tons (about 147 million bushels) of wheat for emergency food needs in developing countries. The FSWR was replaced in the 1996 Farm Act by a new Food Security Commodity Reserve (FSCR) that may include corn, grain sorghum, and rice, in addition to wheat. Almost all of the 93 million bushels of wheat held by the Government at the end of the 1996 crop year were in this grain reserve.

Privately held stocks have also been influenced by government programs, such as the government price-support loan program and, historically, the FOR program. Depending on the accessibility of these stocks, some of these government policies have affected prices.

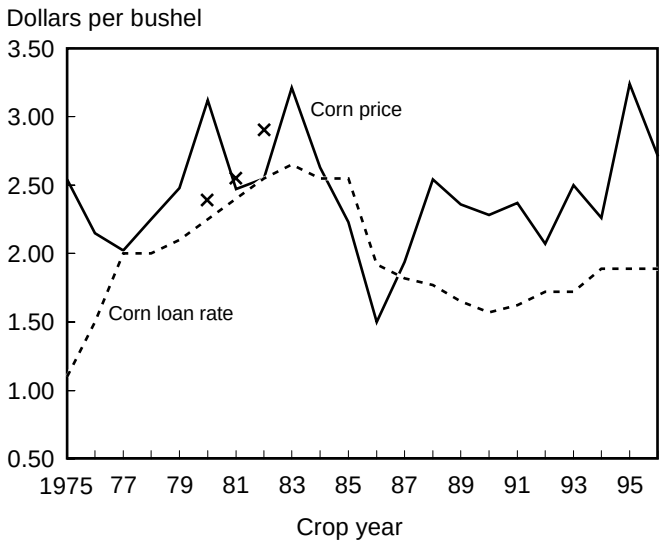
Agricultural Policies: Price Support and Commodity Storage Programs, 1975 to 1996

Beyond the effects of domestic agricultural policies on supply and demand factors, some policies have affected market prices more directly. The most important have been price support and commodity storage programs. This section discusses how these programs evolved from 1975 to 1996 and how their interactions with each other and with additional farm programs affected market prices.

Commodity price support programs for corn and wheat allow producers to receive a loan from the Government at a designated loan rate per unit of production by pledging some of their grain production as loan collateral. Following harvest of the crop, a farmer who has enrolled in the farm program may obtain a loan for all or part of the new crop. For each bushel put under loan and pledged as loan collateral, the farmer receives a per-bushel amount equal to that year's loan rate. Under the loan program, the producer must keep the crop designated as loan collateral in approved storage to preserve the crop's quality. The producer may repay the loan at any time during the length of the loan, usually 9 months for corn and wheat. Prior to 1993, when marketing loans were implemented for corn and wheat (discussed below), the farmer would pay back the loan principal plus accrued interest charges. However, rather than repaying the loan, the farmer could choose instead to default on the loan at the end of the 9-month loan period, keeping the loan money and forfeiting ownership of the loan collateral (the grain) to the Government. If market prices were below the loan rate, the farmer would benefit from defaulting on the loan and keeping the higher loan rate. Additionally, if market prices were above the loan rate, but below the loan rate plus interest, defaulting on the loan would also make economic sense because the cost of settling the loan (loan rate plus interest) would be greater than the market value of the grain.

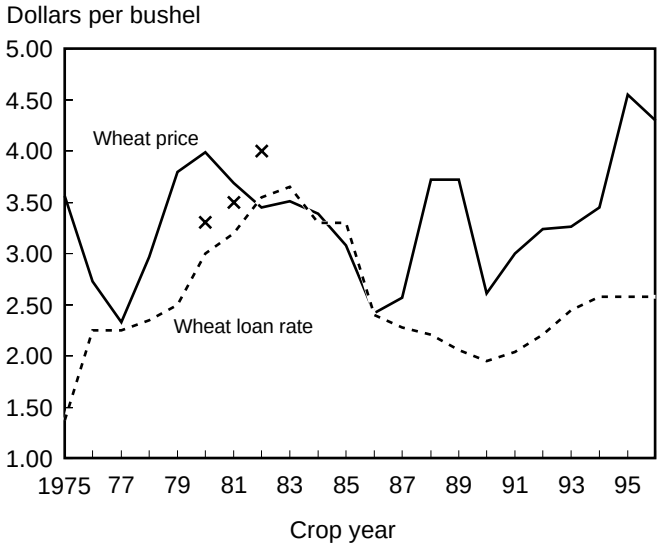
Historically, loan rates for corn and wheat were raised in the late 1970's and remained relatively high through the mid-1980's (figs. 1 and 2). Loan program defaults pushed government-owned stocks of corn to more than 1.1 billion bushels in 1982, or 16 percent of annual use (fig. 3), while government-owned stocks of wheat rose to almost 200 million bushels, representing 8 percent of annual use (fig. 4). Stocks owned by the Government have historically influenced corn and wheat prices because these stocks have generally not been readily accessible to the marketplace.

Figure 1
Corn price and loan rate



X = Higher FOR loan rate, 1980-82.

Figure 2
Wheat price and loan rate



X = Higher FOR loan rate, 1980-82.

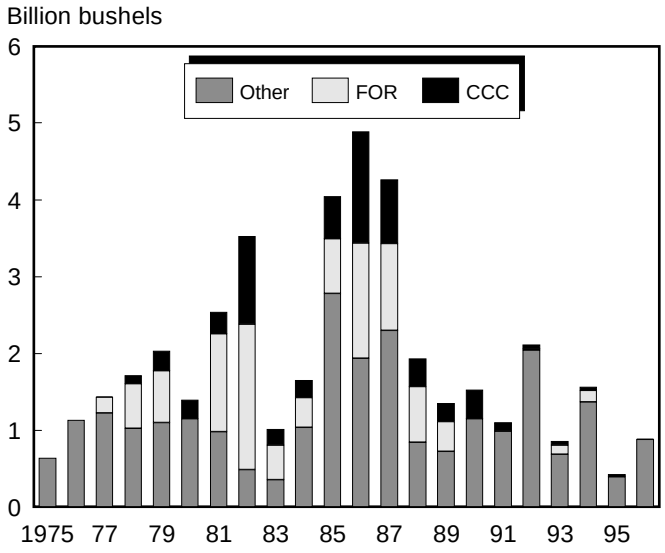
Also, a multi-year FOR program was initiated in the late 1970's under the Food and Agriculture Act of 1977. The FOR provided storage subsidies to farmers to store grain under loan for 3 to 5 years (with some extensions)—farmers agreed not to market their FOR grain for this time period unless the average farm price reached a specified release level. Additional price support was provided under the FOR program in 1980-82, with a higher reserve loan rate than available under the regular, 9-month loan program. The long duration of the FOR program, combined with high release prices needed for grain to exit the reserve, effectively isolated a large amount of grain from the marketplace. By 1982, corn held in the FOR rose to almost 1.9 billion bushels, about 26 percent of annual use, and the wheat FOR exceeded 1 billion bushels, representing 44 percent of annual use. Thus, high price supports along with the isolation of FOR stocks from the marketplace resulted in a significant policy effect on corn and wheat prices.

Changes in the price support program since 1986 have reduced the interference of that program with price determination. Three important policy features of programs enacted in 1985 farm legislation significantly changed the loan program and the effect of price supports on market prices starting in 1986. These changes were part of a general movement in U.S. agricultural policy toward more market orientation. First, price support levels for grains were sharply reduced. Loan rates for corn and wheat were lowered—corn from $2.55 per bushel in 1985 to $1.92 per bushel in 1986, wheat from $3.30 to $2.40. Second, corn produced in 1986-90 was not permitted to enter the FOR; the wheat FOR was opened for wheat produced in 1990, but not for 1986-89 crops. Finally, a new policy instrument, generic certificates,[6] made grain in the reserve more available to the marketplace by allowing early access to that grain before its FOR contract expired.

These policy changes facilitated a reduction in grain stocks in the late 1980's. Corn stocks fell from over 4 billion bushels at the end of the 1986/87 season to 1.5 billion bushels at the end of 1990/91 while government-owned and FOR corn stocks fell from nearly 3 billion bushels to under 400 million bushels, declines accelerated in 1988 by a major drought in the Corn Belt region that sharply lowered corn production. Similarly, total wheat stocks fell from about 1.8 billion bushels at the end of 1986/87 to under 900 million bushels by the end of 1990/91. Government-owned and FOR wheat stocks dropped from nearly 1.3 billion bushels to about 175 million bushels, with less than 14 million bushels in the FOR. As with corn, production difficulties for wheat (in 1988 and 1989) accelerated the decline in stocks. Importantly, however, the combina-

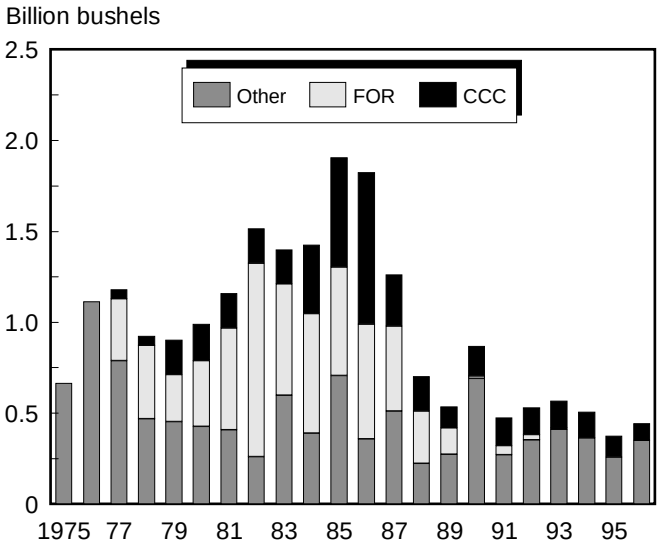
[6] Generic certificates were dollar-denominated negotiable certificates that were issued by USDA in lieu of cash payments to commodity program participants and sellers of agricultural products. Generic certificates did not specify any particular commodity. They could be used to acquire stocks held as collateral on government loans (regular loans or FOR loans) or stocks owned by the CCC. Farmers received generic certificates as payment for participation in numerous government programs. Grain merchants and commodity groups also were issued certificates through the Export Enhancement Program and the Targeted Export Assistance Program.

Figure 3
Corn stocks



FOR is Farmer-Owned Reserve stocks.

Figure 4
Wheat stocks



FOR is Farmer-Owned Reserve stocks.

tion of lower price supports for corn and wheat, no further corn FOR entry and only limited wheat FOR entry, and generic certificates that allowed access to FOR stocks reduced the strong policy effect on price determination for these grains. Essentially, the loan program continued to provide corn and wheat producers a source of short-term liquidity, but it no longer supported prices. Also, the lower level of stocks held by the Government reduced the price effects of public stockholding.

Policy changes since 1990 have continued to keep the price effects of government price support and commodity storage programs small. Since 1991, the corn loan rate has ranged from $1.62 to $1.89 per bushel, while wheat loan rates have ranged from $2.04 to $2.58 per bushel. Until recently, these loan rates have been well below market prices in most years. Further, marketing loans for corn and wheat were implemented starting in 1993 and continued under the 1996 Farm Act. Marketing loans allow repayment of commodity loans at less than the original loan rate if market prices are lower, which decreases the loan program's potential effect on supporting prices because stock accumulation by the Government through loan defaults is reduced. Additionally, although the availability of generic certificates declined in the early 1990's, new FOR rules in the 1990 Farm Act permitted farmers to repay their FOR loans and re-acquire the loan collateral at any time rather than when prices reached specific FOR release levels, thereby continuing the accessibility of those stocks to the marketplace. The 1996 Farm Act suspended the FOR. Finally, government-owned stockholding has continued to decline, with only 2 million bushels of corn held by the CCC at the end of the 1996 crop year and 93 million bushels of wheat held, nearly all of the latter in the Food Security Commodity Reserve. As a consequence, since 1986, prices for corn and wheat have largely been based on market supply and demand conditions with a reduced influence of government price support and commodity stockholding programs.

Previous Price Modeling Research

Many price models for grains have employed the stocks-to-use ratio to represent market conditions in explaining price movements. The stocks-to-use ratio is defined as stocks of the commodity at the end of a particular time period divided by use of the commodity during that time period. As such, market conditions of supply and demand are summarized in this measure. One objective of the analysis presented here is to see how well this simple composite measure captures the effects of market factors in the determination of corn and wheat prices.

Van Meir (1983) and Baker and Menzie (1988) analyzed the relationship between stocks-to-use ratios and corn prices in annual frameworks. Westcott, Hull, and Green (1984, 1985) used such an approach in quarterly models for wheat and corn prices. Numerous other unpublished annual pricing models for corn and wheat using stocks-to-use ratios have been used by USDA in its forecasts. In each model, the stocks-to-use variable is negatively related to prices and provides a downward sloping, nonlinear curve of prices plotted against ending stocks-to-use ratios.

To represent the effects of governmental price support programs on prices, many grain price models have been estimated with the dependent variable of price minus loan rate. The Baker and Menzie annual corn price model and part of the Van Meir analysis of corn prices and stocks used this approach, as did most of the unpublished USDA models. The U.S. price support program affected corn and wheat prices, particularly in the late 1970's through the mid-1980's when high loan rates along with limited accessibility of FOR and government-owned stocks combined to influence market prices. However, changes in the price support program since 1986 have reduced the interference of that program with price determination.

A Pricing Model

The general framework used here relating prices to ending stocks is derived from an equilibrium model for competitive markets with inventories (Labys, 1973). For annually produced commodities, such as corn and wheat, supply is a function of the previous year's price. Demand is a function of prices in the current period and the previous year. Lagged prices are particularly important for crops used for livestock feeding, as livestock production decisions made in previous periods in response to prices in those periods affect livestock inventories, and thus feed demand, over a number of years. Export demand would also be a function of lagged prices to reflect foreign supply response. In its simplest form, without the government price support program, stocks are a function of price. The market-clearing, equilibrium condition determines the price at which supply equals demand plus stocks (equations 1-4).

(1) $S = f(p_{t-1}, z)$ (Supply function)

(2) $D = g(p, p_{t-1}, z)$ (Demand function)

(3) $K = h(p, z)$ (Stocks function)

(4) $S - D - K = 0$ (Equilibrium condition)

S is supply, D is demand, K is ending stocks, p is market price, and z is a set of exogenous variables. The subscripted price variables represent prices in the previous year (t-1). All other variables are for the current year. Supply is positively related to expected price while demand and stocks are negatively related to price.

In equilibrium, prices can be determined from the inverse of the stocks function. This provides a price determination equation, with prices negatively related to stocks.

(5) $p = h^{-1}(K, z)$ (Price equation; inverse stocks function)

Adjustments to the Basic Model

The basic pricing model presented in equation 5 provides a starting point for introducing adjustments that shift the pricing relationship. Adjustments are included for both corn and wheat to account for government loan program and stockholding policies. Additional adjustments are included for wheat to account for global market factors as well as wheat feed use and related cross-commodity pricing considerations. These adjustments result in year-specific upward and downward shifts of the basic functional relationship between ending stocks and prices.

Introducing the government price support loan program adds to the stocks function by incorporating the commodity loan rate (LR) to the function, as represented in equation 3a.

(3a) $K = h(p, LR, z)$ (Stocks function with government loan program)

The government loan program provides an additional feature to stockholding behavior that depends on the loan rate incentive to use the loan program.

With this alternative stocks function, the inverse stocks function gives the following price determination equation.

(5a) $p = h^{-1}(K, LR, z)$

To reflect the different effect that government-owned stocks have on price determination, an additional term representing government stocks (CCC) is added, as shown in equation 5b.

(5b) $p = h^{-1}(K, CCC, LR, z)$

Prices are negatively related to total stocks, but positively related to government-owned stocks, as year-ending stocks held by the government generally have not been available to the marketplace. That is, larger total stocks would be associated with lower prices, but for any given level of total stocks, larger government-owned stocks push prices up. Prices are also positively related to the loan rate in those years that loan rates were relatively high and the FOR isolated stocks from the marketplace.

Additional Considerations for the Wheat Price Model

Two additional adjustments are added to the pricing model for wheat. First, the role of the global wheat market in price determination is added. Although the United

States is the world's leading wheat exporter, its role is not nearly as dominant as is the case for corn. As a result, domestic U.S. wheat prices are influenced to a greater degree by world market conditions beyond what is reflected in U.S. wheat supply, demand, and resulting stocks information. To reflect this global market effect, a variable representing stockholding in four major competitors (European Union, Canada, Australia, and Argentina) is added to the wheat price model. For any given level of wheat stocks in the United States, larger stocks in the major competitor countries shift prices lower.

The second wheat price model consideration is a statistical measurement issue regarding wheat prices for different uses. The farm-level wheat price to be used as the dependent variable in the model is implicitly a weighted average of prices in different uses. While food use represents most domestically used wheat, feed use of wheat can be important in some years. Wheat competes with feed grains particularly well in the summer, when wheat has been harvested but most feed grains have not. When wheat prices are relatively low and wheat is used heavily for feed, more of this lower end-use value is implicitly reflected in the season-average price. Also, when low wheat prices lead to large wheat feeding, typically in the summer, the wheat price tends to be influenced by prices of competing feed grains, particularly corn.

To represent this wheat-pricing consideration, two variables are added to the basic model. First, summer-quarter wheat feed use as a share of total annual wheat use is an indicator of the importance of wheat feeding implicit in the season-average price for wheat.[7] Larger summer-quarter wheat feeding when wheat prices are low gives more implicit weight to wheat prices at a feed value, lowering the season-average price. Second, the summer-quarter corn price provides a measure of the level of cross-commodity pricing influence provided from competing feed grains. The higher the price of corn in the summer, the higher the price of wheat used for feed, and thus the higher the overall season-average wheat price.[8]

Equation 5c adds these wheat price considerations to the general pricing model. The price equation for wheat now includes variables C4K for competitor stocks, FS/U for summer-quarter feed share of annual use, and PCS for the price of corn in the summer quarter. These variables shift the wheat price determination function up or down to reflect the effects of these factors.

$$(5c)\quad p = h^{-1}(K, CCC, LR, C4K, FS/U, PCS, z)$$

[7] Summer-quarter wheat feeding is used in this measure because that is when most actual wheat feeding occurs. In other quarters, actual wheat feeding is smaller so the "feed and residual" category includes a greater share of statistical measurement errors (or residuals) from other categories of supply and demand. In fact, feed and residual in other quarters of the year is frequently negative.

[8] Marketing years for corn and wheat differ because of differences in harvesting dates. As a result, the same summer quarter occurs in different marketing years for corn and wheat. The summer-quarter corn price is from the last quarter of the corn marketing year, but it affects the wheat price in the (first quarter of the) next wheat marketing year. Despite this apparent lag from one marketing year to the next, the effect is concurrent.

Model Implementation

The functional form used to estimate equations 5b and 5c that relate annual prices of corn and wheat prices, respectively, to their stocks-to-use variables is logarithmic (double-log). With a negative coefficient on the stocks-to-use variable, this functional form provides a downward-sloping, convex-shaped relationship between the stocks-to-use ratio and prices. Most other explanatory variables used also are specified in logarithms. However, to address problems encountered in corn and wheat sector simulations using other estimated versions of the price models, the government-owned stocks variable in each equation was not transformed to logarithms. Also, a dummy variable for 1986 was added to the corn price equation to address a problem encountered regarding that year's having a particularly strong influence on the model's parameter estimates, as discussed below.

The models were estimated using annual (marketing year) data for 1975 to 1996. Figures 5 and 6 show corn and wheat prices plotted relative to their annual stocks-to-use ratios during the estimation period. The model specifications shown in equations 6a and 6b can be viewed as providing a basic pricing relationship between prices (p) and the total stocks-to-use ratio (K/U), which shifts upward and downward depending on the year-specific values of the other independent variables in the equations.

Corn price model:

(6a) $\text{Ln}(p) = a + b\,\text{Ln}(K/U) + c\,(CCC/U) + d\,\text{Ln}(LR)\,Dum7885 + e\,Dum86$

Wheat price model:

(6b) $\text{Ln}(p) = a + b\,\text{Ln}(K/U) + c\,(CCC/U) + d\,\text{Ln}(LR)\,Dum7885 + f\,\text{Ln}(C4K/C4U) + g\,\text{Ln}(FS/U) + h\,\text{Ln}(PCS)$

Variable definitions are summarized in table 1. As defined earlier, the variable p is the farm-level price, LR is the commodity loan rate, and K is total stocks. U represents annual utilization of the crop; Dum7885 represents a dummy variable equal to 1 in 1978-85 and equal to 0 in other years; Dum86 represents a dummy variable equal to 1 in 1986 and equal to 0 in other years; and CCC represents government-owned stocks. In the wheat equation, C4K and C4U represent stocks and use in the four main wheat-export competitors (European Union, Canada, Australia, and Argentina), FS represents wheat feed use in the summer quarter, and PCS represents the price for corn in the summer quarter. The terms a, b, c, d, e, f, g, and h are parameters to be estimated.

Figure 5
Corn prices and stocks-to-use ratios, 1975-96

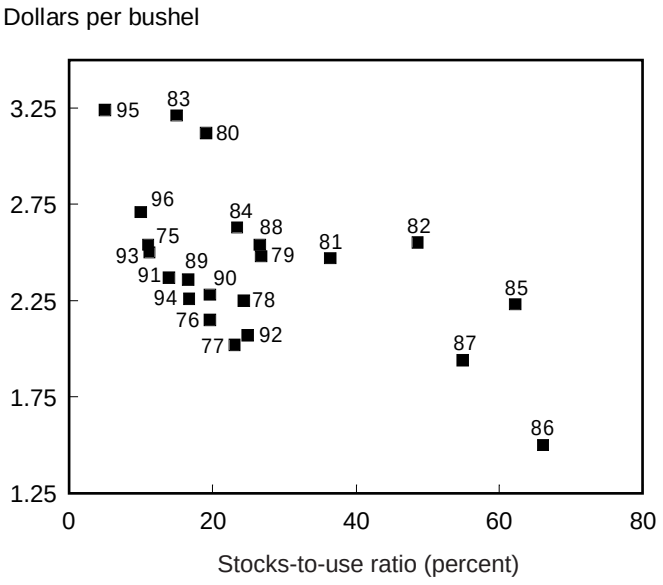
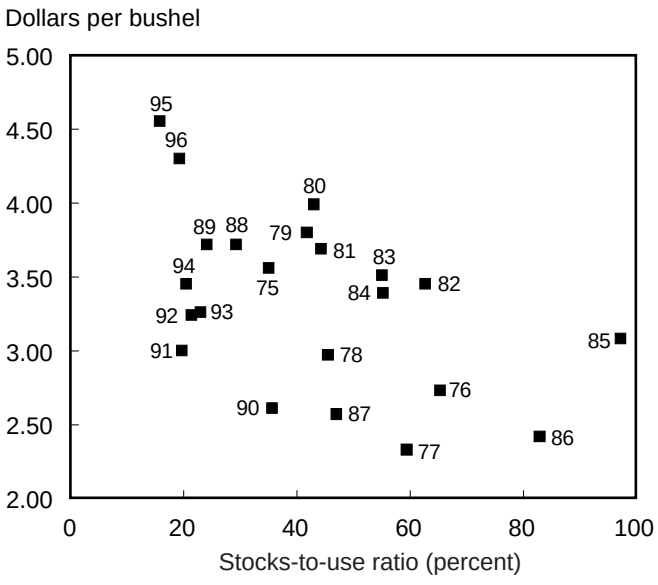


Figure 6
Wheat prices and stocks-to-use ratios, 1975-96



In equations 6a and 6b, total stocks (K) and government-owned stocks (CCC) are measured relative to an indicator of the "scale of activity" in the sector, represented by the realized level of demand, actual utilization (U). This adjustment is needed because of growth in the corn and wheat sectors over the last 25 years, so a particular level of stocks today represents a smaller portion of total use (or realized industry demand) than the same level of stocks in 1975. Each ratio is multiplied by 100 to express the result as a percentage. The first resulting ratio, K/U, is a stocks-to-use variable commonly used in price models, providing a summary measure of market supply and demand conditions and an indicator of relative market tightness for the commodity. The expected sign of the total stocks-to-use coefficient (b) is negative. In contrast, a larger government-owned stocks-to-use ratio (CCC/U) at the end of the year indicates that a greater share of stocks are not accessible to the marketplace, resulting in higher prices. Thus, the coefficient "c" for the government-owned stocks-to-use variable is expected to be positive.

The interaction term of the loan rate (LR) times the dummy variable (Dum7885) represents the combined effects of the loan program and the FOR on corn and wheat prices from the late 1970's through the mid-1980's. The loan-rate variable used in the model includes the higher FOR loan rates available to corn and wheat producers in 1980 through 1982. The years 1978-85, chosen for the interaction term, cover the period when the commodity loan program, in conjunction with the structure of the FOR program, had a significant influence on price levels in the sector. Loan rates were relatively high in those years and the multi-year FOR program, with high release prices, isolated those reserve stocks from the market. The price-supporting aspects of the loan program in the late 1970's through the mid-1980's imply that the expected sign for the coefficient (d) for the loan-rate interaction term is positive.

This model specification for the loan rate contrasts with the approach frequently used in the past of defining the dependent variable as price minus loan rate. For many of those earlier models, the years 1978-85 (when high loan rates and the structure of the FOR program affected price determination) were a larger part of the sample period used for model estimation. Those years represent only 8 of the 22 observations of the sample period used here, which covers 1975 to 1996. Thus, rather than including the loan rate in the dependent variable, it seems more appropriate now to include the loan rate as a separate independent variable for the years when high price supports and the FOR affected prices, providing a policy-shift effect on price determination in those years. With this specification for the loan rate, the dependent variable is the farm-level price.

The corn price equation includes a dummy variable for 1986. In an initial specification without the dummy variable, the Cook's D statistic (Cook) for that year was 2.66, suggesting that 1986 had a strong influence on the model's parameter estimates. In particular, the influence on the coefficient of the government-owned stocks vari-

Table 1— Summary of variable definitions

Variable name	Definition
C4K	Ending stocks of wheat for four main export competitors (EU, Canada, Australia, and Argentina)
C4K/C4U	Stocks-to-use ratio (percent) for wheat for the four main wheat export competitors
C4U	Annual use of wheat, including exports, for four main wheat export competitors
CCC	Government-owned stocks, corn or wheat
CCC/U	Government-owned stocks relative to total use, corn or wheat, percent
Dum7885	Dummy variable equal to 1 in 1978-85 and equal to 0 in other years
Dum86	Dummy variable equal to 1 in 1986 and equal to 0 in other years
FS	Domestic feed use of wheat, summer quarter
FS/U	Summer-quarter wheat feed use as a share of total annual use of wheat, percent
K	Total year-ending U.S. stocks for corn or wheat
K/U	U.S. stocks-to-use ratio, corn or wheat, percent
LR	Commodity loan rate, corn or wheat
p	Farm-level price for corn or wheat
PCS	Price for corn in the summer quarter
U	Annual U.S. utilization, including exports, corn or wheat

able was largest. By using the 1986 dummy variable, the statistically large influence of that year on the parameter estimates is removed, improving the coefficient estimate for government-owned stocks and its corresponding t-statistic.

In the wheat equation, competitor stocks (C4K) are divided by competitor use (C4U). As for the domestic stocks variables, this division adjusts for the growth in the size of those countries' wheat sectors over the estimation period. The ratio is then multiplied by 100 to express the result as a percentage. Wheat use for the EU in this variable nets out intra-EU trade to avoid double counting. The competitor stocks-to-use variable is intended to represent the effects on U.S. wheat prices of conditions in the international marketplace beyond the effects captured through U.S. exports. A larger competitor stocks-to-use ratio would tend to push international wheat prices lower, exerting downward pressure on U.S. prices as well, so the expected sign on the coefficient (f) of the competitor stocks-to-use ratio is negative.

The variables used to represent the feed use effect on wheat prices— summer-quarter wheat feeding as a share of annual wheat use and summer-quarter corn price— would be expected to have opposite effects on wheat prices. As such, their combined relationship could be specified as a ratio. However, since the ratio of the two variables has no particular economic meaning, there is no reason to expect (and thus restrict) their effects on wheat prices to be equal and opposite. Thus, each variable is used separately in the specification of the wheat price model, with an expected negative sign for the coefficient (g) of the feed use share, and an expected positive for the coefficient (h) of the summer-quarter corn price.

The summer-quarter feed-use share variable in the wheat equation was defined as a percentage of total annual wheat use. An adjustment to this measure then is made to accommodate the logarithmic transformation used. This adjustment is needed because summer-quarter feed use can be 0 or negative, and the logarithm is defined only for positive numbers. In fact, the lowest observation in the estimation period for summer-quarter wheat feed (and residual) use was -3 million bushels. To adjust for this, 3 million bushels were added to the summer-quarter wheat feeding data, and then 1 percent of use was added to the numerator each year. Thus, for its lowest value, adjusted summer-quarter wheat feeding used in the model is 0, the adjusted ratio (with 1 percent of use added) equals 1 percent, and logarithm of 1 equals 0.

Farm-level prices used to estimate the model are marketing year averages collected by USDA's National Agricultural Statistics Service (NASS) and re-published by the Economic Research Service in the *Feed Situation and Outlook Yearbook* (April 1999) and the *Wheat Situation and Outlook Yearbook* (March 1999). Data for U.S. stocks, utilization, loan rates, and summer-quarter corn prices, and data for competitor stocks and use for wheat also are from those two yearbook publications. U.S. stocks and utilization data reflect the historical revisions published by NASS in December 1998 (*Field Crops— Final Estimates, 1992-1997* and *Stocks of Grains, Oilseeds, and Hay — Final Estimates, 1993-1998*). FOR loan-rate data for 1980-82 are from Lin, Glauber, Hoffman, Collins, and Evans. EU wheat-use adjustments to subtract intra-trade are based on data from various monthly issues of *Grain: World Markets and Trade* as well as estimated historical data provided by the Foreign Agricultural Service.

Model Results and Properties

The models were estimated with annual marketing year data from 1975 through 1996 using ordinary least squares regression in SAS (SAS Institute).

Corn Equation

The estimated logarithmic regression equation for corn is:

(7a) Ln (p) = 1.619 - 0.2813 Ln (K/U)
(8.6)

+ 0.0149 (CCC/U)
(3.1)

+ 0.2269 Ln (LR) Dum7885
(6.8)

- 0.3256 Dum86
(3.6)

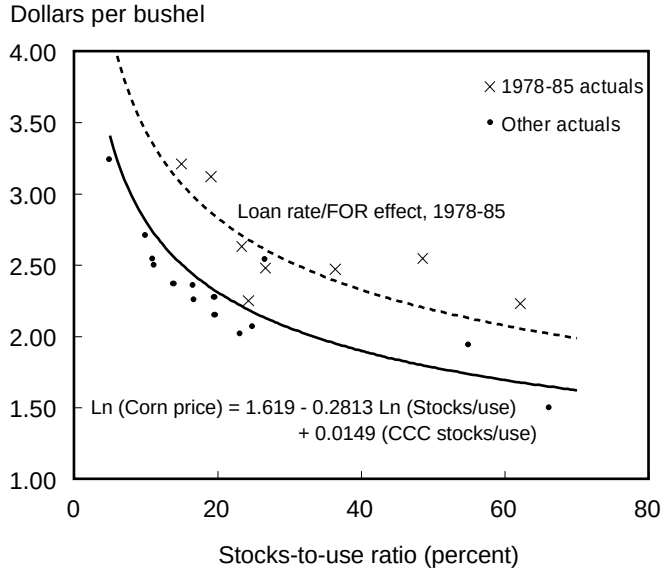
$R^2 = 0.908$
F-value = 41.812
Standard error of the estimate = 0.0583
Durbin-Watson statistic = 1.931
Estimation period: 1975 - 1996

Numbers shown in parentheses under each coefficient are t-statistics. Variable definitions are summarized in table 1.

Nearly 91 percent of the variation in the logarithm of annual corn prices is explained by estimated equation 7a. Transforming the equation to price levels, close to 90 percent of the variation of annual corn prices is explained. Each coefficient has the expected sign, with a negative sign for the total stocks-to-use variable and positive signs for the government-owned stocks-to-use variable and the 1978-85 loan-rate shift variable. Each coefficient is significant at the 1-percent level. The F-value for the overall significance of the equation greatly exceeds the 1-percent critical F-value (4 and 17 degrees of freedom) of 4.67. The Durbin-Watson statistic indicates that first-order autocorrelation is not a problem with the equation.

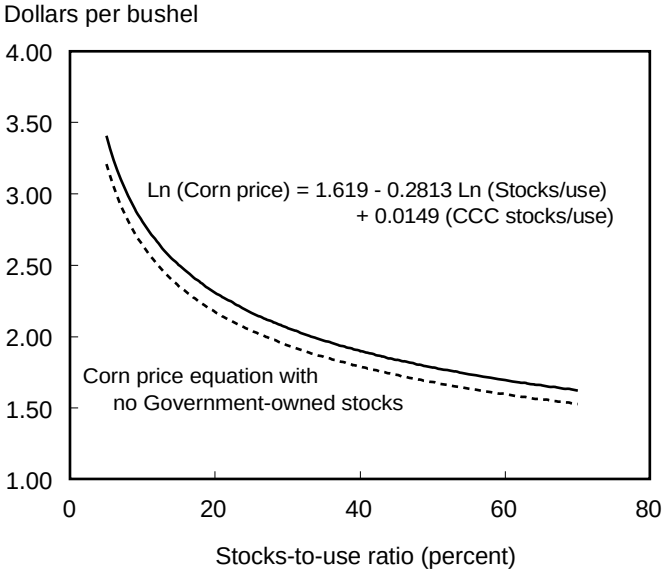
Graphs highlighting the regression equation results for corn are shown in figures 7 and 8. In each figure, corn prices are plotted against ending stocks-to-use ratios. Figure 7 illustrates the price effects in 1978-85 of the higher loan rates and the FOR. The higher price curve incorporates the average price-supporting effect of high loan rates in 1978-85, while the lower price curve omits

Figure 7
Corn price equation—1978-85 loan rate/FOR effect



Note: Both curves evaluated at sample mean value for CCC stocks relative to use, with the 1986 dummy variable set equal to 0.

Figure 8
Corn price equation—Government stocks effect



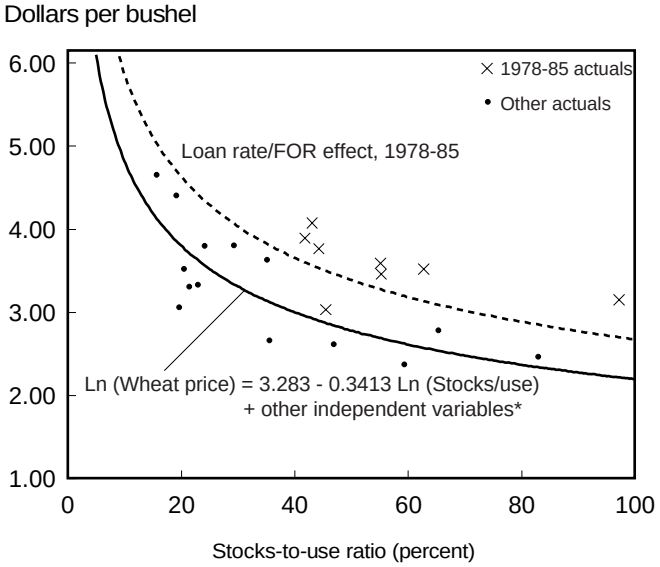
Note: Higher curve evaluated at the sample mean value for CCC stocks relative to use, corresponding to CCC stocks of about 300 million bushels. Both curves assume the 1986 dummy variable equals 0.

that effect. To isolate the loan-rate effect, both price curves in figure 7 are evaluated at the sample-average value of the government-owned stocks-to-use variable. Both curves assume the 1986 dummy variable is equal to 0. The circles and "x's" in figure 7 represent the historical observations for the 1975-96 estimation period, with "x's" representing the 1978-85 observations corresponding to the loan rate/FOR shift variable and the circles representing the other years.

The average difference between the two price curves in figure 7 for the mean stockholding level of the 1978-85 period is about 46 cents per bushel. Net price impacts would be smaller, however. Depending on the aggregate demand elasticity for corn, a net corn-price effect is estimated at 30 cents (-0.5 demand elasticity) to 35 cents (-0.3 demand elasticity), using a static analytical framework, without multi-year dynamic supply response.

Figure 8 indicates the sensitivity of the corn price function to governmental stockholding. It repeats the curve from figure 7 without the loan-rate effect, evaluated at the sample average value of the government-owned stocks-to-use variable, which corresponds to government stockholding of about 300 million bushels. It also shows the function evaluated at government-owned corn stocks of 0, representative of recent years with only small levels of government stockholding for corn. As in figure 7, the 1986 dummy variable is assumed to equal 0 in both curves in figure 8. The difference between the two curves is about 6 percent, ranging from 10 to 20 cents per bushel over the portion of the function shown. With a small amount of corn currently in government stocks, the lower price curve shown in figure 8 is slightly lower than the equation that would currently be used for forecasting corn prices.

Figure 9
Wheat price equation—1978-85 loan rate/FOR effect



"Other independent variables" include Government-owned stocks relative to use, foreign competitor stocks to use, summer-quarter feed use relative to annual use, and summer-quarter corn prices. For both curves, each of these variables is evaluated at its sample mean.

Wheat Equation

The estimated logarithmic regression equation for wheat is:

$$
\begin{aligned}
\text{(7b)}\quad \mathrm{Ln}(p) = {} & 3.283 - \underset{(7.2)}{0.3413}\,\mathrm{Ln}(K/U) \\
& + \underset{(3.5)}{0.008132}\,(CCC/U) \\
& + \underset{(5.9)}{0.1703}\,\mathrm{Ln}(LR)\,Dum7885 \\
& - \underset{(4.5)}{0.3118}\,\mathrm{Ln}(C4K/C4U) - \underset{(4.5)}{0.1111}\,\mathrm{Ln}(FS/U) \\
& + \underset{(3.0)}{0.2191}\,\mathrm{Ln}(PCS)
\end{aligned}
$$

$R^2 = 0.929$
F-value = 32.561
Standard error of the estimate = 0.0569
Durbin-Watson statistic = 2.055
Estimation period: 1975 - 1996

As with the corn equation, numbers shown in parentheses under each coefficient are t-statistics. Again, definitions of the variable names used are summarized in table 1.

Nearly 93 percent of the variation in the logarithm of annual wheat prices is explained by estimated equation 7b. Transforming the equation to price levels, about 92 percent of the variation of annual wheat prices is explained. Each coefficient has the expected sign, with negative signs for the total stocks-to-use variable, competitor stocks-to-use, and wheat feed use, and positive signs for the loan-rate shift variable, government-owned stocks-to-use, and summer-quarter corn prices. Each coefficient is significant at the 1-percent level. The magnitude of the summer-quarter corn price coefficient is larger than the share of total wheat use accounted for

by wheat feeding, suggesting that additional corn-price/wheat-price correlations beyond the feed wheat price effect are reflected in that coefficient estimate.

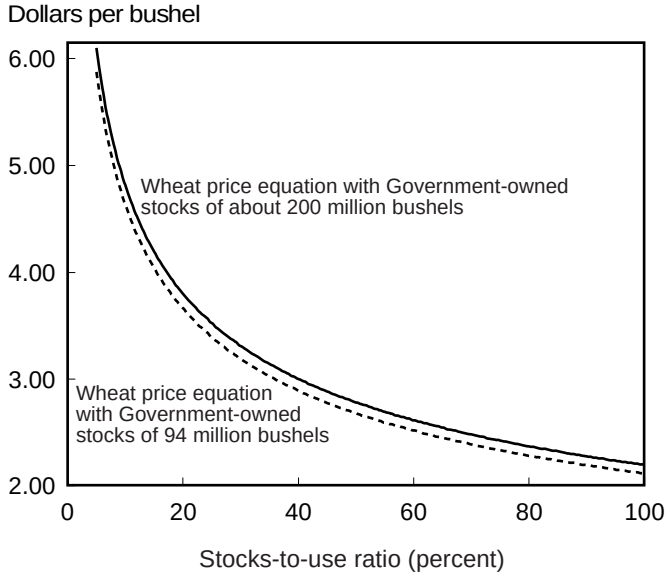
The F-value for the overall significance of the wheat price equation is well above the 1-percent critical F-value (6 and 15 degrees of freedom) of 4.32. First-order autocorrelation is not a problem with the equation, as indicated by the Durbin-Watson statistic.

Graphs showing different features of the regression equation results for wheat are shown in figures 9 through 13. In each graph, wheat prices are plotted against ending stocks-to-use ratios and effects of different shift variables are highlighted. As with corn in figure 7, the circles and "x's" in figure 9 represent the historical wheat-price observations for the 1975-96 estimation period—"x's" represent the 1978-85 observations corresponding to the loan rate/FOR shift variable and the circles represent the other years. The higher price curve in figure 9 incorporates the average price-supporting effect of high loan rates in the years 1978-85 combined with the FOR. The lower price curve omits the effect of the high loan rates. Other independent variables from the wheat regression—government-owned stocks-to-use, competitor stocks-to-use, wheat feed use, and summer-quarter corn prices—are assumed at their sample means in each curve.

The average difference between the two price curves in figure 9 for the stockholding levels of the 1978-85 period is about 59 cents per bushel. As with corn, net wheat-price impacts would be smaller. Again, using a static analytical framework without multi-year dynamic supply response, a net wheat-price effect is estimated at 41 cents (-0.5 demand elasticity) to 47 cents (-0.3 demand elasticity).

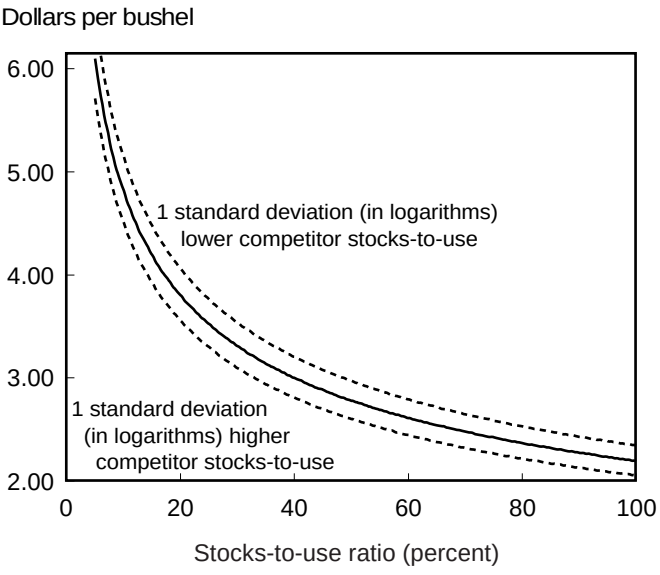
Figure 10 indicates the sensitivity of the wheat price function to government stockholding. It repeats the curve from figure 9 without the high loan-rate/FOR effect of 1978-85, evaluated at the sample average value of the government-owned stocks-to-use variable, and corresponds to government stockholding of about 200 million bushels. It also shows the function evaluated at 1997/98 ending levels of government-owned wheat stocks of 94 million bushels. The difference between the two curves is about 4 percent, ranging from 8 to 23 cents per bushel over the part of the function shown.

Figure 10
Wheat price equation—Government stocks effect



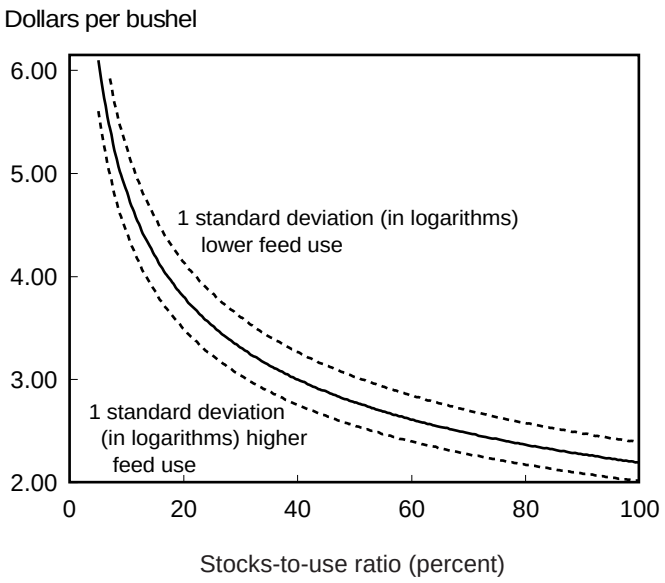
For both curves, other independent variables (except the 1978-85 loan rate shifter) are evaluated at their sample means.

Figure 11
Wheat price equation—Competitor stocks effect



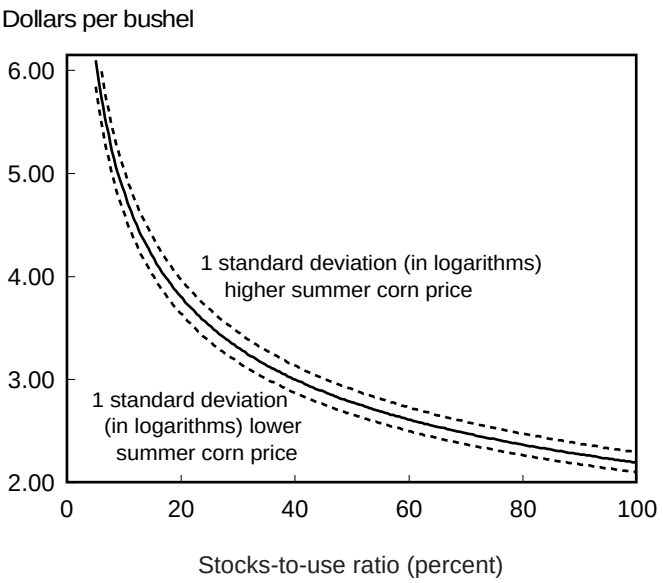
For each curve, other independent variables (except the 1978-85 loan rate shifter) are evaluated at their sample means.

Figure 12
Wheat price equation—Feed use effect



For each curve, other independent variables (except the 1978-85 loan rate shifter) are evaluated at their sample means.

Figure 13
Wheat price equation—Summer corn price effect



For each curve, other independent variables (except the 1978-85 loan rate shifter) are evaluated at their sample means.

Figure 11 shows the effects on the wheat price function for different levels of competitor stocks-to-use ratio. The middle curve repeats the curve from figure 9 without the loan-rate effect, evaluated at the sample average value of the logarithm of competitor stocks-to-use. The other two curves assume logarithms of competitor stocks-to-use ratios 1 standard deviation higher and lower, corresponding to competitor stocks-to-use ratios from 17.5 percent to 26.8 percent. Price impacts shown are about -14 to -39 cents per bushel with higher competitor stocks-to-use and about 15 to 42 cents per bushel with lower competitor stocks-to-use for the portion of the function shown.

Figures 12 and 13 similarly show the effects on the wheat price function for different levels of summer-quarter feed use of wheat and summer-quarter corn prices, respectively, within 1 standard deviation of their sample averages (in logarithms). In figure 12, the wheat feed-use range shown corresponds to about 120 to 455 million bushels. Corresponding price effects for the part of the function shown range from -18 to -50 cents per bushel with higher feed use and 20 to 54 cents per bushel with lower feed use, in each case keeping the total stocks-to-use ratio constant. In figure 13, the range shown for the summer-quarter corn prices is $2.06 to $3.08 per bushel, with corresponding wheat price effects for the part of the function shown ranging from -9 to -26 cents per bushel with the lower corn price and 10 to 27 cents per bushel with the higher corn price.

Evaluation of the Price Models

Figures 14 and 15 show graphs of historical prices for corn and wheat over the model estimation period of 1975-96, along with the predicted values derived from estimated equations 7a and 7b. In general, the price models track actual prices well. Most differences between the model estimates and the actual prices are less than 15 cents per bushel for corn and less than 20 cents per bushel for wheat.

As can be seen in figures 14 and 15, the models capture turning points quite well. A turning-point error can be defined statistically, as in equations 8a and 8b, to occur when

(8a) $(\text{Predicted}_t - \text{Actual}_{t-1})(\text{Actual}_t - \text{Actual}_{t-1}) < 0$

or

(8b) $(\text{Predicted}_t - \text{Predicted}_{t-1})(\text{Actual}_t - \text{Actual}_{t-1}) < 0$

"Predicted" and "Actual" are predicted prices from the models and actual prices, respectively, and subscripts "t" and "t-1" represent current and lagged time periods. Defined this way, the statistic measures whether predicted year-to-year changes from the models are directionally the same as changes in actual prices. Turning-point errors can occur in two ways: first, when actual prices indicate a turning point but predicted prices do not and, second, when actual prices do not indicate a turning point but predicted prices show a turning point.

The different definitions for the occurrence of a turning point in equations 8a and 8b relate to whether the change in the predicted price is measured relative to the previous year's actual price (equation 8a) or the previous year's predicted price (equation 8b). Both measures are useful, but the appropriate definition to use depends on the intended use of the model. For short-term forecasting applications of the models where the previous year's actual price is known, the former measure is more appropriate. For longer term forecasts where the previous year's actual price is not known, the latter definition is better to use. Since these price models are intended for both short-term and longer-term forecasting, both definitions are used. Over the 1975-96 model estimation period, neither price model has any turning-point errors when lagged actual prices are used in the turning-point error definition (equation 8a), while each price model has only 1 turning-point error when lagged predicted prices are used (equation 8b).

Table 2 shows mean absolute errors and mean absolute percentage errors for the corn and wheat models for the full estimation period, 1975-96, and for a selected subsample of recent years covering 1991-96. For the full sample, the mean absolute error is about 9 cents per

Figure 14
Corn prices—Actual and model estimate

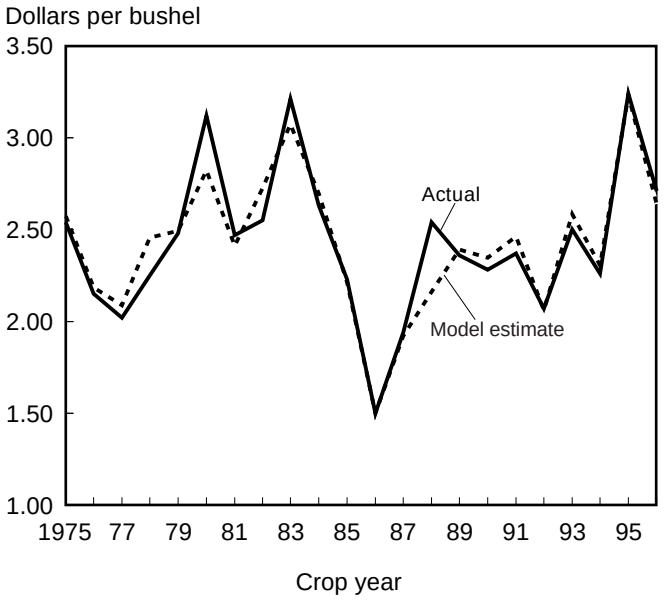


Figure 15
Wheat prices—Actual and model estimate

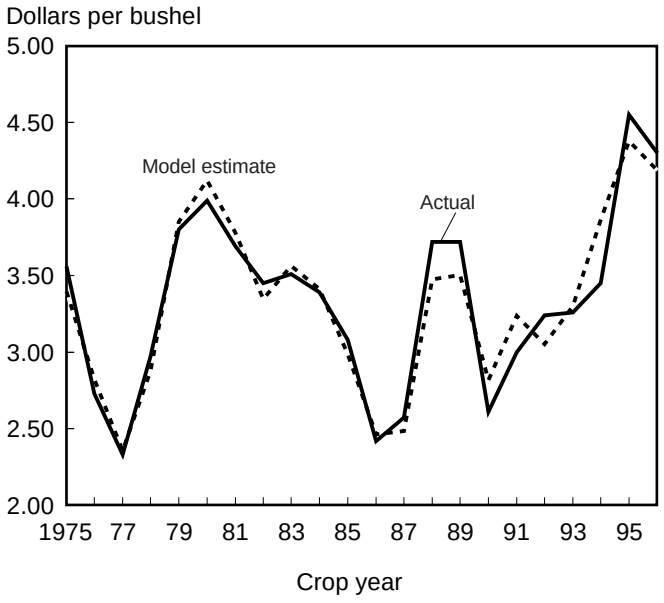


Table 2—Corn and wheat model performance measures, selected periods

Time period	Mean absolute error		Mean absolute percentage error	
	Corn	Wheat	Corn	Wheat
	Cents per bushel		*Percent*	
1975-96	8.7	13.1	3.4	3.9
1991-96	5.1	19.4	2.1	5.5

The corn price equation includes a dummy variable for 1986, so has no error in that year. Omitting 1986 from the corn model performance calculations raises the 1975-96 mean absolute error to 9.1 cents per bushel and the 1975-96 mean absolute percentage error to 3.6 percent.

bushel for corn and 13 cents per bushel for wheat, with a mean absolute percentage error of about 3 percent for corn and 4 percent for wheat. Importantly, for price-forecasting applications, the corn price model performance has been good in recent within-sample years (1991-96), with a mean absolute error of about 5 cents per bushel and a corresponding mean absolute percentage error of about 2 percent. Model performance in those recent within-sample years for wheat has not been as good as for the full sample period, with a mean absolute error of about 19 cents per bushel and a mean absolute percentage error near 6 percent. A potential contributing factor to these larger errors is that the 1991-96 period included years of significant wheat-export price subsidies by both the United States and the EU, which are not included in the wheat price model.

Overall, the statistical measures indicate good performance for the price models and suggest that the price models provide an analytical framework that can be useful in price-forecasting applications.

Price Forecasting Applications

To illustrate how the price models can be used in short-term market analysis, forecasting applications for two years beyond the period used to estimate the models are discussed—the completed 1997/98 crop year and the ongoing 1998/99 crop year as viewed in March 1999.

Corn

USDA corn-sector estimates for the 1997/98 crop year imply an ending stocks-to-use ratio of 14.9 percent. Corn stocks held by the Government at the end of 1997/98 equaled about 4 million bushels. Using these values, the corn price model estimated in this technical bulletin (equation 7a) implies a price of $2.36 per bushel, slightly below (about 3 percent) the USDA-reported corn season average price of $2.43.

For 1998/99, USDA projections in March 1999 implied an ending stocks-to-use ratio for corn of 18.3 percent. The USDA projected that government-owned corn stocks of 12 million bushels would be held at the end of the 1998/99 crop year. The corresponding corn model price estimate of $2.23 per bushel compares with the March 1999 USDA-projected range of $1.90 to $2.10 per bushel. The difference between the USDA-projected price and the model estimate could be an indication of an unusually large model residual (nearly 12 percent) in the current year due to factors beyond the structure of the model. Alternatively, using the price model as a vehicle for making consistency checks among supply, demand, and price forecasts, the difference between the USDA-projected price and the model estimate could be indicative of the USDA-projected stocks in March 1999 (and thus the stocks-to-use ratio) being low relative to the projected price. In this circumstance, subsequent revisions in USDA corn-sector forecasts for the 1998/99 crop year would be expected to reduce use of corn and raise year-ending stocks.

Wheat

For wheat, the ending stocks-to-use ratio for 1997/98 was 31.4 percent. Wheat stocks owned by the Government, mostly in the Food Security Commodity Reserve, were 94 million bushels. Based on these data and other USDA estimates for remaining independent variables in the wheat model (equation 7b), the wheat price model's estimate for the 1997/98 crop year is $3.27 per bushel, compared with the USDA-reported season-average wheat price of $3.38, a 3-percent difference.

In March 1999, USDA's wheat projections for 1998/99 implied an ending stocks-to-use ratio of 39.6 percent. USDA projected year-ending government-owned wheat stocks of 110 million bushels. The 1998 summer-quarter corn price was $2.13 per bushel. Again, using other USDA projections for the remaining independent variables, the wheat price model's estimate for 1998/99 was $2.66 per bushel, compared with the March 1999 USDA-projected range of $2.65 to $2.75 per bushel.

Confidence Intervals

Tables 3 and 4 show 1998/99 price forecasts and statistical confidence intervals over a range of different stocks-to-use ratios. The confidence intervals shown in tables 3 and 4 are contingent on the stocks-to-use ratio and other independent variables being the actual realized values and do not include forecast uncertainty of those variables. In making these model estimates, assumptions for other independent variables were the same as used above for the 1998/99 point estimates: 12 million bushels of corn held by the Government; government-owned wheat stocks at 110 million bushels; the summer-quarter corn price of $2.13 per bushel; and remaining independent variables at their 1998/99 levels projected by USDA in March 1999, using data from that month's publications of *World Agricultural Supply and Demand Estimates* and *Grain: World Markets and Trade.*

The confidence intervals shown are not perfectly symmetric around the point estimates because they are derived in logarithms and then transformed to price levels. For stocks-to-use ratios projected in March 1999, a 95-percent confidence interval covers a range of about 18 cents per bushel for corn and 37 cents per bushel for wheat around their respective point estimates.

Table 3—Corn price model estimates for different stocks-to-use ratios*

Stocks-to-use ratio	Corn price model forecast	95-percent confidence interval
Percent	*- - - Dollars per bushel - - -*	
15	2.36	2.28 – 2.45
16	2.32	2.23 – 2.41
17	2.28	2.19 – 2.37
18	2.24	2.15 – 2.34
19	2.21	2.12 – 2.30
20	2.18	2.08 – 2.28
21	2.15	2.05 – 2.25
22	2.12	2.02 – 2.22
23	2.09	1.99 – 2.20
24	2.07	1.96 – 2.18
25	2.05	1.94 – 2.16

*Assumes CCC corn stocks at the end of 1998/99 equal to 12 million bushels, the USDA forecast in March 1999.

Table 4—Wheat price model estimates for different stocks-to-use ratios*

Stocks-to-use ratio	Wheat price model forecast	95-percent confidence interval
Percent	*- - - Dollars per bushel - - -*	
35	2.78	2.61–2.95
36	2.75	2.58–2.93
37	2.73	2.55–2.91
38	2.70	2.53–2.89
39	2.68	2.50–2.87
40	2.65	2.47–2.85
41	2.63	2.45–2.83
42	2.61	2.42–2.81
43	2.59	2.40–2.79
44	2.57	2.38–2.78
45	2.55	2.35–2.76

*Summer-quarter corn price was $2.13; assumes other independent variables at 1998/99 levels forecast in March 1999 by USDA.

Conclusions

The models presented in this technical bulletin for corn and wheat prices use a stocks-to-use ratio formulation to capture the effects of market supply and demand factors on price determination. The models also address issues regarding the historical influence of government commodity loan and storage programs on price determination. Commodity loan and storage programs had an effect on prices in the late 1970's through mid-1980's, when loan rates were high and the programs affected accessibility of privately held stocks in the FOR. Program changes under 1985 legislation resulted in less program influence on market prices as price supports were reduced and privately held stocks under the loan programs were largely accessible to the marketplace. Publicly held stocks owned by the Government also influence prices for corn and wheat as these stocks are typically not readily available to the marketplace.

For wheat, prices are also influenced by international market conditions, represented by the stocks-to-use ratio of four major competitors. The role of wheat feeding and competition with corn for feed use in the summer quarter also affects the pricing of wheat.

Statistical model evaluation measures as well as the graph of actual prices and model estimates indicate good performance for the price models. This is particularly the case given the large range of corn and wheat prices over the sample period used to estimate the model (1975-96), as well as the changing nature of the influence of government programs on price determination.

The relatively simple structure of the estimated price models and their small data requirements lend themselves to use in price-forecasting applications in conjunction with market analysis of supply and demand conditions. In particular, the models are used within USDA as part of the Department's short-term market analysis and long-term baseline projections activities. In these applications, the models provide an analytical framework for forecasting prices, as well as a vehicle for making consistency checks among supply, demand, and price forecasts.

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