Potential price variability in the US grain and livestock sector in the 1980s under alternative policy scenarios: an econometric approach

Andrew Scott Morton
Iowa State University

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POTENTIAL PRICE VARIABILITY IN THE UNITED STATES GRAIN AND LIVESTOCK SECTOR IN THE 1980S UNDER ALTERNATIVE POLICY SCENARIOS: AN ECONOMETRIC APPROACH

Iowa State University

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Potential price variability in the U.S. grain and livestock sector in the 1980s under alternative policy scenarios: An econometric approach

by

Andrew Scott Morton

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of the Requirements for the Degree of DOCTOR OF PHILOSOPHY

Department: Economics
Major: Agricultural Economics

Approved:

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In Charge of Major Work

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For the Major Department

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For the Graduate College

Iowa State University
Ames, Iowa

1982
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CHAPTER I. INTRODUCTION

The passage of the Food and Agriculture Act of 1977 marked the beginning of a new approach to United States agricultural policy toward grains. Emphasis was shifted toward grain reserves as the primary policy instrument in the tool kit of grain policy instruments. During the previous two decades, price supports and supply control were the primary policy instruments, with publicly-owned grain stocks only a residual of the grains policy (Sharples, 1980).

Since 1977, agricultural policy management strategy has been to allow the grain market to determine price and allocate grain supplies under normal conditions, but to use grain reserves to protect against unusually high or low prices. Emphasis has been placed on reserves that were farmer-owned rather than government-owned, but there has been authority to implement both. This emphasis has continued in provisions of the recently passed Agriculture and Food Act of 1981 (Johnson et al., 1982). Production adjustment would be used only when reserves were considered to be excessive — as was the case in 1978, 1979, and again in 1982.

The purpose of this study is to evaluate the new grains policy and several proposed alternatives in the context of U.S. and world grain market conditions which will exist in the 1980s. A structural econometric model of the U.S. wheat, feed grain, and livestock markets is conceptualized and estimated as the basic tool for policy evaluation. In development of the model, emphasis is given to capturing the historical
influence of loan rates, diversion incentives, government stocks, export subsidies, and food aid on the structure and price dynamics of these interrelated markets. The model focuses on explaining movement of equilibrium prices and quantities on a year-to-year basis. Multiplier analysis is used to assess the historical impact of grain policy instruments on market structure and price dynamics.

In order to evaluate the new grains policy and several other policy alternatives under market conditions of the 1980s, stochastic simulations of the model are run for the crop years 1981-90 under alternative policy scenarios. Market conditions of the 1980s are simulated by projecting exogenous variables of the model to 1990 using a combination of time series and trend methods. Each grain policy scenario is designed to reflect as closely as possible how the scenario has used or would use the set of available policy instruments. For example, in Policy Alternative I which reflects a continuation of current grain policy, a set of operating rules from the 1977-80 period is used to endogenize loan rates, diversion incentives, and government carryover stocks. Each policy alternative is composed of twenty simulations of the model. Error terms in domestic crop yields (supply side shock) and in U.S. grain export demand (demand side shock) take on randomly generated nonzero values over the ten-year simulation period. Taken together, the set of stochastic simulations represents the probability distribution of supply and demand shocks which may be imposed on the U.S. grain livestock sector in the 1980s. Alternative policy scenarios will be evaluated
mainly with respect to their impact on mean level and variability of market prices.

Before examining U.S. grain policy since 1977 in further detail, it is instructive to briefly review the economic and institutional setting of the grain markets and how that setting has changed over the past twenty-five years. This period makes up the sample period of the econometric model.

Economic and Institutional Setting

The intent of this section is to review factors which influenced grain price formation since the early 1950s. One set of factors is the economic forces which have contributed to a long period of surpluses and more recent shortages. Another set is the array of government policies to control supply, demand, and price in surplus periods. This review is particularly important in that it will form the basis of a realistic econometric model.

Wheat

The supply and utilization picture for the U.S. wheat market between 1954 and 1979 is shown in Table 1.1. Surplus conditions existed consistently from 1954-71. During this period, total beginning wheat stocks averaged well in excess of 50 percent of annual production. Food, seed, feed, and export utilization was basically stagnant in the face of expanding production. As a result, the nominal price of wheat remained quite low hovering around the loan rate with the exception of 1966-67 (Figure 1.1).
Table 1.1. Wheat supply and utilization, United States, 1954–79\(^a\)

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<th>Seed</th>
<th>Feed</th>
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b Crop year begins June 1.

c Net of imports.

d Includes on-farm stocks under loan with the Commodity Credit Corporation (CCC).

e Stocks owned by the CCC.

f Stocks held in the farmer-owned reserve.
Figure 1.1. Wheat farm price and loan rate, 1954-79 (USDA, 1980b; 1970; 1964).
Figure 1.2 illustrates that expanding yields were responsible for the tendency to expand supply. The national average yield of wheat in terms of planted acreage nearly doubled from 16.1 in 1954 to 30.0 bushels per acre in 1971. These yield expansions are often attributed to technological advances. The extensive use of mechanized capital, improved seed varieties, fertilizer, and other agricultural chemicals all contributed to yield increases. In addition, Gallagher et al., (1981) argue that progressive tightening of acreage restrictions led to the use of higher quality land. Also a "good weather" cycle in the 1960s may have contributed to yield increases.

Figure 1.3 illustrates that domestic wheat utilization was fairly stable during the 1950s, although moderate increases in level and variability are apparent for the 1960s. Further examination of the major components, 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 1960s.

The reasons for stagnant wheat food demand are well-understood. However, this lack of growth deserves explanation, as it represents a pivotal cause for acute wheat surpluses in the United States. Wheat food demand has the characteristics of an inferior good not only in the United States but throughout economies of the developed world. Negative income elasticities, thus, guarantee that per capita consumption declines as per capita disposable income grows. Moreover, very little adjustment in food demand occurs when prices fluctuate. Modest
Figure 1.2. National average yield of wheat per planted acre; 1954-79 (USDA, 1980b; 1970; 1964).
Figure 1.3 Domestic utilization of U.S. wheat (total food and seed, feed), 1954-79 (USDA, 1980b, 1970; 1964).
expansions of 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 when competitively priced with other grains it is fed. Expansions of wheat feeding in the mid-1960s are the result of a sustained reduction in wheat prices during this period, thereby making wheat competitive with traditional 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 (Gallagher et al., 1981). The variability of wheat feed use is most likely the result of a dependence on cycles in the livestock and feed grain economy.

Figure 1.4 suggests that it is misleading to document the tendency for a stagnant export market by mere examination of total export data. The irregular upward trend during the 1950s which is shown continuing through 1966 in Figure 1.4 is primarily the result of food aid increases. Food aid exports of wheat under Public Law 480 increased from 4.1 million metric tons (MMT) in 1954 to 14.4 MMT in 1965. An increase in commercial exports coincided with food aid reductions between 1966 and 1971. However, this was a result of U.S. policy, rather than changes in foreign market economic conditions.

Stagnant foreign demand during the early post-war period is the result of the gradual loss of the traditional European market without sufficient compensation in other areas. European demand was strong
Figure 1.4. Exports of U.S. wheat (net exports, commercial, food aid), 1960–79 (USDA, 1980b; 1970).
during the immediate post-war period but declined as reconstruction progressed and the European Community (EC) became more effective. The mutual tariff of EC countries gradually increased, thus encouraging indigenous production and discouraging imports. Also, stagnant European demand is the result of the inferior good status of wheat in most industrialized, developed countries. However, as post-war development and income growth coincided with declining real wheat prices, Japanese purchases of foreign wheat expanded almost continually over this period. Developing countries' purchases showed little expansion over this period; although population growth generally exceeded production growth, U.S. food aid and foreign currency shortages generally precluded a corresponding growth in purchases from most developing countries.

Policymakers' strategy for dealing with 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 have been otherwise and at times even resulted in buoyant market prices (Gallagher et al. 1981). However in 1963, wheat producers failed to pass a marketing quota referendum which tied 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.

As shown in Figure 1.1, the wheat loan rate was reduced to $1.24 per bushel in 1963 compared with loan rates in the $1.80 to $2.00 per bushel range in prior years. 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 export subsidies were reduced; average expenditures on P.L. 480 were $385 million and the export subsidy rate averaged 9 cents per bushel for the 1961 to 1971 period (Gallagher et al., 1981).

The high prices of the 1972-76 period resulted from an end to the twenty-year tendency for supply growth. In addition, foreign demand surged to unprecedented levels.

The important changes in conditions of supply and demand can be verified by inspecting yield data (Figure 1.2) and export data (Figure 1.4). Yield growth ceased in 1971 and fluctuated around 27 bushels per acre. Annual average exports nearly doubled from 18.2 MMT in 1966-71 to 30.0 MMT in 1972-77.

Explanation of recent yield stagnation has emphasized a wide range of environmental, technical, and economic conditions. Some view production shortfalls such as 1974 as part of an extensive bad weather cycle in the 1970s. Arguments that the storehouse of technology from the 1950s and 1960s was depleted are also proposed. In turn, arguments which emphasize economic factors point to implications of the past technical changes. Specifically extensive purchases of inputs which have accompanied these advances and recent increases in input prices have discouraged more intensive utilization.

The surge in wheat exports was the result of environmental shocks and policy decisions beyond the control of U.S. agricultural policy-makers. World grain production fell short of normal levels, thus
encouraging exports from all major exporters, including the United States. The Soviet Union reversed previous policies in deciding to make up production shortfalls on the international market and the U.S. relaxed restrictions on trade with the Soviet Union. Dollar devaluations of the early 1970s were the second major U.S. policy change; the cost of U.S. goods abroad was reduced by about 15 percent as a result of devaluation (Gallagher et al., 1981).

Surplus conditions returned in 1977. Five years without acreage controls and three years without a major domestic production shortfall resulted in the most recent stock accumulation. U.S. wheat acreage increased around 25 percent following high prices of the early 1970s and subsequent acreage decontrol. The relatively low prices of 1977-78 attest to the fact that this acreage increase has been sufficient to fill the higher export demands, in spite of level yields in the 1970s.

Perhaps the most striking change in the wheat market of the 1970s from that of the earlier period has been increased price volatility. The coefficient of variation in the farm price of wheat nearly doubled from 17.8 over 1961-70 to 31.6 over 1971-79 (Meyers, 1982). This is partly a result of the U.S. wheat market being increasingly driven by an uncertain export market. Also, as market prices rose from support levels on which they rested during the 1950s and 1960s, they have become more sensitive to the year to year uncertainties of production as well as of exports.
Feed grain

The supply and utilization picture for the U.S. feed grain market between 1954 and 1979 is presented in Table 1.2. Feed grains include corn, grain sorghum, oats, and barley, with corn being the dominant grain in the market accounting for 84 percent of feed grain production and 86 percent of feed grain net exports in 1979. A glance at Table 1.2 reveals that the feed grain market, in comparison with the wheat market, is much larger in terms of volume, has total beginning stocks which represent, on the average, a smaller percentage of annual production, and has feed use as the primary component of domestic utilization. Surplus conditions existed in the feed grain market between 1954 and 1971. Food, seed, and export utilization were relatively stagnant over this period. Feed utilization grew on an annual basis but generally at a slower rate than production. As a result, the nominal price of corn hovered around the price floor set by the corn loan rate (Figure 1.5).

As with wheat, expanding yields were responsible for the increases in feed grain production. The national average yield of corn, in terms of planted acreage, more than doubled between 1954 and 1971, rising from 32.9 to 76.1 bushels per acre (Figure 1.6). Over the same period, sorghum yields grew 261 percent, barley yields grew 63 percent, and oat yields grew 34 percent. The explanation for these yield increases are similar to those advanced for wheat.

Figure 1.7 shows that domestic feed grain utilization had an upward trend throughout the 1950s, 1960s, and early 1970s. Some variability
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Corn, grain sorghum, oats, and barley.


Crop year begins October 1 for corn and grain sorghum and June 1 for oats and barley.

Net of imports.

Includes on-farm stocks under loan with the Commodity Credit Corporation (CCC).

Stocks owned by the CCC.

Stocks held in the farmer-owned grain reserve.
Figure 1.5. Corn farm price and loan rate, 1954-79 (USDA, 1980b; 1970; 1964).
Figure 1.6. National average yield of corn per planted acre, 1954-79 (USDA, 1980b; 1970; 1964).
Figure 1.7. Domestic utilization of U.S. feed grain (total, food and seed, feed), 1954-79 (USDA, 1980b; 1970; 1964).
in the trend can be attributed to variability in feed utilization. Feed grain utilization as food and seed has a slight upward trend through the mid 1970s. Since 1975, the trend has increased, reflecting increased use of corn in alcohol production. Very little adjustment in food and seed use occurs when prices fluctuate while variability in feed utilization is generally attributed to cycles in the domestic livestock sector.

Market prices of the feed grains tend to be highly correlated over time and reflect differences in their relative feeding values. Since corn is the dominant feed grain, the corn market serves well as an indicator of price for the feed grain market taken as a whole.

Unlike wheat, commercial exports have historically made up the vast majority of total net feed grain exports from the United States (Figure 1.8). The mutual tariff of the European community, which became effective in 1962, discouraged corn and sorghum imports during the 1960s. However, income growth in Japan led to substantial increases in per capita meat consumption. This coupled with declining real feed grain prices caused Japanese imports of feed grain to expand almost continually over this entire period. During the 1950s and 1960s, developing countries were a minor market for exports of U.S. feed grain.

Policymakers' strategy for dealing with surplus consisted of acreage restrictions and government stockholding. The importance of corn led to earlier attempts at acreage control, beginning with diversion payments in 1956 under the Soil Bank program (Houck et al., 1976). Similar diversion payments for sorghum and barley were first used in
Figure 1.8. Net total and commercial exports of U.S. feed grain, 1960-79 (USDA, 1980b; 1970).
1961 and 1962, respectively. Oats have not been subject to acreage restrictions.

The period of surplus in the feed grain market ended abruptly in 1972 as can be seen by the rise in farm prices of corn far above the loan rates (Figure 1.5). Stagnation in commercial exports was replaced by very rapid export growth over the entire decade of the 1970s for similar reasons as with wheat. Between 1970 and 1979, U.S. feed grain net exports nearly tripled from 18.6 to 70.8 MMT.

During the 1970s, in percentage terms, growth in net feed grain exports from the United States has exceeded growth in wheat exports and are just slightly behind growth in oilseed exports.

The surge in feed grain exports in 1972 and 1973 coincided with a world grain production shortfall. In addition, the Soviet Union made a policy decision to import grain needed for livestock feeding in the event of domestic crop shortfalls. This policy decision was apparently made to accommodate rising consumer demand for meat. U.S. corn prices peaked in 1974 despite a drop in net exports due to a major shortfall in U.S. feed grain production.

Since 1972, corn prices have been highly volatile due to fluctuations in domestic production caused mainly by weather and due to fluctuations in export demand. The coefficient of variation in the farm price of corn more than tripled from 7.4 over 1961-70 to 26.5 in 1971-79 (Meyers, 1982). The role of export demand in price volatility has increased with the role of exports in overall utilization of feed grain.
The percentage of feed grain production exported by the United States rose from 12 to 30 percent between 1970 and 1979.

Post-1977 Grains Policy

The farmer-owned reserve (FOR), backed up by CCC stocks, is the principal instrument which has been used by the Carter and Reagan Administrations for reducing grain price variability. Since 1977, the FOR has worked in the following way.

**Description of the farmer-owned reserve program**

Annual nonrecourse loans and FOR loans are both provided to eligible farmers at the loan rate specified for the crop under contract, and the farmer retains ownership of the grain used as collateral for the loans. The provisions of the FOR differ in several important ways from the annual loan program (Meyers and Ryan, 1981). The major added benefit is the annual payment of a storage subsidy approximately equal to commercial storage costs in major grain producing states. Since March 1978, FOR loans have also been interest free after the first year, and the interest charge was waived completely on 1979 crop contracts signed after the 1980 embargo of grain shipments to the Soviet Union.

The major added constraints are those which control the redemption of reserve grain. The FOR contract is for three years compared to nine months for the annual loans. Voluntary redemption of contract grain is permitted only after farm prices reach a specified "release

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1 Limited to these in compliance with announced set-aside programs.
level”. After the second consecutive monthly release, storage payments may be suspended. Suspension occurs when the difference between state price and loan levels is greater than the difference between the national release and loan levels. Mandatory redemption occurs when farm prices reach a specified "call level"\(^1\) or the contract expires. If the loan is not repaid within a specified period (typically 90 days) after it is "called," the grain is forfeited to the Commodity Credit Corporation (CCC). Although the initial loan rate is fixed, the release and call levels for all contracts are a fixed percentage of the current loan rate, which generally increases over time. Since the inception of the program, the release level has typically been set at 125 percent of the loan rate for feed grains and at 140 percent of the loan rate for wheat, while call levels have been set at 140 and 175 percent of loan for feed grains and wheat, respectively. The minimum release price for CCC owned grain is approximately 5 percent above the call level of FOR grain, so that CCC inventories are the reserve of last resort.

Initially, the FOR option was available to a farmer only after his annual loan matured. This requirement was relaxed selectively in 1978 and finally was removed for all crops in October 1979. Now direct entry to the reserve is permitted except when the quantity restraint has been reached.\(^2\) This change is important, as it makes reserve quantities more responsive to current market conditions (Meyers and Ryan, 1981).

---

\(^1\)The call level provision was removed in the 1981 farm bill and the release level is now referred to as the trigger level.

\(^2\)The Secretary of Agriculture can authorize size limits on the reserve above or equal to legislated minimums.
In summary, a very flexible set of incentives and disincentives is designed to induce farmers to place grain in the reserve when market prices are near or below the release level and to redeem grain when prices are between the release and call levels. The government has no control over the farmers' decision to sell or hold the grain after it is redeemed, although in many cases a cash sale may be required to repay the loan. The FOR participant sacrifices some control over the reserve grain in exchange for a substantial reduction in carrying costs and risk.

Reserve management strategy

Reserve management strategy since 1977 has been to defend a price corridor in a way that would remove the market price peaks and valleys which would result without government intervention (Sharples, 1980). Ideally, the price corridor gradually would move up and down over time in harmony with the long-run price trend and the market price would not be outside the corridor. Grain reserves would be used as the first line of defense in defending the price corridor with other policy tools used only if necessary. Grain reserves would be accumulated when the price was near or below the lower bound of the price corridor (i.e., loan rate) thus boosting price. Grain would be released from the reserve when price exceeded the FOR release price, thus holding the price near the release level. At times, the grain reserve may be inadequate relative to the policy objectives. It could get too large and become too costly to maintain, or be too small to be effective in buffering
the price-increasing impact of shortages. The backup policy tools would then be used. Production adjustment (set-aside or diversion) could be used to reduce excessive total reserves. The Carter Administration sought a target level for total carryover of 6.7 percent of expected annual world feed grain consumption and 7.5 percent for wheat in order to protect U.S. export commitments and meet emergency aid needs. Production adjustment was then used if total grain carryover was greater than the target level. Also, export controls or direct price controls could be used to moderate extreme price increases once the reserves were gone. These backup policies, however, imply high social and political costs.

Ideally, the price corridor would follow market price trends over time. The market price, however, might not always provide returns to producers that society would consider adequate. Since 1973, deficiency payments have been available to producers when market price fell below the target price. The target price need not move in step with the price corridor. The use of separate policy tools for supporting producer income and for price stabilization was an important legacy from 1973 legislation. Additional discussion of U.S. grains policy since 1977 can be found in Johnson and Eriksen (1977), Johnson et al. (1979), Stucker and Boehm (1978), and in USDA (1980a). Grains policy prior to 1973 is discussed in Cochrane and Ryan (1976).

Grain Policy Objectives

Evaluation of post-1977 grains policy will be based on a group of policy objectives, some of which are conflicting.
Both producers and consumers are concerned about market instability. Economic theory emphasizes the general welfare loss of a highly unstable market. Unfortunately, the concept of instability is nebulous because the perception of what constitutes unstable behavior is largely subjective. It is crucially dependent upon who is evaluating the "instability" and what problems he/she views it to present. For example, from a producer's perspective, only downward fluctuations in commodity prices may be viewed as a problem because of their effects on revenues, whereas from a consumer's perspective, upward fluctuations may be the focus of concern because of their effects on expenditures. From a policymaker's perspective, upward and downward fluctuations in prices resulting from systematic changes in such factors as consumer income may be viewed as acceptable, since these act as signals for resource allocation. However, fluctuations which are created by stochastic factors such as weather or foreign influences are viewed with concern.\(^1\)

Since much of the discussion on instability is directed towards the analysis of government stabilization policies, the perceptions of policymakers are particularly important.

In addition to prices, producers are concerned about both the general level of income generated from farming and about being protected against the unusually low income years. Thus, protection for farmers from low farm income has been a traditional objective of federal grains policy.

\(^1\)For example, changes in trade policy or in exchange rate regimes, etc., may cause unanticipated changes in world agricultural commodity trade patterns.
An additional objective which is often in conflict with the first two objectives but which has become more important in recent years is reduction of stress on the federal budget. Sharples (1980) breaks this policy objective into two factors: 1) by the average annual expenditure due to grains policy, and 2) by the frequency of very large expenditures. It is assumed that if two alternative policies cost about the same over time, but one has a lower probability of extremely large costs, it is preferred over the other.

A policy objective of many citizens is to reduce the role of government in agriculture. In the context of this study, diversion programs, Commodity Credit Corporation (CCC) stock activities, and the farmer-owned reserve (FOR) program would be viewed, by those who hold this objective, as government interference in the market. Less diversion, fewer CCC stocks, a lower probability of CCC purchases or sales, and fewer restrictions on the marketing of FOR grain would be preferred. For example, an unrestricted subsidy on all private stocks of grain would be preferred to the existing FOR program.

A final policy objective consists of two related concepts: 1) concern about the ability of the United States to respond to emergency needs of grain at home and abroad, and 2) a concern that there will be adequate stocks to meet export commitments.

These policy objectives are used to compare and evaluate policy alternatives run in stochastic simulations of the econometric model in the 1980s. Emphasis is placed on reduction of price variability as this policy goal has typically been one of the most difficult to quantify.
In this chapter, conceptualization of the model will be discussed. The objectives of the study are framed against what is possible in an econometric model. Conceptual issues such as model periodicity, sample size, level of aggregation, complexity, and size of model structure are discussed with respect to the objectives of the study. Theoretical issues are discussed in the next section of the chapter. First, price dynamics of the U.S. grain market are discussed using a set of linear supply and demand relationships. Second, theoretical issues underlying each of the major structural components of the model are discussed.

Conceptualization

An econometric model is a positive tool of analysis. It can be used to provide estimates of the value of the endogenous variables associated with particular values of the predetermined variables, and in a dynamic model, to predict time paths of the endogenous variables. Econometric modeling is usually directed at one of two broad purposes: (1) To forecast variables of interest or (2) to represent the underlying economic structure of a market or sector. Forecasting does not necessarily require knowledge of the structural coefficients and forecasting models, as a result, can be relatively simple. A structural model can be used for structural analysis or forecasting.

The purpose of the model also influences the extent of the model. A number of econometric models have been constructed specifically to
look at a single policy measure and only that part of the sector which is immediately relevant to their purposes. Such models can be very useful in analyzing particular commodity markets. However, they cannot be expected to provide much insight into linkages between commodity markets. For this reason, other models have been developed to analyze policy effects on more than one market in a sector and have included, for example, both livestock and feed grain markets.

Once a model has been constructed, it may be used to estimate policy effects either by simulation or multipliers, or both. The intended uses should and often do affect the specification of the model.

Objectives of the study

Given the statement of the problem in the previous section, objectives of the model can be summarized as follows:

(1) Construct a structural econometric model of the U.S. wheat, feed grain, and livestock sector. With particular emphasis on explaining the dynamic price formation process.

(2) Add to the stock of econometric knowledge of behavior in the grain markets. Areas of weakness in the literature include (a) acreage response to price where government intervention occurs on an irregular basis, (b) the nature of the demand function for U.S. grain exports, (c) the behavior of private speculative storage within the context of a government stockpiling regime, and (d) the joint probability distribution of random supply and demand shifters.
(3) Determine what are the prospects for grain market price instability in the 1980s. What will be the impact through the decade ahead in terms of the policy objectives enumerated in the previous section of:

(a) Continuation of the current grain policy complex (Policy Alternative I).

(b) Discontinuation of the farmer-owned reserve (FOR), CCC stock ownership, and authority for acreage set-asides. This is essentially the free market alternative (Policy Alternative II).

(c) Replacement of the FOR with a simple subsidy to private storage at any price (Policy Alternative III).

(d) Discontinuation of set-aside authority (Policy Alternative IV).

Periodicity

The basic periodicity of the grain markets is annual. Production occurs once a year. Demand and price react to supply determined by production and inventory at the beginning of each marketing year. However, one could argue for a quarterly model of the grain markets on the basis that the decision process underlying demand is actually taken more frequently than the annual period of observation. MacGregor and Kulshreshtra (1980) employ a quarterly model in attempting to explain price formation in the international feed grain market. An annual model is favored here because it is necessary for generating reasonable simulations ten years into the future and because quarterly international data are quite difficult in not impossible to obtain.
Sample size

The sample used for estimation will extend from 1954 to the 1979 crop year. The crop year for wheat begins June 1 and for feed grain October 1. The crop year immediately following the Korean War is a convenient starting year for the sample while 1979 is currently the most recent year of finalized data.

Delineation of model boundaries

Another issue in the conceptualization process involves delineation of model boundaries. The designation of particular variables as exogenous defines the boundaries of the model. There are computational advantages in estimating a smaller narrowly defined model. However, the disadvantage of such a model lies in ignoring linkages between the market of interest and other markets. If such linkages are not truly exogenous, significant bias may be built into the model. Since the emphasis in the present model is on representing the dynamic price formation process in the grain markets, it is important to endogenize all major components of demand and supply for grains.

Thus, the linkage between U.S. grain markets and the domestic livestock market is endogenous. This linkage is of particular importance with respect to feed grain. The linkage between the U.S. grain markets and the international grain market is also endogenous in the model. Ideally, all substitute commodities for these major grain categories should be endogenous. However, in the present analysis, the soybean market is left exogenous despite its interaction with the feed grain
market. Some bias is accepted here to reduce the size and complexity of the model. Also, linkages to the general economy are left exogenous.

**Aggregation**

Another issue is the level of aggregation used within the model. In econometric models, aggregation of certain variables is a convenient and often used method for simplifying the economic system under analysis. The level of aggregation is a function of the model's objectives but is also influenced by the technical characteristics of the system. For aggregation to be satisfactory, the commodities to be analyzed must be reasonably homogeneous (Martin, 1980).

In the present model, since the primary interest with respect to the domestic livestock sector is in its interface with the grain markets, all livestock commodities are aggregated into one group. Aggregation within the livestock equations will be described fully later.

On the demand side of the feed grain model, corn, grain sorghum, oats, and barley are aggregated together on a simple weight basis. These grains are relatively homogeneous in their utilization as animal feeds. In addition, the farm level prices of the feed grains tend to be highly correlated over time which suggests that little is to be gained by separating these grains on the demand side. Given these arguments, one could argue for ignoring the minor feed grains completely and modeling only corn. However, such an approach has limitations on the supply side of the model. The feed grains are grown in different regions of the country, compete with different crops for land, and
are affected by different weather. Corn is grown mainly in the Midwest and competes primarily with soybeans for acreage. Grain sorghum is concentrated in the Southern Plains and competes mainly with winter wheat and cotton while barley is grown mostly in the Northern Plains and competes mostly with spring wheat and oats for acreage. Besides regional differences, acreage control programs typically differ for each of these crops on a year-to-year basis. Finally, the impact of weather on yields differs by crop but is not independent. In order to accurately represent the impact of weather on grain production, crop yields should be analyzed separately. Thus, on the supply side of the model, each crop is handled separately.

Theoretical Model

The basic annual framework of either the wheat or feed grain market is quite similar and can be summarized in the following set of linear relationships:

\[
\begin{align*}
Q_{t+1} &= a_1 + \beta_1 P_t - \gamma_1 P_{St} \\
D_t &= a_2 - \beta_2 P_t + \gamma_2 P_{St} \\
I_t &= a_3 - \beta_3 P_t - \gamma_3 Q_{t+1} \\
Q_P_t + I_{t-1} &= D_t + I_t
\end{align*}
\]

where \(a_i, \beta_i, \gamma_i > 0\) for all \(i\)

endogenous in \(t\): \(Q_{t+1}, D_t, I_t, P_t\)

exogenous in \(t\): \(P_{St}\)

predetermined in \(t\): \(Q_P_t, I_{t-1}\)
Current production \( (QP_t) \) depends on past market conditions \( (P_{t-1}, PS_{t-1}) \). In the demand block, current utilization \( (D_t) \) rises as price \( (P_t) \) falls and as substitute prices \( (PS_t) \) rise.

Speculators hold inventories \( (I_t) \) on the belief that prices will be higher in the future than they are in the present. In econometric models, this translates to equations where inventories are related to the difference between next year's expected price and the current price. Following Gallagher et al. (1981), production in the following crop year \( (QP_{t+1}) \) is assumed to be the crucial determinant of next year's expected price. This amounts to a "rational price expectation" of inventory behavior such that price expectations are formulated on the basis of the best available information (Muth, 1961). Indeed, Houck and Pearson (1977) have shown that USDA intentions and crop forecast information is used in assessing price prospects and inventory holding decisions. Obviously, it is a simplification to suggest that inventories depend on actual production in the following year since USDA yield forecasts are subject to error. Nonetheless, this simplification lends itself to the specification of a dynamic commodity model.

At equilibrium, production and last year's storage \( (I_{t-1}) \) are equal to utilization plus this year's storage. Thus, current price, current utilization, carryout, and production next year are solved simultaneously.

**Price dynamics**

Inventory speculation enhances price stability of the market. Gallagher et al. (1981) show this with a standard cobweb diagram.
(Figure 2.1). $S_1$ and $TD_1$ represent "supply" and "demand" relations from the equation system 2.1-2.4. $S_2$ and $TD_2$ represent the system without the relation between future production inventories ($\gamma_3=0$). Both sets of curves have the same long run equilibrium price ($P_e$). However, $S_1$ and $TD_1$ have slopes that guarantee smaller price oscillations and a faster rate of convergence on equilibrium price. Gallagher et al. (1981) show that long-run equilibrium price is equal for each of these systems since $P_e$ does not depend on $\gamma_3$. Moreover, long run price stability is ensured when the slope of the supply curve ($\beta_1 - \beta_3 - \gamma_3 \beta_1$) is less than the slope of the demand curve ($\beta_1 + \beta_3 + \gamma_3 \beta_1$). In addition, the link between future production and inventories ($\gamma_3 > 0$) results in a more inelastic supply from $t-1$ to $t$ and a more elastic demand in $t$.

Suppose government stockholding ($R_t$) is now added to the system. Furthermore, suppose government stocks are farmer-held, in that farmers are given a set of incentives to hold government stocks when prices are low and disincentives to release government stocks when prices are high. This hypothetical reserve policy is analogous to the current farmer-owned reserve program. The system is now restated as follows:

\[
\begin{align*}
Q_{t+1} &= \alpha_1 + \beta_1 P_t + \gamma_1 P_{St} \\
D_t &= \alpha_2 + \beta_2 P_t + \gamma_2 P_{St} \\
I_t &= \alpha_3 + \beta_3 P_t - \gamma_3 Q_{t+1} - f_3 R_t
\end{align*}
\] (2.5-2.7)

\[1\text{In this case, CCC stocks are assumed to be zero.}\]
Figure 2.1. Supply and demand curves with \((S_1, TD_1)\) and without \((S_2, TD_2)\) relation between inventories and future production (Gallagher et al., 1981)

\[
S_t = I_{t-1} + QP_t
\]

\[
TD_t = D_t + I_t
\]
Supply ($S_3$) and demand ($TD_3$) relations are obtained in the same manner as previously.

\[
S_3 = QP_t + I_{t-1} + R_{t-1} \quad (2.10)
\]
\[
TD_3 = D_t + I_t + R_t \quad (2.11)
\]

After substitution and rearranging the slopes of these curves are:

\[
\frac{dS_3}{dP_{t-1}} = \beta_1 - \beta_3 - \gamma_3 \beta_1 + \lambda_3 \beta_4 - \beta_4 \quad (2.12)
\]
\[
\frac{dTD_3}{dP_t} = - \beta_2 - \beta_3 - \gamma_3 \beta_1 + \lambda_3 \beta_4 - \beta_4 \quad (2.13)
\]

Equations (2.12) and (2.13) differ from the slopes of $S_1$ and $TD_1$ from Figure 2.1 as shown:

\[
\frac{dS_1}{dP_{t-1}} - \frac{dS_3}{dP_{t-1}} = - \lambda_3 \beta_4 + \beta_4 \quad (2.14)
\]
\[
\frac{dTD_1}{dP_t} - \frac{dTD_3}{dP_t} = - \lambda_3 \beta_4 + \beta_4 \quad (2.15)
\]

$S_3$ is more inelastic (less positive) than $S_1$ and $TD_3$ is more elastic (more negative) than $TD_1$ if $- \lambda_3 \beta_4 + \beta_4 > 0$. That is, a farmer-held government stockpiling regime described previously in the presence of private speculative storage will guarantee smaller price oscillations and a faster rate of convergence on long run equilibrium price provided values of the structural parameters $\lambda_3$ and $\beta_4$ are such that $- \lambda_3 \beta_4 + \beta_4 > 0$. Provided the demand for stocks held under the government program is not
totally inelastic ($\beta_4 > 0$) this inequality reduces to $\lambda_3 > 0$. The substitution effect of government stocks for private stocks ($\lambda_3$) is bounded by the interval [0,1]. If $\lambda_3 = 1$, a one bushel increase in government carryover would be matched by a one bushel decrease in private carryover and price stability would be unaffected by the reserve program. If $\lambda_3 = 0$, private stocks would be unaffected by an increase in government stocks and price stability would be enhanced by the reserve program. If $\lambda_3$ lies somewhere on [0,1], price stability will be enhanced with the magnitude of enhancement depending on the magnitude of $\beta_4$. As price response of government stocks held by farmers increases, price stability increases.

The magnitudes of $\lambda_3$ and $\beta_4$ are empirical questions. U.S. General Accounting Office (1981) employed a reduced form model of the wheat market and concluded that $\lambda_3$ is quite close if not equal to one. Sharples (1980) and Meyers et al. (1981) employ structural models of private stocks of wheat and conclude $\lambda_3$ is in the .2 to .3 range. Meyers and Ryan (1981) are the first researchers who have attempted to measure $\beta_4$ with respect to the existing farmer-owned reserve (FOR) program. Since the FOR has only been in effect since 1977, only crude approximations of $\beta_4$ are possible. The preliminary analysis suggests FOR response to price to be quite elastic for wheat.

**Grain supply response**

Grain supply in any period consists of beginning stocks (both commercial and government) and production. Beginning inventories are
predetermined and yields are traditionally viewed as dependent on weather and technology. To the extent that fertilizer and chemical applications influence productivity, however, it is plausible that yields (or production) outcomes are partially the result of economic decisions. In the present analysis, yields in terms of planted acreage are viewed as exogenous and stochastic. The nature of the joint probability distribution between crop yields will be dealt with in discussions involving stochastic simulations of the model.

Farmer's planting decisions depend mainly upon expected prices and expected prices of competing crops in a free-market environment. However, the array of government commodity programs complicates the analysis for most major U.S. crops; including wheat and feed grains (excluding oats). 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 over the 1954-79 sample period.

The concepts of "effective" support and/or diversion rates developed in Houck et al. (1976) and used in Gallagher (1978) and Arzac and Wilkinson (1979) are used to measure the impact of annual commodity programs on crop acreage. For each crop, the problem is to combine into a few quantitative variables the price and income supporting features of annual commodity programs and their acreage controlling aspects. The effective support rate is illustrated as follows:

\[ ESP = r^*LR \]  

(2.16)
The loan rate (LR) is typically set by the government to act as a price floor in the market. Suppose, as was often the case in the 1950s and 1960s, that excess supply conditions warranted a reduction in LR. But, assume that political, social, and other considerations linked to farm income levels make it impossible or undesirable for policymakers to reduce the loan rate. A support rate of LR could be announced, but in order to obtain LR, producers might be induced or required to reduce planted acreage. Thus, an effective support price (ESP) exists which embodies the constraint (r) attached to the availability of LP.

In addition to restrictions on receiving the loan rate, voluntary acreage programs of the recent past have included direct payments to program participants for withdrawing land from production and leaving it idle.

\[ EDR = w*DR \]  

Suppose DR is the payment rate for diversion, w is the base acreage eligible for diversion, and EDR is the effective diversion payment rate. At a fixed level of DR (which can and often is related to LR), w can vary between 0 and 1.0. If there is no limit on acreage eligible for diversion, w equals 1.0. The smaller the permitted diversion, the closer w is to zero. Unfortunately, actual program provisions were not specified so that support and diversion rate variables are unambiguous for quantification and inclusion in supply analyses. Recent studies (Houck et al., 1976) and (Gallagher, 1981) have refined these variables for all of the major U.S. field crops in an attempt to capture year-to-year program changes in a consistent manner.
Given profit-maximizing behavior by producers, acreage planted \((AP_t)\) will be a function of lagged market prices \((P_{t-1}, PS_{t-1})\) effective support and diversion variables for the crop and substitutes and other supply shifters \((X_t)\). Lagged acreage reflects gradual adjustments to changing market conditions over time.

\[
AP_t = f(AP_{t-1}, P_{t-1}, PS_{t-1}, ESP_t, EDR_t, ESPS_t, EDRS_t, X_t) \quad (2.18)
\]

Acreage relationships estimated directly from equation (18) often suffer from high correlation between \(P_{t-1}\) and \(ESP_t\). Gallagher (1978) provides a method in which both variables are integrated together to give a single measure of expected price. He argues that an econometric model of producer response to price should assign the dominant allocative role to support prices under weak market conditions and to market prices under strong market conditions. To do this requires a rather complicated function of current-year support price \((ESP_t)\) and lagged market price \((P_{t-1})\).

\[
PE_t = ESP_t + \alpha [(D_t + 1) \ln(D_t + 1) - D_t] \quad (2.19)
\]

where

\[D_t = P_{t-1} - ESP_t > 0\]

and

\[\alpha > 0\]

The advantage of this expected price formation is that the response of expected price to changes in market or support price can be expressed as a simple function of the difference between market and support price \((D_t)\):

\[
\frac{\partial PE_t}{\partial P_{t-1}} = \beta (D_t) \quad (2.20a)
\]
where \[ \beta(D_t) = \alpha \ln(D_t + 1) \]

When \( \alpha > 0 \) and not large then \( 0 \leq \beta(D_t) \leq 1 \). An examination of \( \beta(D_t) = \alpha \ln(D_t + 1) \) verifies that supply elasticities can adjust appropriately with market conditions, under the restrictions placed on \( \alpha \). \( \beta(D_t) \) is zero, for example, when the market price falls to the loan rate \( (D_t = 0) \)—the corresponding elasticities for market and support prices are zero and one, respectively. As market conditions strengthen, \( \beta(D_t) \) increases, so the market price elasticity increases and the support price elasticity decreases.

**Inventory demand for grain**

Modeling commodity inventories have always been a difficult problem. Typical inventory holders include consumers, processors, producers, and a combination of dealers, brokers, wholesalers, and others uniquely classified as speculators. Yet a consumer, as well as a producer, may possess inventories for transaction, precautionary, or speculative reasons. This would not impose a serious problem, for example, if the data regarding producers' and consumers' inventories were divided to reflect different motives, but accounting systems seldom report inventory data even at the level of disaggregation of producers and consumers.

The simplest known explanation of inventory behavior is an accelerator; according to which inventories vary directly and proportionately with current production. Goodwin (1947) modified this theory in an
attempt to incorporate factors such as expectations about prices, market conditions, and the cost of funds with which to buy stocks. Goodwin assumes that firms adjust their inventories only partially toward their desired or equilibrium level in each period. This may occur because costs of acquiring stocks quickly may be prohibitively high, the composition of stocks may be so varied that all cannot be adjusted at the same time, and commodities may also be ordered only infrequently or under long-term contractual arrangement which may require holding large or small stocks at various times regardless of the level of productive activity. The flexible accelerator may be written as follows where $I^*_t$ are desired carryover stocks and $Q_t$ is current production in year $t$.

$$I^*_t = a_1 + a_2 Q_t$$  

(2.21)

Firms adjust actual stocks in a certain period only a fraction of the distance required to reach desired stocks.

$$I_t - I_{t-1} = p(I^*_t - I_{t-1})$$  

(2.21)

where $0 < p < 1$

Introducing the relationship for desired stocks and manipulating, the final expression for the flexible accelerator is

$$I_t = p a_1 + p a_2 Q_t + (1-p) I_{t-1}$$

(2.22)

or

$$I_t = b_1 + b_2 I_{t-1} + b_3 Q_t$$

(2.22a)

The modified flexible accelerator employed by Gallagher et al. (1981) and Meyers et al. (1981) attempts to include the speculative motive by adding current market price ($P_t$) and expected price as embodied by next year's
production. Government carryover \( R_t \), as represented by CCC and FOR stocks, is also included as additional information which is used in forming price expectations.

\[
I_t = f(I_{t-1}, P_t, Q_t, Q_{t+1}, R_t)
\]

(2.23)

This formulation of inventory behavior abstracts from the cost of holding grain between crop years which may be important. However, at this level of aggregation, there is no reliable data source of storage costs. Also, storage costs over the sample period probably varied little.

**Domestic demand for grain**

The food demand equations for wheat and feed grain are specified 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 (Henderson and Quandt, 1971). Demand depends upon the commodity price, \( P_t \), the price of substitutes \( P_S_t \), and income \( Y_t \). Hence, an individual's demand for grain \( D_{FOOD_t}^i \) can be written as follows:

\[
D_{FOOD_t}^i = f(P_t, P_S_t, Y_t^i)
\]

(2.24)

Under the assumption of identical consumer tastes, market demand \( D_{FOOD_t} \) can be written in terms of population \( POP_t \) and individual demands:

\[
D_{FOOD_t} = POP_t \cdot f(P_t, P_S_t, Y_t^i)
\]

(2.25)

The assumption of similar consumer tastes leads to population elasticities of one. Thus, the equation is written in per capita terms for estimation:
\[
\frac{\Delta \text{FOOD}_t}{\Delta \text{POP}_t} = f(P_t, P_s, Y_t) \tag{2.26}
\]

Domestic feed demand specification is based on derived demand theory. This model outlines the behavior of a profit-maximizing producer in purchasing inputs for his enterprise (Womack, 1976). Under the case where all factors of production are variable, input demand \(\text{DFEED}_t\) depends upon the input price \(P_t\), price of substitute inputs \(P_s\), output price \(PL_t\), and a measure of animal units being fed grain \(\text{GCAU}_t\).

\[
\text{DFEED}_t = f\left(\frac{P_t}{PL_t}, \frac{P_s}{PL_t}, \text{GCAU}_t\right) \tag{2.27}
\]

Feed grain competes principally with soybean meal in feed use in all livestock categories, particularly hogs, while wheat competes mainly with grain sorghum in the U.S. Southwest feeder cattle industry. The demand for grain as feed also depends on herd building dynamics captured in \(\text{GCAU}_t\).

**Domestic livestock market**

The domestic livestock market is specified in a manner similar to the annual beef market model of Reutlinger (1966). Livestock inventory \(\text{GCAU}_t\) fed over the current crop year is a function of lagged livestock inventory, the current price of corn \(P_t\), and finished livestock \(PL_t\).

\[
\text{GCAU}_t = f(\text{GCAU}_{t-1}, P_t, PL_t) \tag{2.28}
\]
Livestock supply \((LS_t)\) is a function of current and lagged inventory, livestock price, the price of corn, and finished livestock:

\[
LS_t = f(GCAU_t, GCAU_{t-1}, P_t, PL_t)
\]

(2.29)

The third equation relates livestock price to current livestock supply and to disposable per capita income \((Y_t)\).

\[
PL_t = f(LS_t, Y_t)
\]

(2.30)

This formulation has the advantage of remaining quite simple while capturing the major linkages to the grain markets through the price and inventory variables.

Reutlinger observed negative correlation between livestock supply and price and positive correlation between livestock supply and the price of corn in equation 2.29, which he explained by the peculiar nature of the product. A given supply of livestock may be marketed currently or retained to build up inventory; hence, the net effect of a rise in the price of the product (or a decline in the price of an input) may be negative with regard to current supply.

Grain exports

The specification of feed grain and wheat exports is based on work by Bredahl, Womack, and Matthews (1978).

Of total U.S. feed grain exports, corn, on the average, makes up approximately 95 percent, with grain sorghum making up the remainder. Argentina, South Africa, and Thailand are the principal export competitors of the United States in the world corn market (Table 2.1).
Table 2.1. Domestic and trade policies and market shares of major importers and exporters of corn

<table>
<thead>
<tr>
<th>Country or region</th>
<th>Market share (percent)</th>
<th>Domestic and trade policy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exporters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argentina</td>
<td>7</td>
<td>Domestic consumption and production prices are fixed. Exports are influenced by variation in exchange rates and export taxes.</td>
</tr>
<tr>
<td>South Africa</td>
<td>4</td>
<td>Domestic consumption and production prices are fixed by the South African Maize Board. Variation in exports are primarily associated with variation in production.</td>
</tr>
<tr>
<td>Thailand</td>
<td>3</td>
<td>Export quotas with prices determined by U.S. prices allocate almost all of the exportable surplus.</td>
</tr>
<tr>
<td>United States</td>
<td>73</td>
<td>Free market with the exception of a formal agreement on range of export volume with the Soviet Union.</td>
</tr>
<tr>
<td><strong>Importers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EEC-9</td>
<td>38</td>
<td>Wholesale prices determined by minimum import prices.</td>
</tr>
<tr>
<td>Other Western Europe</td>
<td>1</td>
<td>State trading with resale price determined by the state trading agency.</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>8</td>
<td>State trading with imports determined by production short falls and livestock production goals.</td>
</tr>
<tr>
<td>Japan</td>
<td>15</td>
<td>Free trade.</td>
</tr>
</tbody>
</table>

Note: (Bredahl, Meyers, Collins, 1979).

b Average share of world trade over the 1975-79 crop years (Webb, 1981).
Table 2.1 (continued)

<table>
<thead>
<tr>
<th>Country or region</th>
<th>Market share (percent)</th>
<th>Domestic and trade policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soviet Union</td>
<td>16</td>
<td>State trading with range of imports determined by formal agreement.</td>
</tr>
<tr>
<td>Rest of World</td>
<td>12</td>
<td>Varies from free trade to highly restricted trade.</td>
</tr>
</tbody>
</table>
Table 2.2. Domestic and trade policies and market shares of major importers and exporters of wheat

<table>
<thead>
<tr>
<th>Country or region</th>
<th>Market share (percent)</th>
<th>Domestic and trade policy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exporters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>13</td>
<td>All export sales are made by the Australian Wheat Board. Internal consumption price is fixed. Producer price is determined by export price.</td>
</tr>
<tr>
<td>Canada</td>
<td>18</td>
<td>All export sales are made by the Canadian Wheat Board. Producer price is determined by the export price with guaranteed minimum prices. Internal consumption price has been fixed during period of high prices.</td>
</tr>
<tr>
<td>United States</td>
<td>41</td>
<td>Free trade with the exception of a formal agreement on range of export volume with the Soviet Union.</td>
</tr>
<tr>
<td><strong>Importers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EEC-9</td>
<td>15</td>
<td>Wholesale price determined by minimum import price.</td>
</tr>
<tr>
<td>Other Western Europe</td>
<td>2</td>
<td>State trading with resale price determined by the state trading agency.</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>7</td>
<td>State trading with imports determined by production short falls and consumption goals.</td>
</tr>
<tr>
<td>Japan</td>
<td>8</td>
<td>State trading with a fixed resale price.</td>
</tr>
<tr>
<td>Soviet Union</td>
<td>10</td>
<td>State trading with range of imports determined by the formal agreement.</td>
</tr>
<tr>
<td>Rest of World</td>
<td>58</td>
<td>Varies from free trade to highly restricted trade.</td>
</tr>
</tbody>
</table>

\(^a\)Source: (Bredahl, Meyers, Collins, 1979).

\(^b\)Average share of world trade over the 1975-79 crop years (Webb, 1981).
However, the United States is clearly the dominant exporter. Domestic and trade policy of these countries, in general, isolates internal corn prices at both the consumer and producer levels from world prices. Thus, non-United States corn export supply (ESNUSt) is assumed to be completely inelastic with respect to the world price (U.S. corn price).

Major importing regions of corn are the European Community, other Western Europe, Japan, Soviet Union, and the developing world (rest of world in Table 2.1). These regions follow insulating domestic and trade policies with the exception of Japan and parts of the developing world. The import demand of these regions (IMPDₜ) is determined by policy prices, world prices (Pₜ), production (IQₜ), and long-term trade agreements. Bredahl et al. (1978) argue that the import demand of the European Community, other Western Europe, and the Soviet Union are completely inelastic with respect to international prices due to their domestic policy. However, there may be some price response in import demand by Japan, Eastern Europe, and the rest of the world. Thus, the export demand schedule (XDUSₜ) faced by the United States can be written as follows:

\[ XDUSₜ = IMPDₜ - ESNUSt \] (2.31)

Export demand is a function of international price (Pₜ), policy prices particularly, the corn threshold price of the European Community (CTPEECₜ)¹, shifters from the livestock sector (LSₜ), supply of corn in

¹The threshold price is the minimum import price of the European Community. The variable levy is the difference between the world price and CTPEECₜ.
importing regions and corn exports of principal competing countries \((\text{ESNUS}_t)\).

\[
\text{XDUS}_t = f(P_t, \text{CTPEEC}_t, \text{LS}_t, \text{IMPS}_t, \text{ESNUS}_t)
\]  

(2.32)

The theoretical specification for wheat exports is very similar with several important exceptions. As in the case of domestic demand for wheat as food, commercial wheat exports are estimated in per capita terms. Thus, wheat consumers are assumed to have identical tastes and preferences, and a population elasticity of one is implicitly assumed. Second, U.S. government exports of wheat under P.L. 480 are an important explanatory variable of historical commercial wheat exports. Third, while soybeans are an important feed grain substitute in the international market, corn and rice are important substitutes for wheat.

Finally, a word regarding exchange rates. Trade theory suggests that importers view international prices in terms of their own currency. Thus, in the specification of export demand schedules for U.S. grain, international prices should be expressed in terms of the importers currency. In most empirical studies of export demand for U.S. agricultural products, dollar denominated prices are deflated by the U.S. dollar/SDR exchange rate. However, a problem arises in that the SDR rate reflects a market basket of currencies of only highly developed industrialized countries. While this may cause few problems in the feed grain export demand equation, Collins, Meyers, and Bredahl (1980) show that the SDR rate is a poor exchange rate measure for export demand of U.S. wheat since a majority of these exports go to the developing world. In this
study, trade-weighted exchange rates for corn and wheat developed in Stallings (1981) will be used to improve the specification of U.S. grain exports. Table 2.3 shows the SDR rate (SDR), the wheat trade-weighted value of the U.S. dollar (WTWVDOL), and the corn trade-weighted value of the U.S. dollar (CTWVDOL) over the 1970s. Until 1971, with the advent of a quasi flexible exchange rate system, each of these measures equal 1.0. During the 1970s, CTWVDOL roughly parallels the SDR rate while WTWVDOL rises significantly above the SDR rate over most of the decade. The WTWVDOL reflects the rise of the U.S. dollar relative to currencies of the developing world during much of the 1970s. Differences between exchange rate measures suggest the measure chosen will have a significant impact on price response of demand for U.S. exports.
Table 2.3. A comparison of alternative exchange rate measures$^a$

<table>
<thead>
<tr>
<th>Crop year</th>
<th>SDR$^b$</th>
<th>WTGVWDL$^c$</th>
<th>CTGVWDL$^d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>1971</td>
<td>0.997</td>
<td>0.994</td>
<td>0.931</td>
</tr>
<tr>
<td>1972</td>
<td>0.921</td>
<td>0.975</td>
<td>0.876</td>
</tr>
<tr>
<td>1973</td>
<td>0.839</td>
<td>0.951</td>
<td>0.870</td>
</tr>
<tr>
<td>1974</td>
<td>0.831</td>
<td>0.994</td>
<td>0.882</td>
</tr>
<tr>
<td>1975</td>
<td>0.824</td>
<td>1.066</td>
<td>0.956</td>
</tr>
<tr>
<td>1976</td>
<td>0.866</td>
<td>1.162</td>
<td>1.009</td>
</tr>
<tr>
<td>1977</td>
<td>0.856</td>
<td>1.233</td>
<td>0.973</td>
</tr>
<tr>
<td>1978</td>
<td>0.799</td>
<td>1.343</td>
<td>0.965</td>
</tr>
<tr>
<td>1979</td>
<td>0.774</td>
<td>1.713</td>
<td>1.063</td>
</tr>
</tbody>
</table>


$^b$SDR per U.S. dollar rate.


CHAPTER III. ESTIMATION OF THE MODEL

The model developed, estimated, and simulated in this study is based on the structural form of a mixed block recursive type of model. Following Kmenta's (1971) notation, the structural form of a system of G equations, G endogenous variables, K predetermined variables, and T observations can be written in matrix form as follows:

\[ \beta y_t + \gamma x_t = u_t, \quad t = 1, 2, \ldots , T \] (3.1)

where

\[
y_t = \begin{bmatrix}
y_{1t} \\
y_{2t} \\
\vdots \\
y_{Gt}
\end{bmatrix}
\quad , \quad x_t = \begin{bmatrix}
x_{1t} \\
x_{2t} \\
\vdots \\
x_{Kt}
\end{bmatrix}
\quad , \quad u_t = \begin{bmatrix}
u_{1t} \\
u_{2t} \\
\vdots \\
u_{Gt}
\end{bmatrix}
\]

The y's are jointly dependent variables (JDV), x's are predetermined (exogenous and lagged dependent) variables (PDV) and the u's are stochastic disturbances. The \( \gamma \) is a GxK matrix of known structural coefficients. Matrix \( \beta \) can have different forms depending on the type of a system. If the system consists of all simultaneous equations, Matrix \( \beta \) of known coefficients is of the form

\[
\beta = \begin{bmatrix}
\beta_{11} & \beta_{12} & \cdots & \beta_{1G} \\
\beta_{21} & \beta_{22} & \cdots & \beta_{2G} \\
\vdots & \vdots & & \vdots \\
\beta_{G1} & \beta_{G2} & \cdots & \beta_{GG}
\end{bmatrix}
\]
If the coefficient matrix with R systems (blocks) is as follows:

\[
B = \begin{bmatrix}
\beta_{11} & \beta_{12} & \cdots & \beta_{1R} \\
0 & \beta_{22} & \cdots & \beta_{2R} \\
\vdots & \vdots & \ddots & \vdots \\
0 & 0 & \cdots & \beta_{22}
\end{bmatrix}
\]  
(3.3)

where the \( \beta \)'s are matrices of given dimensions, the model is called block recursive. The model developed for this study (presented later in the chapter) is of the block recursive type.

The model represented later in the chapter is identified and hence yields unique model solutions.

Various appropriate econometric techniques are used to estimate the single equations and systems of equations used in this simulation model.

Single Equation Estimation

A single equation econometric model with dependent variable \( y \), and explanatory variables \( x_1, x_2, \ldots, x_K \), linear in variables and coefficients, can be written in matrix form as

\[
Y = XB + U
\]

where the dimensions of \( Y \) and \( X \) are \( (T \times I) \) and \( (T \times K) \), respectively. The \( B \) is a vector \( (K \times 1) \) of structural parameters and \( U \) is a vector \( (T \times 1) \) of structural parameters and \( U \) is a vector \( (T \times 1) \) of stochastic disturbances. The usual assumptions about the disturbance terms are

\[
E(U) = 0
\]

\[
E(UU') = \sigma^2 I_T
\]

(3.5)

(3.6)
where $\sigma^2$ is a true variance and $I_T$ is a (T×T) identity matrix. Additional assumptions are that $X$ is a matrix of fixed observations and has a rank of $k<T$.

**Ordinary least squares**

Ordinary least squares (OLS) estimators of the structural parameters in a single equation with the above-mentioned assumptions are given by

$$\hat{B} = (X'X)^{-1} X' Y$$  \hspace{1cm} (3.7)

These are best linear unbiased estimators (BLUE).

**Autoregressive least squares**

Autoregressive least squares (ALS) is applied to those single equations where the error terms are serially correlated. Assumption 3.6 now does not hold. It is changed because

$$E(u_t^2) = \sigma^2$$  \hspace{1cm} (3.8)

but $$E(u_{t} u_{t+s}) \neq 0 \text{ for all } t \text{ and } s \neq 0.$$  

Under such autoregressive error structure, the OLS estimates are unbiased but not efficient. Also, the precise forms of $t$ and $F$ tests are not valid. Therefore, assuming the first order autoregressive scheme and using $\hat{\rho}$ (the estimate of the autoregressive parameter)

$$u_t = \rho u_{t-1} + \varepsilon_t$$  \hspace{1cm} (3.9)

the original model (3.4) is transformed using SAS-79 (Barr et al., 1979). This transformation yields the error term ($\varepsilon_t$) with all the
desirable properties. Then OLS is applied. The resulting ALS estimates are unbiased and efficient.

**Seemingly unrelated equations estimation**

A system of unrelated equations (SUR) consists of a group of equations which are linked as the disturbance terms are correlated across equations (Kmenta, 1971). One relevant example of such a system is crop yields of the feed grains and wheat. Error terms of each equation are likely to be correlated with the other equations at a given point in time, i.e.: contemporaneous correlation. A system of $G$ seemingly unrelated equations can be written as follows:

$$Y_j = X_jB_j + U_j, \quad j = 1,2,\ldots,G$$  \hspace{1cm} (3.10)

where

- $Y_j$ is a vector of $T \times 1$
- $X_j$ is a matrix of $T \times K_j$
- $B_j$ is a vector of $K_j \times 1$
- $U_j$ is a vector of $T \times 1$

By "stacking" all the $Y$ and $U$ vectors, the model can be written as

$$
\begin{bmatrix}
Y_1 \\
Y_2 \\
\vdots \\
Y_G
\end{bmatrix} = 
\begin{bmatrix}
X_1 & 0 & \cdots & 0 & B_1 & U_1 \\
0 & X_2 & \cdots & 0 & B_2 & U_2 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\
0 & 0 & \cdots & X_G & B_G & U_G
\end{bmatrix}
$$

or in a more concise form

$$Y = XB + U$$

A method used to estimate such a system is described below.
Three stage least squares

It is assumed that there is no heteroscedasticity and autocorrelation between error terms within equations; however, there exists cross-equation correlation. This can be seen from the following variance-covariance matrix.

\[
E(UU') = \Omega = \begin{bmatrix}
\sigma_{11} & \sigma_{12} & \cdots & \sigma_{1G} \\
\sigma_{21} & \sigma_{22} & \cdots & \sigma_{2G} \\
\vdots & \vdots & \ddots & \vdots \\
\sigma_{G1} & \sigma_{G2} & \cdots & \sigma_{GG}
\end{bmatrix}
\times X \times I
\]

Application of OLS equation-by-equation does not take into account the cross-equation correlation. Therefore, as proposed by Zellner (1962), application of Aitken's generalized least squares to the whole system simultaneously yields parameter estimators asymptotically more efficient than single equation OLS estimators. This method is also called 3SLS since it involves basically the same steps. This method is used in estimating crop yields. Crop yields are exogenous in the present model, but are estimated for future simulation of the model which will be explained in greater detail in Chapter VI.

Simultaneous Equations Estimation

A theoretical system of simultaneous equations described earlier in equation 3.1 is

\[\beta y_t + \tau x_t = u_t, \quad t = 1, 2, \ldots, T\]
where $y'$s are $G$ JDVs and $x'$s are $K$ PDVs. $\beta$ and $\gamma$ are matrices of structural coefficients associated with JDVs and PDVs, respectively.

The assumption of no serial correlation for each equation, i.e.,

$$E(u_t u_{t+s}) = 0 \text{ for all } t \text{ and } s \neq 0$$

is made. But, the error terms across the equations are likely to be correlated for each time period, due to the simultaneity among equations, i.e.,

$$E(u_i u_j) \neq 0 \text{ for equations } i \text{ and } j.$$  

An application of OLS equation-by-equation to the system gives biased and generally inconsistent estimates of the structural parameters.

**Two-stage least squares**

Two-stage squares (2SLS) is a limited information method of estimating simultaneous equations. It assumes that the right-hand-side endogenous variables of an equation are correlated with the disturbance term, but the disturbance terms across equations are not correlated, i.e., equation 3.13 does not hold (Pindyck and Rubenfeld, 1976, pp. 267-268). The derivation of a 2SLS estimator is given in Intrilligator (1978, pp. 384-394). The resulting estimates are still biased but consistent.

**Autoregressive two-stage least squares**

It is possible that disturbance terms in some of the equations are serially correlated, i.e., assumption 3.12 becomes $E(u_t u_{t+s}) \neq 0$ for $s \neq 0$. In such cases, autoregressive two-stage least squares (A2SLS) should be
used to obtain consistent and efficient estimators. Fuller (1978) has suggested a procedure to obtain A2SLS estimates using SAS-79 in the presence of a lagged endogenous variable on the right-hand-side of the equation. This is formally described in Fuller (1976). In situations without a lagged endogenous variable on the right-hand-side, Fuller's rather complicated procedure is not necessary. In this case, consistent and efficient estimators can be obtained by applying ALS to first-stage estimates of 2SLS.

**Three-stage least squares**

The 2SLS does not take into consideration the covariance matrix of disturbance terms of the structural equations. Three-stage least squares (3SLS) take explicit account of this covariance matrix that is estimated from the second-stage residuals. Hence, it is called a full information method. It differs from 3SLS in seemingly unrelated equation systems in that it uses 2SLS estimates rather than OLS estimates. The estimates produced by 3SLS are consistent and asymptotically more efficient than 2SLS. The derivation of 3SLS estimators is presented in Intrilligator (1978, pp. 403-411).

Of the structural equations of the model, the minor feed grain price equations and commercial export equations for wheat and food grains are estimated using 3SLS as two separate systems because of high correlation among equations estimated by 2SLS. Also, the estimated variance-covariance matrix of disturbance terms of the export equations serves as a basis for generating demand side shocks to the model for the stochastic simulations described in Chapter VI.
Estimated Model

The final form of the estimated model is shown below. The model consists of 35 equations, including 19 behavioral relationships and 16 identities. Table 3.1 gives the computer code, variable description, and sources of all time series used to estimate the model. Variables requiring further description than is possible in Table 3.1 are presented in Appendix A. Instrument sets used to estimate equations in the simultaneous block of the model are given in Appendix C. The model contains 35 endogenous variables and 45 exogenous variables, 15 of which are U.S. grain policy instruments. Equations 3.14-3.18, 3.24-3.34, and 3.46-3.48 are the behavioral relationships of the wheat, feed grain, and domestic livestock markets, respectively. Each equation includes the estimated coefficients, \( t \)-statistics (parentheses), elasticities of major variables (brackets), \(^2\) estimation technique, \( R^2 \), mean square error, Durbin-Watson or \( H \) statistic,\(^1\) and in equations adjusted for autocorrelation, the estimated autocorrelation coefficient.

**Wheat supply**

\[
\begin{align*}
WPA_{t+1} &= 39.754 + 0.5319 \times WPA_t - 9.444 \times D6272_{t+1} - 10.578 \times IPPF_{t+1} \\
&\quad + 3.2278 \times IPPF_t - 0.473 \times COTESP_{t+1} \\
&\quad \quad \quad \text{(2.832)} \quad \text{(3.293)} \quad \text{(9.89)} \quad \text{(1.248)} \quad \text{(1.151)} \quad \text{(1.668)} \\
&\quad \quad \quad [0.043] \quad [0.098] \quad [0.168] \\
&\quad = 0.8145 \quad \text{MSE} = 23.528 \quad H = 1.1369
\end{align*}
\]

\(^1\)The \( H \)-statistic replaces the Durbin-Watson statistic in the presence of a lagged dependent variable on the right-hand-side of the equation. The \( H \) is asymptotically normal with zero mean and unit variance for testing against first-order autocorrelation (Judge et al., 1980, pp. 219-220).

\(^2\)Evaluated at means of 1960-79.
Table 3.1. Variables used in the grain market model, code used for variables, description, units variables are in, and the sources for the data

<table>
<thead>
<tr>
<th>Code</th>
<th>Variable description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{WPA}_{t+1})</td>
<td>Wheat planted acreage</td>
<td>million acres</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>(\text{WPF}_t)</td>
<td>Wheat price received by farmers</td>
<td>dollars per bushel</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>(\text{SW}_t)</td>
<td>Commercial carryover stocks of wheat</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>(\text{PRODM}_{t+1})</td>
<td>Wheat production</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>(\text{DFOODW}_t)</td>
<td>Utilization of wheat as food, seed, and other nonfeed</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>(\text{DFEEDW}_t)</td>
<td>Utilization of wheat as feed</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>(\text{LSTKPI}_t)</td>
<td>Index of prices received by farmers for meat animals</td>
<td>index, 1967 = 1.00</td>
<td>USDA, 1981c</td>
</tr>
<tr>
<td>(\text{GCAU}_t)</td>
<td>Grain-consuming animal units</td>
<td>million units(^a)</td>
<td>USDA, 1981c</td>
</tr>
<tr>
<td>(\text{CBW}_t)</td>
<td>Commercial wheat exports</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>(\text{TSW}_t)</td>
<td>Total carryover stocks of wheat</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>(\text{TEW}_t)</td>
<td>Total exports wheat</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>(\text{WLSTKPRD}_t)</td>
<td>Weighted average of domestic beef, pork, and poultry production</td>
<td>million pounds</td>
<td>USDA, 1981c</td>
</tr>
</tbody>
</table>

\(^a\)Index series based on average feeding rates for years 1969-71. In calculations for feeding years 1969-79, cattle numbers used are new categories shown in USDA (1980b).
Table 3.1 (continued)

<table>
<thead>
<tr>
<th>Code</th>
<th>Variable description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPA(_{t+1})</td>
<td>Corn planted acreage</td>
<td>million acres</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>GSPA(_{t+1})</td>
<td>Grain sorghum planted acreage</td>
<td>million acres</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>OPA(_{t+1})</td>
<td>Oats planted acreage</td>
<td>million acres</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>BPA(_{t+1})</td>
<td>Barley planted acreage</td>
<td>million acres</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>CPF(_t)</td>
<td>Corn price received by farmers</td>
<td>dollars per bushel</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>GSPF(_t)</td>
<td>Grain sorghum price received by farmers</td>
<td>dollars per bushel</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>OPF(_t)</td>
<td>Oats price received by farmers</td>
<td>dollars per bushel</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>BPF(_t)</td>
<td>Barley price received by farmers</td>
<td>dollars per bushel</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>SFG(_t)</td>
<td>Commercial carryover stocks of feed grain</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>PRODFG(_{t+1})</td>
<td>Feed grain production</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>DFOODFG(_t)</td>
<td>Utilization of feed grain as food, seed, and other nonfeed</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>DFEEDFG(_t)</td>
<td>Utilization of feed grain as feed</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>CEFG(_t)</td>
<td>Commercial feed grain exports</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>TSFG(_t)</td>
<td>Total carryover stocks of feed grain</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
</tbody>
</table>
Table 3.1 (continued)

<table>
<thead>
<tr>
<th>Code</th>
<th>Variable description</th>
<th>Units</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEGF</td>
<td>Total exports of feed grain</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>ECPF</td>
<td>Expected corn price</td>
<td>dollars per bushel</td>
<td>Gallagher, 1978</td>
</tr>
<tr>
<td>ESBPF</td>
<td>Expected soybean price</td>
<td>dollars per bushel</td>
<td>Gallagher, 1978</td>
</tr>
<tr>
<td>PRODC</td>
<td>Corn production</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>PRODGS</td>
<td>Grain sorghum production</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>PRODB</td>
<td>Barley production</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>PRODO</td>
<td>Oats production</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>PRODFG</td>
<td>Feed grain production</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
</tbody>
</table>

List of policy variables (exoRenous)

<table>
<thead>
<tr>
<th>WHEDR</th>
<th>Effective diversion rate for wheat</th>
<th>dollars per bushel</th>
<th>Gallagher, 1981; Gallagher et al., 1981</th>
</tr>
</thead>
<tbody>
<tr>
<td>CESP</td>
<td>Effective support price for corn</td>
<td>dollars per bushel</td>
<td>Gallagher, 1978; 1981</td>
</tr>
<tr>
<td>CEDR</td>
<td>Effective diversion rate for corn</td>
<td>dollars per bushel</td>
<td>Gallagher, 1978; 1981</td>
</tr>
<tr>
<td>GSED</td>
<td>Effective diversion rate for sorghum</td>
<td>dollars per bushel</td>
<td>Houck et al., 1976; Gallagher, 1981</td>
</tr>
<tr>
<td>OESP</td>
<td>Effective support price for oats</td>
<td>dollars per bushel</td>
<td>Houck et al., 1976; Gallagher, 1981</td>
</tr>
</tbody>
</table>
Table 3.1 (continued)

<table>
<thead>
<tr>
<th>Code</th>
<th>Variable description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBESP&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Effective support price for soybeans</td>
<td>dollars per bushel</td>
<td>Houck et al., 1976; USDA, 1980b</td>
</tr>
<tr>
<td>COTESP&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Effective support price for cotton</td>
<td>dollars per bushel</td>
<td>Houck et al., 1976; USDA, 1980b</td>
</tr>
<tr>
<td>SWFOR&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Farmer-owned reserve carryover stocks of wheat</td>
<td>million metric tons</td>
<td>USDA, 1980c</td>
</tr>
<tr>
<td>SWCCC&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Carryover wheat stocks owned by the Commodity Credit Corporation</td>
<td>million metric tons</td>
<td>USDA, 1980c</td>
</tr>
<tr>
<td>SFGFOR&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Farmer-owned reserve carryover stocks of feed grain</td>
<td>million metric tons</td>
<td>USDA, 1980c</td>
</tr>
<tr>
<td>SFGCCC&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Carryover feed grain stocks owned by the Commodity Credit Corporation</td>
<td>million metric tons</td>
<td>USDA, 1980c</td>
</tr>
<tr>
<td>WES&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Wheat export subsidy</td>
<td>dollars per bushel</td>
<td>Gallagher et al., 1981</td>
</tr>
<tr>
<td>RES&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Rice export subsidy</td>
<td>dollars per bushel</td>
<td>Gallagher et al., 1981</td>
</tr>
<tr>
<td>GOVEW&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Government wheat exports under P.L. 480</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>GOVEFG&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Government feed grain exports under P.L. 480</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
</tbody>
</table>
Table 3.1 (continued)

<table>
<thead>
<tr>
<th>Code</th>
<th>Variable description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{6272}^{t+1}$</td>
<td>Dummy variable to represent wheat diversion policy</td>
<td>$(1961-71) = 1$</td>
<td>-</td>
</tr>
<tr>
<td>$IPPF_{t+1}$</td>
<td>Index of prices paid by farmers for all commodities used in production</td>
<td>$1967 = 1.0$</td>
<td>USDA, 1980a; 1970; 1964</td>
</tr>
<tr>
<td>$CPI_{t}$</td>
<td>Consumer price index less food</td>
<td>$1967 = 1.0$</td>
<td>USDC, 1980</td>
</tr>
<tr>
<td>$PCDI_{t}$</td>
<td>Per capita disposable income</td>
<td>dollars</td>
<td>USDC, 1980</td>
</tr>
<tr>
<td>$D_{6467}^{t}$</td>
<td>Dummy variable in wheat feeding equation</td>
<td>$(1964, 1967) = 1$</td>
<td>-</td>
</tr>
<tr>
<td>$WP_{OPNUS}^{t}$</td>
<td>World population excluding U.S.</td>
<td>million people</td>
<td>United Nations, 1981</td>
</tr>
<tr>
<td>$WTWVDOL_{t}$</td>
<td>Wheat trade-weighted value of the U.S. dollar</td>
<td>$1970 = 1.0$</td>
<td>Stallings, 1981</td>
</tr>
<tr>
<td>$RPHOU_{t}$</td>
<td>Price medium grain rice, FOB-Houston</td>
<td>dollars per cwt.</td>
<td>Gallagher et al., 1981; USDC, 1980f</td>
</tr>
<tr>
<td>$WSUPNUS_{t}$</td>
<td>World wheat supply excluding U.S.</td>
<td>million metric tons</td>
<td>USDA, 1980e</td>
</tr>
<tr>
<td>$IMPW_{t}$</td>
<td>U.S. wheat imports</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>$D_{66}^{t+1}$</td>
<td>Dummy variable representing change in calculation of effective support rates</td>
<td>$(1965-79) = 1$</td>
<td>-</td>
</tr>
</tbody>
</table>

The units are in parentheses and the sources are listed below the table.
Table 3.1 (continued)

<table>
<thead>
<tr>
<th>Code</th>
<th>Variable description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPAM&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Dummy variable representing change in corn diversion program in 1961</td>
<td>million acres</td>
<td>Houck et al., 1976</td>
</tr>
<tr>
<td>VCC&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Corn production costs</td>
<td>dollars per acre</td>
<td>Gallagher, 1978; USDA, 1981a</td>
</tr>
<tr>
<td>VCSB&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Soybean production costs</td>
<td>dollars per acre</td>
<td>Gallagher, 1978; USDA, 1981a</td>
</tr>
<tr>
<td>AWWM&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Dummy variable representing change in grain sorghum diversion program</td>
<td>million acres</td>
<td>Houck et al., 1976</td>
</tr>
<tr>
<td></td>
<td>in 1961</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;T+1&lt;/sub&gt;</td>
<td>Time trend</td>
<td>1954 = 1, 1955 = 2,...</td>
<td>-</td>
</tr>
<tr>
<td>D73&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Dummy variable representing Nixon Administration wage-price freeze of</td>
<td>(1973) = 1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1973</td>
<td>(otherwise) = 0</td>
<td></td>
</tr>
<tr>
<td>SBPF&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Soybean price received by farmers</td>
<td>dollars per bushel</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>SBMP&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Soybean meal price at Decatur, 44 percent protein</td>
<td>dollars per ton</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>IMPFG&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>U.S. feed grain imports</td>
<td>million metric tons</td>
<td>USDA, 1980b; 1970; 1964</td>
</tr>
<tr>
<td>YLDW&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Yield of wheat in terms of planted acreage</td>
<td>bushels per acre</td>
<td>calculated</td>
</tr>
<tr>
<td>YLDC&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Yield of corn in terms of planted acreage</td>
<td>bushels per acre</td>
<td>calculated</td>
</tr>
</tbody>
</table>
Table 3.1 (continued)

<table>
<thead>
<tr>
<th>Code</th>
<th>Variable description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>YLDGS(_{t+1})</td>
<td>Yield of grain sorghum in terms of planted acreage</td>
<td>bushels per acre</td>
<td>calculated</td>
</tr>
<tr>
<td>YLDB(_{t+1})</td>
<td>Yield of barley in terms of planted acreage</td>
<td>bushels per acre</td>
<td>calculated</td>
</tr>
<tr>
<td>YLDO(_{t+1})</td>
<td>Yield of oats in terms of planted acreage</td>
<td>bushels per acre</td>
<td>calculated</td>
</tr>
<tr>
<td>RFC(_t)</td>
<td>Range feed conditions (index)</td>
<td>percentage index</td>
<td>USDA, 1981c</td>
</tr>
<tr>
<td>CTPPEEC(_t)</td>
<td>Corn threshold price in the European Community</td>
<td>U.O.A. per metric ton</td>
<td>USDA, 1981b</td>
</tr>
<tr>
<td>CTWWDOL(_t)</td>
<td>Corn trade weighted value of the U.S. dollar</td>
<td>1970 = 1.0</td>
<td>Stallings, 1981</td>
</tr>
<tr>
<td>LPRDDEV(_t)</td>
<td>Hog and poultry production in the European Community, Japan, Eastern Europe, and USSR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCOMEXP(_t)</td>
<td>Corn exports from Argentina, S. Africa, and Thailand</td>
<td>million metric tons</td>
<td>USDA, 1980d; Bredahl et al., 1978; USDA, 1980e</td>
</tr>
</tbody>
</table>
Wheat demand

\[ SW_t = 9.166 + 0.222*SW_{t-1} - 3.457*\frac{WPF_t}{CPIF_t} + 0.511*PRODW_t \]
\[ - 0.273*PRODW_{t+1} - 0.242*SWGOV_t \]
\[ (2.318) (1.926) (2.918) (4.537) \]
\[ [0.616] [2.000] \]
\[ (2.547) (3.724) \]
\[ [1.069] [0.845] \]
\[ 2SLS: 1954-79 \quad R^2 = 0.9047 \quad MSE = 6.513 \quad H = 1.0896 \]

\[ DFOODW_t = 8.113 + 0.00284*SW_{t-1} \]
\[ - 0.2585 \]
\[ (7.070) (6.905) \]
\[ [0.469] \]
\[ ALS: 1954-79 \quad R^2 = 0.6652 \quad MSE = 0.6115 \]

\[ DFEEDW_t = 15.572 - 2.544*\frac{WPF_t}{LSTKPI_t} + 2.505*\frac{GSFF_t}{LSTKPI_t} \]
\[ + 0.00026*GCAU_t - 1.134*D6467_t + 2.437*D73_t \]
\[ (1.438) (2.896) (1.665) (1.735) (1.066) \]
\[ (2.148) (1.639) (2.430) \]
\[ 2SLS: 1954-79 \quad R^2 = 0.8002 \quad MSE = 0.9689 \quad DW = 1.5417 \]

\[ CEW_{t} \]
\[ = 19.657 - 0.284*(WPF_t - WES_t)*WTWVDOL_t \]
\[ + 0.416*(WPHOU_t - RES_t)*WTWVDOL_t - 0.142*\frac{WSUPNU_{t}}{WPOPNU_{t}} \]
\[ + 1.227*\frac{GOVEW_t}{(WPOPNU_{t})} \]
\[ (4.447) (0.624) \]
\[ (0.143) \]
\[ (2.220) (5.029) \]
\[ (3.603) (3.18) \]
\[ 3SLS: 1962-79 \quad R^2 = 0.900 \quad MSE = 1.382 \]
Wheat market identities

\[ \text{PRODW}_{t+1} = \frac{1}{36.7437} \times (\text{YLDW}_{t+1} \times \text{WDA}_{t+1}) \]  
(3.19)

\[ \text{SWGOV}_t = \text{SWFOR}_t + \text{SWCCC}_t \]  
(3.20)

\[ \text{TSW}_t = \text{SW}_t + \text{SWGOV}_t \]  
(3.21)

\[ \text{TEW}_t = \text{CEW}_t + \text{GOVEW}_t \]  
(3.22)

\[ \text{PRODW}_t + \text{TSW}_{t-1} + \text{IMPW}_t = \text{TSW}_t + \text{DFOODW}_t + \text{DFEEDW}_t + \text{TEW}_t \]  
(3.23)

Feed grain supply

\[ \begin{align*}
\text{CPA}_{t+1} &= 71.661 + 0.194\times\text{CPA}_t - 1.948\times\text{D66}_t + 0.677\times\text{SPM}_{t+1} \\
&\quad + (8.481) (2.589) (2.443) (2.315) \\
&\quad + 726.547\times\text{CEP}\text{F}_{t+1} - 91.575\times\text{ESBPF}_t + (4.500) (2.620) (1.801) \\
&\quad - 38.790\times\text{CEDR}_{t+1} - 0.173\times\text{COTESP}_{t+1} + 5.547\times\text{GSPF}_t + (3.771) (2.100) (1.683) \\
&\quad + 0.095 \quad [0.095] \quad [0.114] \quad [0.106]
\end{align*} \]  
(3.24)

2SLS: 1954-79 \( R^2 = 0.9483 \) MSE = 3.304 \( H = 1.399 \)

\[ \begin{align*}
\text{GSPA}_{t+1} &= 59.409 + 0.438\times\text{GSPA}_t - 1.111\times\text{AWWM}_t + 1.750\times\text{D66}_t + (4.939) (3.148) (3.971) (1.924) \\
&\quad - 15.752\times\text{GSED}\text{R}_{t+1} - 0.173\times\text{COTESP}_{t+1} + 5.547\times\text{GSPF}_t + (3.771) (2.100) (1.683) \\
&\quad + 0.084 \quad [0.084] \quad [0.206] \quad [0.193]
\end{align*} \]  
(3.25)

2SLS: 1957-79 \( R^2 = 0.7614 \) MSE = 2.037 \( H = 0.5506 \)
\[
O_{PA_{t+1}} = -2.640 + 0.854OPA_t + 4.929\frac{O{ESP}_t}{IPF_{t+1}} + 3.789\frac{OPF_t}{IPF_{t+1}}
\]
\[
\begin{align*}
(1.327) & \quad (16.354) \\
(1.464) & \quad (1.245) \\
[0.104] & \quad [0.098]
\end{align*}
\]
2SLS: 1954-79 \[ R^2 = 0.9767 \quad MSE = 2.299 \quad H = 0.235 \]

\[
B_{PA_{t+1}} = 3.243 + 0.707BPA_t + 3.645\frac{B{FF}_t}{WFF_{t+1}} - 0.150T_{t+1}
\]
\[
\begin{align*}
(0.730) & \quad (3.530) \\
(1.104) & \quad (2.525) \\
[0.186]
\end{align*}
\]
2SLS: 1954-79 \[ R^2 = 0.8814 \quad MSE = 1.043 \quad H = 0.329 \]

**Feed grain demand**

\[
S{FG}_t = 64.078 + 0.052S{FG}_{t-1} - 21.861\frac{C{PF}_t}{C{PILF}_t} + 0.071\times PRODFG_t + 0.121\times PRODFG_{t+1} - 0.259\times SFGGOV_t
\]
\[
\begin{align*}
(8.810) & \quad (0.548) \\
(8.593) & \quad (2.586) \\
[1.209] & \quad [0.455]
\end{align*}
\]
2SLS: 1954-79 \[ R^2 = 0.893 \quad MSE = 5.790 \quad H = 0.649 \]

\[
D{FOODFG}_t = 0.411 - 0.015\frac{C{PF}_t}{C{PILF}_t} + 0.005\times PCDI_t
\]
\[
\begin{align*}
(0.172) & \quad (0.02) \\
(7.097) & \quad (7.097) \\
[0.001] & \quad [0.933]
\end{align*}
\]
A2SLS: 1954-79 \[ R^2 = 0.7018 \quad MSE = 0.933 \]
\[
\text{FEEDPG}_t = 68.792 - 33.038*\frac{\text{CPF}_t}{\text{LSTKPI}_t} + 0.258*\frac{\text{SBMP}_t}{\text{LSTKPI}_t} + 0.0026*\text{GCAU}_t + 29.285*\text{D73}_t
\]
\[
+ (1.189) (4.150) (3.005) (0.360) (0.169) (3.905) (5.577) (1.741)
\]
\[\text{2SLS: 1954-79} \quad R^2 = 0.8994 \quad \text{MSE} = 33.296 \quad \text{DW} = 1.782\]

\[
\text{CEFG}_t = 12.883 - 22.051*\frac{\text{CPF}_t}{\text{SBPF}_t} - 0.677*\frac{\text{CTPEEC}_t}{\text{SBPF}_t * \text{CTWVDCL}_t} + 0.0029*\text{LPRDDEV}_t - 1.721*\text{COMEXP}_t
\]
\[
+ (0.475) (0.568) (1.683) (0.346) (0.547) (4.9067) (1.317) (1.862) (0.420)
\]
\[\text{3SLS: 1962-79} \quad R^2 = 0.900 \quad \text{MSE} = 1.382\]

**Price equations of minor feed grains**

\[
\frac{\text{GSPF}_t}{\text{CPILF}_t} = 0.172 + 0.839*\frac{\text{CPF}_t}{\text{CPILF}_t} - 0.704*\frac{\text{PRODGS}_t}{\text{CPILF}_t} + 1\]
\[
+ (2.186) (20.153) (1.806)
\]
\[\text{3SLS: 1961-79} \quad R^2 = 0.907 \quad \text{MSE} = 1.173\]

\[
\frac{\text{BPF}_t}{\text{CPILF}_t} = 0.097 + 0.903*\frac{\text{CPF}_t}{\text{CPILF}_t} - 1.662*\frac{\text{PRODB}_t}{\text{CPILF}_t} + 1\]
\[
+ (0. 883) (11.232) (3.421)
\]
\[\text{3SLS: 1961-79} \quad R^2 = 0.907 \quad \text{MSE} = 1.173\]

\[
\frac{\text{OPF}_t}{\text{CPILF}_t} = 0.122 + 0.443*\frac{\text{CPF}_t}{\text{CPILF}_t} + 1\]
\[
+ (1.507) (6.766)
\]
\[\text{3SLS: 1961-79} \quad R^2 = 0.907 \quad \text{MSE} = 1.173\]
Livestock market

\[
\frac{\text{LSTKPI}_t}{\text{CPILF}_t} = 1.028 - 0.00018*\text{WLSTKPRD}_t
\]

(4.14) (5.737)

[2.265]

\[
\frac{\text{PCDI}_t}{\text{CPILF}_t} = 0.00094 + 0.515
\]

(6.355) [1.966]

A2SLS: 1961-79 \( R^2 = 0.7197 \) MSE = 0.0061

\[
\text{WLSTKPRD}_t = 8152.592 - 2545.763*\frac{\text{LSTKPI}_t}{\text{CPILF}_t}
\]

(2.935) (4.313)

[0.178]

+ 0.072*GCAU_t + 283.995*T_t \( \hat{\rho} = 0.667 \)

(1.941) (7.948)

[0.346]

A2SLS: 1961-79 \( R^2 = 0.8587 \) MSE = 127955.7

\[
\text{GCAU}_t = 59245.32 + 0.469*\text{GCAU}_{t-1} - 6469.54*\frac{\text{CPF}_t}{\text{CPILF}_t}
\]

(4.0518) (2.765) (4.083)

[0.116]

\[
\frac{\text{LSTKPI}_t}{\text{CPILF}_t} + 5977.106*\frac{\text{CPF}_t}{\text{CPILF}_t} = 216.607*\text{RFC}_t
\]

(1.643) (1.690)

[0.090] [0.220]

TSL5: 1961-79 \( R^2 = 0.7096 \) MSE = 3009561 \( DW = 2.9126 \)
\begin{align*}
\text{PROD}_{t+1} &= \frac{1}{39.36825} \times (YLD_{t+1} \times CPA_{t+1}) \\
\text{PRODGS}_{t+1} &= \frac{1}{39.36825} \times (YLDGS_{t+1} \times GSPA_{t+1}) \\
\text{PRODC}_{t+1} &= \frac{1}{68.89444} \times (YLDO_{t+1} \times OPA_{t+1}) \\
\text{PRODB}_{t+1} &= \frac{1}{45.929625} \times (YLDB_{t+1} \times BPA_{t+1}) \\
\text{PRODFG}_{t+1} &= \text{PROD}_{t+1} + \text{PRODGS}_{t+1} + \text{PRODC}_{t+1} + \text{PRODB}_{t+1} \\
\text{SFGGOV}_t &= \text{SFGFOR}_t + \text{SFGCCC}_t \\
\text{TSFG}_t &= \text{SFG}_t + \text{SFGGOV}_t \\
\text{TEFG}_t &= \text{CEF}_t + \text{GOVEFG}_t \\
\text{PRODFG}_t + \text{TSFG}_{t-1} + \text{IMPFG}_t &= \text{TSFG}_t + \text{DFOODFG}_t \\
&\quad + \text{DFEDFG}_t + \text{TEFG}_t \\
\text{ECPF}_{t+1} &= \text{CESP}_t + 0.88505 \times ((CPF_t - CESP_{t+1} + 1) \times \\
&\quad \log(CPF_t - CESP_{t+1} + 1) - (CPF_t - CESP_{t+1})) \\
\text{ESBPF}_{t+1} &= \text{SBESP}_{t+1} + 0.59777 \times ((SBPF_t - SBESP_{t+1} + 1) \times \\
&\quad \log(SBPF_t - SBESP_{t+1} + 1) - (SBPF_t - SBESP_{t+1}))
\end{align*}
Deflators

Before entering into discussion of the estimated equations, it is useful to explain the role of deflators in this model. All price and income variables in the model are deflated to reflect 1967 constant dollars. On the supply side of the model, the index of prices paid by farmers for production (IPPF\textsubscript{t}) is used as a deflator, while on the demand side the consumer price index less food items (CPILF\textsubscript{t}) is used. Both of these variables are calculated on a calendar year basis which overlaps by varying degrees with the wheat and feed grain crop years. The calendar year is matched with a crop year with which it overlaps to the greatest extent. For example, CPILF in calendar year t is matched with the wheat price in crop year t (June-May). The CPILF in calendar year t+1 is matched with the corn price in crop year t (October-September). Other calendar year variables which are matched to the grain crop years in a similar fashion are LSTKPI and PCDI.

Acreage equations

The estimated equations for acreage planted of wheat, corn, grain sorghum, oats, and barley are specified in a manner similar to the theoretical model presented in the last chapter. Lagged acreage is significant at the 5 percent level in each equation which indicates gradual adjustments to changing market conditions.

An attempt was made to disaggregate wheat acreage response into spring and winter equations but the aggregated approach produced better results. The overall fit of the wheat acreage equations is poorer than
the feed grain equations, but it compares reasonably with other wheat acreage studies. Acreage response appears quite inelastic with respect to last year's price. The effective support rate for wheat was not significant in any specification probably due to correlation with price. Wheat diversion is measured with a dummy variable \( (D6272_{t+1}) \) and the effective diversion rate for wheat. Results indicate that cotton is the most important substitute crop for wheat. An attempt was made to incorporate an expected price variable of the Gallagher (1978) type in order to improve acreage response to both market price and loan rates. However, this variable was always of the wrong sign and insignificant in all specifications.

The corn acreage equation (3.24) features expected prices for \( t+1 \) which are a nonlinear function of last year's market price and current year's effective support price as described in the previous chapter. The expected price equations are taken directly from Gallagher (1978). The statistical properties of this equation are quite good with almost 95 percent of historical variation in corn acreage explained; all variables have the correct sign and are significant at the 5 percent level with the exception of expected soybean price (significant at the 10 percent level). Corn acreage responds significantly to corn diversion policy as measured by the effective diversion rate. Acreage response is again fairly inelastic with respect to corn and soybean expected prices. Results confirm the dominance of soybeans as a corn acreage substitute. A change in the method of calculating effective support prices after 1965 is reflected in \( D66_{t+1} \). The impact of
discontinuing the policy of allowing sorghum to be planted on diverted corn acreage in 1961 is reflected in $\text{SPAM}_{t+1}^{1}$.

The minor feed grain equations also have reasonably good statistical properties. Results indicate that grain sorghum competes mainly with wheat and cotton, and barley competes with wheat for acreage. Price elasticities in these crops are somewhat larger than for wheat and corn, ranging from .098 for oats to .193 for grain sorghum. Diversion policy is significant at the 5 percent level in sorghum while the effective support rate is marginally significant for oats. These equations embody simple naive price expectations.

**Domestic demand**

The domestic demand equations for wheat and feed grain are roughly similar in their specification, particularly for private carryover stocks and food utilization.

In light of past historical difficulty in estimating stock equations, the statistical properties of 3.15 and 3.28 are excellent. All explanatory variables have the correct sign and are significant at the 5 percent level. Coefficients on lagged stocks suggest that feed grain carryover adjusts more quickly to changing conditions relative to wheat stocks. Relative to other demand components, stock demand appears to be relatively elastic with respect to current price. Current production is highly significant in both equations. Expected price as

\[ \text{SPAM}_{t+1} \]

1. $\text{SPAM}_{t+1}$ equals grain sorghum planted acreage between 1954-60. From 1961-79, $\text{SPAM}_{t+1}$ takes on the average value of grain sorghum planted acreage between 1954-60.
measured by next year's production is also highly significant in both equations and the estimated elasticities are fairly large, suggesting a sizable speculative component in private stocks. Results also indicate that government stocks, for both wheat and feed grain, displaced private stocks but at less than a one for one basis (-.242 for wheat and -.259 for feed grain). The estimated coefficients suggest that an increase in government stocks by 1 bushel reduces private stocks approximately .25 bushels and thus increases total carryover by .75 bushels. This result suggests that government stockholding, measured by CCC and FOR stocks, has historically contributed significantly to price stability.

The acreage and stock equations all contain lagged endogenous variables which could lead to autocorrelation. However, the H-statistics of these equations fail to reject the hypothesis of no first order autocorrelation.

Demand equations for food, seed, and nonfood use are shown in 3.16 and 3.29. In the case of wheat, a reasonable price effect could not be found which is consistent with previous work. In the feed grain equation, price is left in despite its lack of statistical significance because it does have the correct sign. Both of these equations are corrected for autocorrelation.

Feed utilization equations are shown in 3.17 and 3.30. Both of these equations have good statistical properties given the historical variation in the dependent variables. Results indicate the importance of sorghum as a substitute feed for wheat in cattle rations. Soybean
meal is the dominant substitute in the case of feed grains. Grain-consuming animal units (GCAU_t) are an important demand shifter in these equations. The significance of the dummy variable in the 1973 crop year reflects abnormally high grain feeding in that year, relative to retail meat prices which were frozen due to the unanticipated Nixon Administration wage-price freeze. The dummy variable, D6467, is included to account for distortions in the usual seasonal patterns of wheat and grain sorghum price (Gallagher et al., 1981).

**Foreign demand**

Commercial demand for U.S. grain exports is shown in 3.18 and 3.31. Wheat exports are estimated in per capita terms. All variables have the correct sign and are significant at the 5 percent level with the exception of wheat price which has the correct sign but is not significant. Most studies of U.S. wheat exports have had difficulty in finding a significant own price effect due to trade restrictions inherent in the market over the sample period. Results indicate that export demand is relatively inelastic at .143. This is less elastic than most other studies, for example, Gallagher et al. (1981, pp. 104) estimated the wheat export price elasticity at .72. One reason for the inelastic price response in the current study is due to the role of the exchange rate. The WTWVDOL_t is heavily weighted toward currencies of developing nations which import U.S. wheat (Table 2.1). In the 1970s, the value of these currencies fell against the U.S. dollar. Thus, the import price of wheat was rising relative to the dollar price throughout much of the decade.
(Table 2.2). This effect is not picked up in studies such as Gallagher's which ignore exchange rates or in studies which utilize the SDR/dollar rate as an exchange rate measure. The SDR rate rose against the U.S. dollar during most of the 1970s. However, the SDR rate reflects currencies of industrialized developed nations which import a relatively small share of U.S. wheat. Rice is a substitute for wheat exports as one would expect. The supply of wheat outside the U.S. and P.L. 480 wheat shipments are also important explanatory variables in explaining historical wheat exports. The wheat threshold price of the EEC was found to be an insignificant factor in explaining U.S. wheat export demand in preliminary specifications.

All variables in the feed grain export equation (3.31) are significant at the 10 percent level with the exception of the corn/soybean price ratio. This variable has the correct sign but is not significant. As in the case of wheat, the price variable is left in the estimated equation because of its theoretical plausibility. Export demand for feed grain appears to be somewhat more elastic with respect to own price than for wheat. The specification of the exchange rate reflects the importance of the European Community as an importer of U.S. corn and grain sorghum. The variable levy is levied against imported feed grain but not soybeans. Thus, the corn threshold price divided by the world price of soybeans represents the corn/soybean import price ratio from the Community's standpoint. The variable levy adjusts for changes in the world price of corn inclusive of exchange rate charges. Feed grain exports are also influenced by production of hogs and poultry in the
major corn importing regions \( (LPRDDEV_t) \) and by corn exports from Argentina, Thailand, and South Africa.

Equations 3.32-3.34 relate farm prices of grain sorghum, barley, and oats to the farm price of corn and the ratio of next year's production to corn production.

**Domestic livestock market**

The estimated equations of 3.46-3.48 make up the structural representation of the domestic livestock market. The price farmers receive for meat animals \( (LSTKPI_t) \) is related to a weighted average of beef, pork, and poultry production\(^1\) and disposable per capita income. This is essentially a price dependent demand equation for livestock. The size of the estimated elasticities suggest that price is relatively sensitive to changes in production and per capita income. Over 70 percent of historical livestock price variability is explained by these two variables. Livestock production is related to livestock price, grain-consuming animal units, and a time trend to represent technological improvements in broiler production. Negative production response to own price is consistent with the theoretical argument presented in Chapter II. Herd building dynamics are captured in the animal units equation. Grain-consuming animal units are a function of their lagged value, corn price, livestock price, and a variable which reflects the condition of range areas in the Southwest for cattle feeding \( (RFC_t) \). Specifications which included lagged prices were statistically inferior

\(^1\)Weights are based on the average farm level price of beef, hogs, and poultry from 1970-78.
to the chosen equation. Results suggest that animal units respond gradually to economic conditions and price elasticities are roughly equal for input (corn price) and output (livestock price) prices.
CHAPTER IV. HISTORICAL VALIDATION OF THE MODEL

This chapter is devoted to an examination of the econometric model's ability to predict past events in the U.S. grain livestock sector. The historical period per se is not of great 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 the model's solution outside that period (Gallagher et al., 1981).

In the validation run, the structural form of the model is dynamically simulated over the 1962-79 period. This period represents the longest period over which all structural equations are estimated. The simulation procedure is dynamic in the sense that solved values are used for lagged values of endogenous variables rather than the actual values for those variables. Using solved values instead of actual values to feed lagged endogenous values is a stricter test of the model and indicates how the model may behave if used for projections over long periods. Since some equations are not linear with respect to the endogenous variables, a nonlinear simulation procedure, SIMNLIN from SAS/ETS (SAS, 1980), is used to solve the model. Newton's solution procedure which uses analytic derivatives to solve the model is used for the validation run and all future simulations. Root mean square errors and turning point errors are two common measures used to evaluate the historical simulation.
Root Mean Square Error

One criterion used to evaluate a simulation model is the "fit" of the individual variables in a simulation context. One way to test the performance of the model is to perform a historical simulation and examine how closely each endogenous variable tracks its corresponding historical data series. The most commonly used quantitative measure of how closely an individual variable tracks its corresponding data series is called the RMS (root mean square) error. The RMS error is defined as follows:

\[
\text{RMS error} = \sqrt{\frac{1}{T} \sum_{t=1}^{T} (P_t - A_t)^2}
\]  

(4.1)

where

- \( P_t \) = the solved value of the endogenous variable in period \( t \)
- \( A_t \) = the actual value of the endogenous variable in period \( t \)
- \( T \) = the number of periods of the simulation

The RMS error is thus a measure of the deviation of the simulated variable from its actual time path (Pindyck and Rubenfeld, 1976). The magnitude of this error can be evaluated only by comparing it with the average size of the variable in question.

Another measure of this deviation, but in percentage terms, is called the RMS percent error.

\[
\text{RMS percent error} = \sqrt{\frac{1}{T} \sum_{t=1}^{T} \left( \frac{P_t - A_t}{A_t} \right)^2}
\]  

(4.2)

Both measures are presented for endogenous variables of the model in Table 4.1.
Table 4.1. Root mean square absolute and percentage errors for endogenous variables based on 1962-79 dynamic simulation

<table>
<thead>
<tr>
<th>Code</th>
<th>Variable</th>
<th>RMS error</th>
<th>RMS percentage error&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wheat market</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WPA&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Wheat planted acreage</td>
<td>3.55</td>
<td>5.15</td>
</tr>
<tr>
<td>WPF&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Wheat price received by farmers</td>
<td>0.74</td>
<td>29.75</td>
</tr>
<tr>
<td>SW&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Commercial carryover stocks of wheat</td>
<td>3.31</td>
<td>28.91</td>
</tr>
<tr>
<td>PRODW&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Wheat production</td>
<td>2.62</td>
<td>5.15</td>
</tr>
<tr>
<td>DFOODW&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Utilization of wheat as food and seed, and other nonfeed</td>
<td>0.58</td>
<td>3.43</td>
</tr>
<tr>
<td>DFEEDW&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Utilization of wheat as feed</td>
<td>1.48</td>
<td>101.00</td>
</tr>
<tr>
<td>CEW&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Commercial wheat exports</td>
<td>2.10</td>
<td>21.16</td>
</tr>
<tr>
<td>TSW&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Total carryover stocks of wheat</td>
<td>3.31</td>
<td>20.19</td>
</tr>
<tr>
<td>TEW&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Total exports of wheat</td>
<td>2.10</td>
<td>9.15</td>
</tr>
<tr>
<td><strong>Feed grain market</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPA&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Corn planted acreage</td>
<td>2.01</td>
<td>2.69</td>
</tr>
<tr>
<td>GSPA&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Grain sorghum planted acreage</td>
<td>1.90</td>
<td>10.56</td>
</tr>
</tbody>
</table>

<sup>a</sup>Presented in percentage terms.
Table 4.1 (continued)

<table>
<thead>
<tr>
<th>Code</th>
<th>Variable</th>
<th>RMS error</th>
<th>RMS percentage error</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPA&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Oats planted acreage</td>
<td>1.89</td>
<td>9.15</td>
</tr>
<tr>
<td>BPA&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Barley planted acreage</td>
<td>1.82</td>
<td>18.86</td>
</tr>
<tr>
<td>CPF&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Corn price received by farmers</td>
<td>0.25</td>
<td>11.68</td>
</tr>
<tr>
<td>GSPF&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Grain sorghum price received by farmers</td>
<td>0.22</td>
<td>11.71</td>
</tr>
<tr>
<td>BPF&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Barley price received by farmers</td>
<td>0.25</td>
<td>14.43</td>
</tr>
<tr>
<td>OPF&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Oats price received by farmers</td>
<td>0.16</td>
<td>14.09</td>
</tr>
<tr>
<td>SFG&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Commercial carryover stocks of feed grain</td>
<td>5.01</td>
<td>25.02</td>
</tr>
<tr>
<td>PRODFG&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>Feed grain production</td>
<td>5.56</td>
<td>3.11</td>
</tr>
<tr>
<td>DFOODFG&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Utilization of feed grain as food, seed and other nonfeed</td>
<td>1.17</td>
<td>7.41</td>
</tr>
<tr>
<td>DFEEDFG&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Utilization of feed grain as feed</td>
<td>6.24</td>
<td>5.44</td>
</tr>
<tr>
<td>CEFG&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Commercial exports of feed grain</td>
<td>6.26</td>
<td>26.37</td>
</tr>
<tr>
<td>TSFG&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Total carryover stocks of feed grain</td>
<td>5.01</td>
<td>23.05</td>
</tr>
<tr>
<td>TEFG&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Total exports of feed grain</td>
<td>6.26</td>
<td>24.03</td>
</tr>
</tbody>
</table>
Table 4.1 (continued)

<table>
<thead>
<tr>
<th>Code</th>
<th>Variable</th>
<th>RMS error</th>
<th>RMS percentage error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic livestock market</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSTKPI&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Index of prices received by farmers for meat animals</td>
<td>0.22</td>
<td>14.19</td>
</tr>
<tr>
<td>GCAU&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Grain-consuming animal units</td>
<td>1713.70</td>
<td>2.29</td>
</tr>
<tr>
<td>WLSTKPRD&lt;sub&gt;t&lt;/sub&gt;</td>
<td>Weighted average of domestic beef, pork, and poultry production</td>
<td>829.55</td>
<td>5.38</td>
</tr>
</tbody>
</table>
The percentage error in wheat utilization as feed is by far the largest at 101.00 percent. The next largest error is in wheat farm price at 29.75 percent and commercial wheat carryover at 28.91 percent. In the feed grain market, commercial carryover and commercial stocks have the largest percentage errors at 25.02 and 26.37 percent, respectively. Error in feed grain prices range between 11.68 and 14.43 percent with corn farm price at 11.68 percent. Percentage errors in production are quite small for both wheat and feed grain at 5.15 and 3.11 percent, respectively. In the livestock market, percentage errors range between 2.29 and 14.19 percent with livestock price at 14.19.

These results suggest that the model performs least well in the wheat market. Feed use, commercial carryover, and commercial export have the largest percentage error. Stocks are the most important in terms of size of error.

Turning Point Errors

Turning points are another way of evaluating historical performance. 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. Following Gallagher et al. (1981), these four possibilities are arranged in a 2x2 table in Figure 4.1 (N refers to the absence, T to the presence of a turning point). The first letter refers
Figure 4.1. Possible combinations of predicted and actual turning points

Source: (Gallagher et al., 1981).
to actual values, the second to predictions. Thus, the number of correct predictions is $NN + TT$. False signals are represented by $NT$ and missed turns by $TN$. Turning points are determined by considering the sequence of predicted sign changes ($P_t - P_{t+1}$) and actual sign changes ($A_t - A_{t-1}$) used by Gallagher.

In this context, a turning point is defined as: (1) 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 sign changes. The definition excludes repeated directional errors and "corrective" directional changes (which result in an agreement of signs). Table 4.2 presents results of the turning point analysis for prices of wheat, corn, and livestock. Numbers in this table are based on predicted versus actual plots presented in Figures 4.2-4.4. In Table 4.2, 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.

Corn price performs best with the highest proportion of correctly predicted turning points and the fewest missed. All five turning point errors in wheat price were of the false prediction type, while turning point errors in livestock price were roughly split between the missed turn and falsely predicted types. Overall, the incidence of turning point errors is relatively small. Of 40 total turning points in these three price variables, 13 are errors. False predictions
Table 4.2. Frequency of turning points and errors in wheat, corn, and livestock price

<table>
<thead>
<tr>
<th>Variable</th>
<th>Actual</th>
<th>Predicted</th>
<th>Correctly predicted</th>
<th>Missed</th>
<th>Falsely predicted</th>
<th>Actual</th>
<th>Predicted</th>
<th>Number of repeated directional errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(TT+TN)</td>
<td>(TT+NT)</td>
<td>TT</td>
<td>TN</td>
<td>NT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WPF</td>
<td>5</td>
<td>11</td>
<td>3</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>CPF</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>LSTKPI</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Excludes turning points in last three columns.

Directional changes that correct previous turning point errors.
Figure 4.2. Predicted versus actual values for farm wheat price, historical simulation, 1962-79
Figure 4.3. Predicted versus actual values for farm corn price, historical simulation, 1962-79
Figure 4.4. Predicted versus actual values for index of price paid to farmers for meat animals, historical simulation, 1962-79
of errors by the model in wheat price probably contribute to turning point error in livestock price.

Tables 4.2-4.4 provide a good picture of the model's ability to predict historical prices. Generally, predicted prices of all three commodities follow actual prices quite closely from 1962 through the early 1970s. The model continues to predict corn prices reasonably well over 1974-79, however, turning point errors occur in 1976 and 1978. These errors appear to be related to turning point errors in the minor feed grain acreage equations which cause errors in total feed grain production. Price expectations in these acreage equations are possibly not sophisticated enough to properly handle the divergence between market prices and loan rates which occurred during this period.

Wheat prices predictions suffer from a similar problem over 1974-79. Turning point errors occur in 1974 and 1977. The wheat acreage equation does not respond adequately to increases in wheat prices over 1977-79, thus, wheat acreage is under predicted and wheat price is over predicted in each of the years. In addition, 1977 error is suspiciously large. After all computer work was finished on this project, an error in actual wheat price data was found for 1977. The model was estimated with \( WPF_{1977} = 2.83 \) dollars per bushel instead of its actual value of only 2.33 dollars per bushel. The over predicting of wheat price in 1977 can be partly attributed to this error.

\[\text{However, the estimated corn acreage equation has this ability.}\]
Livestock price is over-predicted during the 1973-77 period. The full impact of the Nixon wage-price freeze is probably not fully accounted for and the aggregated version of the livestock markets in the model is possibly not robust enough to fully account for the severe contraction which occurred in domestic livestock markets over this period. However, errors in livestock price are, in general, relatively small as suggested by the RMS in Table 4.1.

In summary, the model's ability to predict past events in markets of interest is quite good with some qualifications. The RMS errors are generally small in percentage and absolute terms. The incidence of turning point errors relative to the total number of turning points is low. The predictive power of the model is weakest with respect to the wheat market, particularly in wheat use as feed, acreage response to price in the 1970s and, thus, over some of these years, in price itself.
CHAPTER V. MULTIPLIER ANALYSIS

Multipliers provide insight into how the U.S. grain livestock sector will react to changes which occur outside the sector. Short-run or impact multipliers measure the impact of a current period exogenous change on current period values of endogenous variables. Intermediate and long-run multipliers provide insights into dynamic behavior of the model.

The structural form of the model presented in Chapter III can be rewritten in the following form when disturbance terms are set to zero:

\[ \nabla Y_t = \nabla Y_{t-1} + \phi X_t \]  
(5.1)

where
- \( \nabla, \beta = G \times G \) matrices of estimated structural coefficients
- \( \phi = G \times K \) matrix of estimated structural coefficients
- \( Y_t = G \times 1 \) vector of endogenous variables
- \( X_t = K \times 1 \) vector of exogenous variables

The reduced form of 5.1 relates current endogenous variables \( Y_t \) to current exogenous variables \( X_t \) and lagged endogenous \( Y_{t-1} \) variables:

\[ Y_t = A Y_{t-1} + BX_t \]  
(5.2)

where
- \( A = \nabla^{-1} B \)
- \( \beta = \nabla^{-1} \phi \)

Matrix B measures the effect of a change in current values of exogenous variables (short-run multiplier).
\[
\frac{\partial Y_t}{\partial X_t} = B = t^{-1} \phi 
\]  
(5.3)

Interim multipliers show the effect of a period \(t-j\) change in \(X\) on values of \(Y\) in period \(t\) (Gallagher et al., 1981).

\[
M_j = \frac{\partial Y_t}{\partial X_{t-j}} = A^j B \]  
(5.4)

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

\[
\Delta Y_{n,0} = \sum_{j=0}^{n} M_j = \sum_{j=0}^{n} A^j B \]  
(5.5)

The necessary and sufficient condition for model stability is that the characteristic roots of \(A\) are less than one in absolute values (Gallagher et al., 1981).

### Selected Short-Run Multipliers

Selected short-run multipliers for the wheat, feed grain, and domestic livestock markets are presented in Tables 5.1-5.3. Multipliers are based on the 1979 crop year. Thus, model equations which required linearization were linearized around 1979 values. Multipliers may not be valid for variable values significantly different from their 1979 values.
Table 5.1. Effect of current increases in exogenous variables on wheat acreage, production next year, utilization, and price^.

<table>
<thead>
<tr>
<th>Exogenous variable</th>
<th>Units</th>
<th>Change</th>
<th>1979 value</th>
<th>WPA (_{t+1})</th>
<th>PRODW (_{t+1})</th>
<th>DFOODW (_{t})</th>
<th>DFEEDW (_{t})</th>
<th>CEW (_{t})</th>
<th>TSW (_{t})</th>
<th>WPF (_{t})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979 value</td>
<td></td>
<td></td>
<td></td>
<td>Million acres</td>
<td>MMT</td>
<td>MMT</td>
<td>MMT</td>
<td>MMT</td>
<td>MMT</td>
<td>Dollars/bushel</td>
</tr>
<tr>
<td>WHEEDR (_{t+1})</td>
<td>$/bu.</td>
<td>1.0</td>
<td>0.0</td>
<td>-3.459</td>
<td>-2.807</td>
<td>0.000</td>
<td>-0.155</td>
<td>-0.355</td>
<td>0.490</td>
<td>0.169</td>
</tr>
<tr>
<td>COTESP (_{t+1})</td>
<td>$/cwt.</td>
<td>10.0</td>
<td>57.8</td>
<td>-1.546</td>
<td>-1.254</td>
<td>0.000</td>
<td>-0.069</td>
<td>-0.150</td>
<td>0.219</td>
<td>0.008</td>
</tr>
<tr>
<td>SWGOV (_{t})</td>
<td>MMT</td>
<td>1.0</td>
<td>12.3</td>
<td>0.177</td>
<td>0.144</td>
<td>0.000</td>
<td>-0.145</td>
<td>-0.314</td>
<td>0.459</td>
<td>0.159</td>
</tr>
<tr>
<td>WSUPNUS (_{t})</td>
<td>MMT</td>
<td>10.0</td>
<td>439.9</td>
<td>-0.331</td>
<td>-0.268</td>
<td>0.000</td>
<td>0.271</td>
<td>-0.829</td>
<td>0.558</td>
<td>-0.297</td>
</tr>
<tr>
<td>PRODW (_{t})</td>
<td>MMT</td>
<td>1.0</td>
<td>58.1</td>
<td>-0.114</td>
<td>-0.093</td>
<td>0.000</td>
<td>0.094</td>
<td>0.203</td>
<td>0.704</td>
<td>-0.103</td>
</tr>
<tr>
<td>RPHOU (_{t})</td>
<td>$/cwt.</td>
<td>1.0</td>
<td>21.4</td>
<td>0.304</td>
<td>0.247</td>
<td>0.000</td>
<td>0.762</td>
<td>-0.249</td>
<td>-0.513</td>
<td>0.273</td>
</tr>
<tr>
<td>PCDI (_{t})</td>
<td>$</td>
<td>100.0</td>
<td>7,464.0</td>
<td>0.036</td>
<td>0.029</td>
<td>0.130</td>
<td>0.001</td>
<td>-0.054</td>
<td>-0.051</td>
<td>0.027</td>
</tr>
</tbody>
</table>

^Short-run or impact multipliers.
Table 5.2. Effect of current increases in exogenous variables on corn acreage, feed grain production next year, utilization, and price\(^{a}\)

<table>
<thead>
<tr>
<th>Exogenous variable</th>
<th>Units</th>
<th>Change</th>
<th>1979 value</th>
<th>CPA(_{t+1})</th>
<th>PRODFG(_{t+1})</th>
<th>DFOODFG(_t)</th>
<th>DFEEDFG(_t)</th>
<th>CEFG(_t)</th>
<th>TSEFG(_t)</th>
<th>CPF(_t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979 value</td>
<td></td>
<td></td>
<td></td>
<td>Million acres</td>
<td>MMT</td>
<td>MMT</td>
<td>MMT</td>
<td>MMT</td>
<td>MMT</td>
<td>dollars/bushel</td>
</tr>
<tr>
<td>CEDR(_{t+1})</td>
<td>$/bu.</td>
<td>1.0</td>
<td>0.0</td>
<td>-13.177</td>
<td>-26.236</td>
<td>-0.001</td>
<td>-1.921</td>
<td>-0.353</td>
<td>2.274</td>
<td>0.101</td>
</tr>
<tr>
<td>SFGGOV(_t)</td>
<td>MMT</td>
<td>1.0</td>
<td>25.2</td>
<td>0.0450</td>
<td>0.139</td>
<td>0.000</td>
<td>-0.044</td>
<td>-0.810</td>
<td>0.519</td>
<td>0.023</td>
</tr>
<tr>
<td>CTPEEC(_t)</td>
<td>UOA(^b)/metric ton</td>
<td>10.0</td>
<td>182.0</td>
<td>-0.057</td>
<td>-0.175</td>
<td>0.000</td>
<td>0.552</td>
<td>-0.830</td>
<td>0.280</td>
<td>-0.030</td>
</tr>
<tr>
<td>CCOMEXP(_t)</td>
<td>MMT</td>
<td>1.0</td>
<td>8.3</td>
<td>-0.105</td>
<td>-0.323</td>
<td>0.000</td>
<td>1.018</td>
<td>-1.534</td>
<td>0.516</td>
<td>-0.053</td>
</tr>
<tr>
<td>LPRDDEV(_t)</td>
<td>MMT</td>
<td>1,000.0</td>
<td>29,543.0</td>
<td>0.177</td>
<td>0.544</td>
<td>0.000</td>
<td>-1.715</td>
<td>2.585</td>
<td>-0.869</td>
<td>0.080</td>
</tr>
<tr>
<td>PRODFG(_t)</td>
<td>MMT</td>
<td>10.0</td>
<td>233.9</td>
<td>-0.570</td>
<td>-1.740</td>
<td>0.002</td>
<td>5.490</td>
<td>1.010</td>
<td>3.490</td>
<td>-0.290</td>
</tr>
<tr>
<td>SBPF(_t)</td>
<td>$/bu.</td>
<td>1.0</td>
<td>6.28</td>
<td>-0.499</td>
<td>-0.735</td>
<td>-0.001</td>
<td>-2.414</td>
<td>3.457</td>
<td>-1.043</td>
<td>0.126</td>
</tr>
<tr>
<td>PCDI(_t)</td>
<td>$</td>
<td>100.0</td>
<td>8,551.0</td>
<td>0.047</td>
<td>0.015</td>
<td>0.145</td>
<td>0.012</td>
<td>-0.084</td>
<td>-0.232</td>
<td>0.024</td>
</tr>
</tbody>
</table>

\(^{a}\) Short-run or impact multipliers.

\(^{b}\) European Community units of account.
Table 5.3. Effect of current increases in exogenous variables on livestock production, price, and grain-consuming animal units$^a$

<table>
<thead>
<tr>
<th>Exogenous variable</th>
<th>Units</th>
<th>Change</th>
<th>1979 value</th>
<th>1967 = 1.0</th>
<th>WLISTKPRD$_t$</th>
<th>LSTKPI$_t$</th>
<th>GCAU$_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979 value</td>
<td></td>
<td></td>
<td></td>
<td>17,804.9</td>
<td>2.62</td>
<td>81,966.0</td>
<td></td>
</tr>
<tr>
<td>CEDR$_{t+1}$</td>
<td>$/bu.$</td>
<td>1.0</td>
<td>0.0</td>
<td>-36.050</td>
<td>0.016</td>
<td>-266.511</td>
<td></td>
</tr>
<tr>
<td>WHEDR$_{t+1}$</td>
<td>$/bu.$</td>
<td>1.0</td>
<td>0.0</td>
<td>-0.296</td>
<td>0.000</td>
<td>-2.193</td>
<td></td>
</tr>
<tr>
<td>SFGGOV$_t$</td>
<td>MMT</td>
<td>1.0</td>
<td>25.2</td>
<td>-8.225</td>
<td>0.004</td>
<td>-60.805</td>
<td></td>
</tr>
<tr>
<td>SWGOV$_t$</td>
<td>MMT</td>
<td>1.0</td>
<td>12.3</td>
<td>-0.278</td>
<td>0.001</td>
<td>-2.057</td>
<td></td>
</tr>
<tr>
<td>CTPEEC$_t$</td>
<td>UQA$^b$</td>
<td>10.0</td>
<td>182.0</td>
<td>10.366</td>
<td>-0.005</td>
<td>70.663</td>
<td></td>
</tr>
<tr>
<td>CCOMEXP$_t$</td>
<td>MMT</td>
<td>1.0</td>
<td>8.3</td>
<td>19.101</td>
<td>-0.009</td>
<td>141.211</td>
<td></td>
</tr>
<tr>
<td>LPRDDEV$_t$</td>
<td>MMT</td>
<td>1,000.0</td>
<td>29,543.0</td>
<td>-32.185</td>
<td>0.014</td>
<td>-237.936</td>
<td></td>
</tr>
<tr>
<td>WSUPNUS$_t$</td>
<td>MMT</td>
<td>10.0</td>
<td>439.9</td>
<td>0.520</td>
<td>0.000</td>
<td>3.842</td>
<td></td>
</tr>
<tr>
<td>PRODFG$_t$</td>
<td>MMT</td>
<td>10.0</td>
<td>233.9</td>
<td>100.310</td>
<td>-0.046</td>
<td>762.217</td>
<td></td>
</tr>
<tr>
<td>PRODW$_t$</td>
<td>MMT</td>
<td>1.0</td>
<td>58.1</td>
<td>0.179</td>
<td>0.000</td>
<td>1.327</td>
<td></td>
</tr>
<tr>
<td>PCDI$_t$</td>
<td>$</td>
<td>100.0</td>
<td>8,551.0</td>
<td>-192.125</td>
<td>0.180</td>
<td>-63.547</td>
<td></td>
</tr>
<tr>
<td>SBPF$_t$</td>
<td>$/bu.$</td>
<td>1.0</td>
<td>6.28</td>
<td>-45.310</td>
<td>0.020</td>
<td>-334.965</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ Short-run or impact multipliers.
$^b$ European Community units of account.
Table 5.4. Effect of an exogenous demand increase in per capita disposable income$^a,b$

<table>
<thead>
<tr>
<th>Period</th>
<th>Wheat farm price $/bu.</th>
<th>Corn farm price $/bu.</th>
<th>Livestock price 1967 = 1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979 value</td>
<td>3.82</td>
<td>2.52</td>
<td>2.62</td>
</tr>
<tr>
<td>0</td>
<td>0.2729</td>
<td>0.2397</td>
<td>1.7976</td>
</tr>
<tr>
<td>1</td>
<td>0.0761</td>
<td>0.0457</td>
<td>0.0255</td>
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<tr>
<td>2</td>
<td>0.0416</td>
<td>0.0189</td>
<td>0.0123</td>
</tr>
<tr>
<td>3</td>
<td>0.0237</td>
<td>-0.0057</td>
<td>0.0048</td>
</tr>
<tr>
<td>4</td>
<td>0.0139</td>
<td>-0.0044</td>
<td>0.0016</td>
</tr>
<tr>
<td>5</td>
<td>0.0084</td>
<td>-0.0023</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

$^a$Per capita disposable income increases one thousand dollars.

$^b$Interim multipliers.
Simultaneity between next year's supply and this year's demand has interesting ramifications for grain market multipliers. For example, a 1 dollar increase in the incentive to divert wheat acreage decreases planted next year by 3.5 million acres and next year's production by 2.8 MMT. Thus, the incentive to hold commercial inventories through the current crop year increases causing the current wheat prices to rise 0.17 dollars per bushel, which depresses other current demand components. A similar impact can be seen on the feed grain market when the corn effective diversion rate is increased. When government stocks of wheat are raised 1 MMT total carryover is enhanced .46 MMT and wheat price is raised .16 dollars per bushel. Since current price is raised, next year's production rises .14 MMT while domestic utilization and commercial exports fall .15 and .31 MMT, respectively. A 1 MMT increase in government feed grain stocks has a similar but smaller impact on corn price of .02 dollars per bushel. This is partly explained by the larger size of the feed grain to the domestic livestock market. An increase in government feed grain stocks pulls up both livestock (0.004) and corn prices, since animals units fed falls as corn price rises by 61 thousand units. Increases in exogenous substitute prices (soybeans and rice) increase current feed grain and wheat prices .13 and .27 dollars per bushel, respectively.

Dynamics

The dynamic properties of the model are presented in Table 5.4 for an exogenous increase of $1,000 per capita disposable income.
The effects of this one year disturbance on each period is given by the interim multipliers, as described in Equation 5.4. Examination of Table 5.4 suggests that the model is stable as price fluctuations in all three price variables diminish over time.
CHAPTER VI. STOCHASTIC SIMULATIONS

A major purpose of this study is to simulate instability in the U.S. grain and livestock sector which is likely to come about in the 1980s under alternative grain policy scenarios. Stochastic simulations of the econometric model over 1981-90 are evaluated to achieve this purpose. Based on the discussion in Chapter I, the sources of market instability are fluctuations in domestic crop yields and in U.S. grain exports. Thus, the joint probability distribution of these variables must be estimated in order to perform the stochastic simulations. Also, values for the remaining exogenous variables must be determined to solve the model over the future period. These variables can be broken down into grain policy instruments and others. Grain policy management "rules" are used to endogenize the grain policy instruments under a given policy scenario. Finally, the remaining exogenous variables must be projected over the future period in a realistic manner.

Stochastic Variables

Domestic crop yields of wheat, corn, grain sorghum, barley, and oats and U.S. exports of wheat and feed grain are stochastic variables for the simulation experiments. Domestic crop yields are likely to be correlated for two reasons: (1) Technological improvement in U.S. agricultural production over the historical sample period (1954-79) has caused yields of each crop to increase over time and (2), in any given year, weather effects are likely to cause yield deviations from trend to be correlated.
Variability among domestic crop yields is modeled in the following fashion (Chowdhury and Heady, 1980):

\[ Y = B \mathbf{X} + \mathbf{U} \]  

(6.1)

where

\[ \begin{bmatrix} YLD \\ YLDG_{t} \\ YLDO_{t} \\ YLDB_{t} \\ YLDW_{t} \end{bmatrix} = \begin{bmatrix} 1 \\ T_{t} \\ T_{t}^2 \end{bmatrix} \begin{bmatrix} \text{Matrix of } \ U_{ct} \\ \text{intercepts and } U_{st} \\ \text{slopes } U_{ot} \end{bmatrix} \begin{bmatrix} U_{ct} \\ U_{st} \\ U_{ot} \end{bmatrix}. \]

\[ \mathbf{Y} = \mathbf{X} \mathbf{B} \]

(6.2)

Therefore, \[ \hat{\mathbf{U}} = \mathbf{Y} - \hat{\mathbf{Y}} \]

\[ = \mathbf{Y} - \hat{\mathbf{B}} \mathbf{X} \]

(6.3)

where \( \hat{\mathbf{Y}}, \hat{\mathbf{U}}, \) and \( \hat{\mathbf{B}} \) are estimates of \( \mathbf{Y}, \mathbf{U}, \) and \( \mathbf{B}, \) respectively. From the estimated residuals, vector \( \hat{\mathbf{U}}, \) the following variance-covariance matrix \( \hat{\Omega} \) is constructed:
\[ \Omega = \begin{bmatrix} \hat{\sigma}_{c}^2 & \hat{\sigma}_{cs} & \hat{\sigma}_{co} & \hat{\sigma}_{cb} & \hat{\sigma}_{cw} \\ \hat{\sigma}_{sc} & \hat{\sigma}_{s}^2 & \hat{\sigma}_{so} & \hat{\sigma}_{sb} & \hat{\sigma}_{sw} \\ \hat{\sigma}_{oc} & \hat{\sigma}_{os} & \hat{\sigma}_{o}^2 & \hat{\sigma}_{ob} & \hat{\sigma}_{ow} \\ \hat{\sigma}_{bc} & \hat{\sigma}_{bs} & \hat{\sigma}_{bo} & \hat{\sigma}_{b}^2 & \hat{\sigma}_{bw} \\ \hat{\sigma}_{wc} & \hat{\sigma}_{ws} & \hat{\sigma}_{wo} & \hat{\sigma}_{wb} & \hat{\sigma}_{w}^2 \end{bmatrix} \tag{6.4} \]

where \( \hat{\sigma}_{i}^2 \) is the estimated variance of the ith crop; \( \hat{\sigma}_{ij} \) is the estimated covariance between ith and jth crop; and c, s, o, b, and w denote corn, grain sorghum, oats, barley, and wheat, respectively. Now a set of random numbers \( \delta \) is generated by using the NORMAL function of SAS (Barr et al., 1979) such that

\[ \delta \sim N(0, I) \quad \text{where} \quad I = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{6.5} \]

Thus, an assumption of normality is made in generating random numbers. These generated random numbers are then used to calculate a set of residual terms \( \tilde{U} \) following the probability distribution of \( U \). Thus, the probability distribution of estimated residuals \( \tilde{U} \) is used to generate \( \tilde{U} \) such that

\[ \tilde{U} \xrightarrow{\text{N}(0, \Omega)} \text{N}(0, \Omega) \quad \text{U} \sim \text{N}(0, \Omega) \tag{6.6} \]

where \( n \) is the number of observations.

From each generated random number, one normal deviate is computed. A matrix of normal deviates \( \tilde{U} \) is thus generated from a set of random numbers by using the following relationship:
\( \bar{U} = \emptyset \delta \) \hspace{1cm} (6.7)

such that \( E(\emptyset \delta^t \emptyset^t) = \Omega \)

or \( \emptyset E(\delta \delta^t) \emptyset^t = \hat{\Omega} \)

or \( \hat{\Omega} = \emptyset \emptyset^t \) (since \( \delta \sim \mathcal{N}(0, I) \))

Matrix \( \emptyset \) is upper triangular and is multiplied with the matrix of generated random numbers \( \delta \) to develop the matrix of \( \bar{U} \) of the size 5xp; where 5 is for the five crops considered in this study and p is the total number of generated random numbers for each crop in a particular crop year. Finally, a matrix of yields \( \bar{Y} \) of size 5xp is generated using the following relationship:

\[
\bar{Y} = \hat{\delta} X K + \bar{U} \hspace{1cm} (6.8)
\]

where \( K \) is row sum vector of size \( p \). These generated yields capture the effects of production of one crop on another under the only restriction that \( \bar{Y} \) would follow the probability distribution of the actual \( Y \).

A matrix of 5xp yields are independently generated for each year of the future simulation (1981-90) by a unique set of random numbers \( \delta \) for each crop year. Thus, disturbance terms in the yield equations are not autocorrelated. The SUR results are presented below:

\[
Y_{LDC_t} = 34.021 + 2.798 T_t - 0.033 T_t^2 \hspace{1cm} (6.9)
(8.719) \hspace{0.5cm} (4.201) \hspace{0.5cm} (1.369)
\]

\[
Y_{LDS_t} = 10.118 + 3.504 T_t - 0.089 T_t^2 \hspace{1cm} (6.10)
(3.321) \hspace{0.5cm} (6.739) \hspace{0.5cm} (4.773)
\]

\[
Y_{LDB_t} = 21.873 + 1.373 T_t - 0.022 T_t^2 \hspace{1cm} (6.11)
(11.408) \hspace{0.5cm} (4.194) \hspace{0.5cm} (1.834)
\]
\[ \text{YLDQ}_t = 27.997 + 1.131 T_t - 0.033 T_t^2 \]  
\( (14.628) \quad (3.463) \quad (2.773) \)  
\[ \text{YLDW}_t = 17.095 + 0.806 T_t - 0.014 T_t^2 \]  
\( (12.897) \quad (3.564) \quad (1.701) \)

SUR: 1954-79  
WMSE = 1.130\(^1\)  
WR\(^2\) = 0.670\(^2\)

The estimated variance-covariance matrix is

\[ \hat{\Omega}_1 = \begin{bmatrix} 
\text{Corn} & \text{Sorghum} & \text{Barley} & \text{Oats} & \text{Wheat} \\
33.221 & 18.408 & 8.672 & 3.121 & 2.636 \\
18.408 & 20.250 & 3.008 & 4.631 & 3.590 \\
8.672 & 3.008 & 8.022 & 3.934 & 1.339 \\
3.121 & 4.631 & 3.934 & 7.993 & 2.115 \\
2.639 & 3.590 & 1.339 & 2.115 & 3.834 
\end{bmatrix} \]

In any given year, deviations in trend\(^3\) U.S. wheat and feed grain exports are also likely to be correlated due to weather and other stochastic factors. The export equations were estimated using three-stage least squares (3SLS).

Given the variance-covariance matrix of disturbance terms from 3SLS estimates of U.S. commercial exports of wheat and feed grain (Equations 3.18 and 3.31 in Chapter III) the joint probability distribution of export deviations from trend is also determined. The estimated variance-covariance matrix from 3.18 and 3.31 is

\(^1\)Weighted mean square error for the system.

\(^2\)Weighted R\(^2\) for the system.

\(^3\)In this case, trend exports are determined by the behavioral equations of the model.
Using \( \Omega \) and following the procedure outlined in 6.5-6.7, a set of error terms is generated for a given crop year for U.S. wheat and feed grain exports. Thus, a set of \( p \) supply and demand shocks is generated for each year of the future simulation. In order to save computer funds \( p=20 \). Thus, 80 simulations of the model are required to represent four policy alternatives.

Grain Policy Instruments

For the stochastic simulations, loan rates, diversion or set-aside incentives, government stocks, and food aid levels must be endogenized to represent each grain policy alternative. Rules governing the setting of these policy instruments are discussed for each policy simulation.

Policy Alternative I: Continuation of the present grain policy complex

Policy Alternative I is designed to represent continuation of U.S. grain policy management strategy employed since 1977 as described in Chapter I. Carryover stocks of wheat and feed grain in the farmer-owned reserve (FOR) are truly endogenous in the grain markets in that farmer participation is voluntary and depends on current price and program provisions. Linear approximations of farmer response to the FOR are calculated using actual real prices and quantities from the
1977-80 period (Table 6.1). Meyers, Womak, and Bredahl (1981) initially postulated linear relationships for ending FOR stocks ($\text{SFOR}_t$) and current price ($P_t$) by assuming the net annual change in reserves ($\text{SFOR}_t - \text{SFOR}_{t-1}$) equal zero when current price equals the FOR release price ($P_t = PR_t$). The point so defined and the point of equilibrium price ($P_t$) and equilibrium quantity ($\text{SFOR}_t$) determine a linear function. Based on this methodology, linear coefficients are computed for each year for the function $\text{SFOR}_t = f(P_t)$ for both wheat and feed grain. The data and equations are given in Table 6.1. Substantial differences exist between the annual functions for the same commodity which reflect changes in program provisions over time. The "average" intercept and slope are computed from each group of four equations to represent farmer response, on average, over the 1977-80 period for wheat and feed grain. FOR response functions for wheat and feed grain used in Policy Alternative I are

\[
\text{SWFOR}_t = 42.97 - 21.24*\frac{\text{CPF}_t}{\text{CPILF}_t} \quad [3.77] \\
\text{SFGFOR} = 60.23 - 42.84*\frac{\text{CPF}_t}{\text{CPILF}_t} \quad [3.77]
\]

Numbers in brackets are elasticities based on mean values over the 1977-80 period. The elasticities suggest that demand for reserves held by farmers are quite elastic with respect to current price. Limitations on size of FOR accumulations are not imposed in this policy alternative. Under the 1977 legislation, the Secretary of Agriculture can place size
Table 6.1. Data and coefficients for linear FOR functions

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Crop year</th>
<th>(PR^b_t, SFOR^c_{t-1})</th>
<th>(P^c_t, SFOR^d_t)</th>
<th>Intercept</th>
<th>Slope</th>
<th>Elasticity^e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>1977</td>
<td>(1.77,0)</td>
<td>(1.31,9.3)</td>
<td>35.78</td>
<td>-20.22</td>
<td>2.85</td>
</tr>
<tr>
<td></td>
<td>1978</td>
<td>(1.72,9.3)</td>
<td>(1.56,10.7)</td>
<td>24.35</td>
<td>-8.75</td>
<td>1.28</td>
</tr>
<tr>
<td></td>
<td>1979</td>
<td>(1.64,10.7)</td>
<td>(1.79,6.8)</td>
<td>53.34</td>
<td>-26.00</td>
<td>6.84</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>(1.72,6.8)</td>
<td>(1.62,9.8)</td>
<td>58.40</td>
<td>-30.00</td>
<td>4.96</td>
</tr>
<tr>
<td>Feed grain</td>
<td>1977</td>
<td>(1.31,0)</td>
<td>(1.06,10.2)</td>
<td>53.45</td>
<td>-40.80</td>
<td>4.21</td>
</tr>
<tr>
<td></td>
<td>1978</td>
<td>(1.17,10.2)</td>
<td>(0.99,16.4)</td>
<td>50.50</td>
<td>-34.44</td>
<td>2.05</td>
</tr>
<tr>
<td></td>
<td>1979</td>
<td>(1.08,16.4)</td>
<td>(1.03,17.5)</td>
<td>40.16</td>
<td>-22.00</td>
<td>1.44</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>(1.07,17.5)</td>
<td>(1.24,4.9)</td>
<td>96.80</td>
<td>-74.12</td>
<td>18.28</td>
</tr>
</tbody>
</table>

^Source: (USDA, 1982c).

^Release price (deflated by the consumer price index less food items, 1967=1.0).

^Price received by farmers (deflated by the consumer price index less food items, 1967=1.0).

^Carryover FOR stocks (million metric tons).

^Evaluated at \((P_t, SFOR_t)\) for crop year \(t\).
limits on the FOR but they must be larger than legislated minimums (Sharples, 1980). In practice, such minimums have not been set.

After FOR stocks, CCC owned stocks are the second line of defence against price variability. It is assumed here that the government does not accumulate CCC stocks when prices are low. This could happen if large numbers of farmers default on their nine month CCC loans as did happen in the 1950s and 1960s. However, such accumulations have not occurred since the advent of the FOR in 1977. CCC stocks are released at 180 percent and 145 percent of the loan rates for wheat and corn, respectively. Once these stocks are released, they are no longer available for future periods. If they are not released, they are carried over into the next period in the simulation.

For the purpose of the future simulations, effective support rates and loan rates are one and the same. Loan rates for any given crop year are assumed to equal a five-year moving average of past nominal prices. While this is not the actual formula used to set loan rates, it does reflect the price corridor strategy of post-1977 grains policy described in Chapter I. Thus, loan rates remain below current market prices and adjust slowly over time with the long-run equilibrium price trend.

Rules which endogenize the set-aside decision on a year-to-year basis, embody the Carter Administration's set-aside decision rule. The Carter Administration adopted "desired" levels of total wheat and feed grain carryover to equal 6.75 and 7.50 percent of expected world utilization of feed grain (EWRDTFGU_\_t) and wheat (EWRDTWU_\_t), respectively.
(Sharples, 1980). These desired levels of grain carryover are considered to be enough to meet export and emergency aid commitments. If total actual carryover is greater than desired levels, a set-aside is imposed. This rule is adopted in Policy Alternative I; however, total beginning stocks are used instead of ending stocks to aid model convergence. Thus, if beginning stocks in crop year $t$ are greater than the desired level, a set-aside is imposed on spring plantings (still in $t$) which determine production for $t+1$. When a set-aside is imposed, the effective diversion rates for wheat, corn and grain sorghum are set equal to the real values of $\text{WHEDR}_{t+1}$, $\text{CEDR}_{t+1}$, and $\text{GSDR}_{t+1}$ in 1978. Thus, the model represents incentives to idle land inherent in the 1979 set-aside for wheat and feed grains.

**Policy Alternative II: Free market**

Policy Alternative II is designed to represent conditions in the U.S. grain and livestock sector which would arise if all commodity programs were ended at the beginning of the 1981 crop year. Set-aside authority is ended in this alternative. The actual FOR stocks held at the beginning of 1981 are included in commercial stocks as if the reserve program were simply ended in 1981. CCC stocks follow the same release rule described in Policy Alternative I. Loan rates are replaced with lagged market price, with the exception of cotton. The cotton loan rate ($\text{COTESP}_{t+1}$) appears as a substitute price in the wheat and grain sorghum acreage equations. The projected values of the cotton loan rate for 1981-90 serve as a proxy for lagged cotton market price.
Policy Alternative III: Replacement of the farmer-owned grain reserve with a simple subsidy to private storage at any price

This policy change has been advocated as a way to improve U.S. grain reserve policy. In the model, this policy change is adopted by subtracting the real value of the annual per bushel FOR storage subsidy from farm price in the commercial carryover equations. The storage subsidy was 26.5 cents per bushel from 1977-80 for both wheat and feed grain. The real value of this storage subsidy in 1981 is maintained throughout the future period. Other instruments are set in the same fashion as in Policy Alternative I, with the exception of FOR stocks which are simply added to private carryover in 1981 at the start of the future simulation.

Policy Alternative IV: Discontinuation of set-aside authority

Policy Alternative IV is designed to represent a continuation of U.S. grain policy management strategy employed since 1977, with the exception of authority to implement acreage set-asides. Thus, all effective diversion rates are set to zero under this alternative.

Projection of Other Exogenous Variables

The remaining exogenous variables of the model are projected over the 1981-90 period using a combination of time series and trend methods. Projected values of exogenous variables are contained in Appendix B. A number of the variables are projected using the FORECAST procedure of SAS/ETS (SAS, 1980). The variable WPONUS is projected.
using 1954–79 data. The variables $\text{EWRDTWU}_t$, $\text{EWRDTFGU}_t$, $\text{RPHOU}_t$, $\text{SWUPNUS}_t$, $\text{RFC}_t$, and $\text{LPRDDEV}_t$ are projected using 1960–79 data. The variables $\text{VCC}_{t+1}$, $\text{VCSB}_{t+1}$, $\text{SBPF}_t$, and $\text{SBMP}_t$ are projected based on 1965–79 data. Real per capita disposable income ($\text{PCDI}_t/\text{CPILF}_t$) is assumed to grow 1.74 percent per year over 1981–90. This matches real income growth over the 1970s. Supply and demand side price deflators $\text{IPPF}_t$ and $\text{CPILF}_t$, respectively, are assumed to increase 7.7 percent per year over the future period. This growth rate matches the 1970–79 growth rate in $\text{CPILF}_t$ and the 1965–79 growth rate in $\text{IPPF}_{t+1}$. The $\text{CPILF}_t$ deflator is used to present simulation results of all nominal variables in real terms. Export subsidies on U.S. wheat ($\text{WES}_t$) and rice ($\text{RES}_t$) commercial exports are set equal to zero for 1981–90. Food aid levels of wheat and feed grain are set equal to their average volume over 1975–79. The exchange rate measures ($\text{WTWVDOL}_t$ and $\text{CTWVDOL}_t$) are highly volatile and difficult to predict over such a lengthy forecast period. They are both set equal to their average values over 1975–79. Finally, the soybean effective support rate ($\text{SBESP}_{t+1}$) is assumed to equal 70 percent of the exogenous soybean price. The cotton effective support rate ($\text{COTESP}_{t+1}$) is assumed to match increases in the index of prices paid by farmers ($\text{IPPF}_{t+1}$).

Base Simulation

A base simulation of the model is performed prior to the stochastic simulations under the various policy scenarios. The base  

\footnote{The CTPEEC variable is projected based on 1962–79 data.}
simulation is nonstochastic and is used to assess the "reasonableness" of model results given projections of the exogenous variables.

For the base simulation, exogenous variables take on values presented in Appendix B. The linear FOR functions presented in equations 6.16 and 6.17 are used to simulate aggregate response to the farmer-owned reserve. CCC stocks are left exogenous at their 1980 actual values of 5.3 and 7.1 MMT for wheat and feed grain, respectively. Also, rules for set-aside implementation are left out of the base. Thus, effective diversion rate variables take on zero values throughout the simulation.

Initial attempts at a reasonable base suggest the need for minor fine tuning of the model. Initially, wheat acreage is projected to be well below levels of the 1970s, even at similar prices. This is consistent with under-prediction of wheat acreage in the latter 1970s (Chapter IV). This problem is handled by increasing the intercept in the wheat average equation to add 6.0 million acres per year. Also in preliminary runs of the model, barley planted acreage tends to fall radically over the future period, apparently due to relationships between the feed grain yield functions. Yields, it should be remembered, are functions of linear and quadratic time trends. More reasonable results are obtained when a lower bound of 6.0 million acres per year is set for barley planted acreage. The linear and quadratic time trends in the wheat and minor feed grain yield equations are held at their 1981 values \( T_{1981} = 28 \) over the entire future period. This
adjustment allows mean yields of these crops to avoid falling over the future period (Appendix B).

Values of the endogenous variables obtained from the base simulation are presented in Table 6.2. Prices of wheat, corn, and livestock are presented in nominal and 1967 constant dollars (deflated by CPILF). Wheat and corn prices rise substantially in nominal terms, but are essentially flat in real terms over the 1980s. Wheat prices actually fall 12.7 percent in real terms over 1981-90 while real corn prices rise 8.9 percent. Real livestock prices rise 42.0 percent or 3.9 percent per year.

Wheat production expands only 0.3 percent per year from 62.9 to 64.5 MMT due to flat yields and real prices over the decade. Wheat utilization expands somewhat faster than production at 1.1 percent per year, but not enough to generate an increase in real wheat prices. Wheat FOR carryover ranges from 15.9 to 2.22 MMT. In general, FOR carryover remains somewhat below the legislated minimum ceiling of 20.4 MMT (750 million bushels).

Feed grain production expands 1.1 percent per year, from 208.9 to 230.0 MMT, due to increases in real corn prices and yields. Feed grain utilization increases 1.2 percent per year generating corn price increases. Feed grain FOR carryover ranges from 22.5 to 26.8 MMT. As with wheat, feed grain FOR carryover generally remains below the legislated minimum ceiling of 25.4 MMT (1.0 billion bushels).
Table 6.2. Values of the endogenous variables from the base simulation, 1981-90

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<tr>
<td>FWPA_{t+1}</td>
<td>80.627</td>
<td>76.624</td>
<td>75.154</td>
<td>75.219</td>
<td>76.123</td>
<td>77.425</td>
<td>78.842</td>
<td>80.205</td>
<td>81.465</td>
<td>82.618</td>
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<td>(million bushels)</td>
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<td></td>
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<td></td>
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<tr>
<td>PRODW_{t+1}</td>
<td>62.948</td>
<td>59.823</td>
<td>58.675</td>
<td>58.726</td>
<td>59.432</td>
<td>60.448</td>
<td>61.554</td>
<td>62.619</td>
<td>63.603</td>
<td>64.502</td>
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<tr>
<td>CEW_t</td>
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<td>33.090</td>
<td>33.774</td>
<td>34.004</td>
<td>34.042</td>
<td>34.042</td>
<td>34.127</td>
<td>34.397</td>
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<tr>
<td>WPF_t</td>
<td>3.35</td>
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<td>2.99</td>
<td>3.32</td>
<td>3.78</td>
<td>4.28</td>
<td>4.75</td>
<td>5.11</td>
<td>5.41</td>
<td>5.68</td>
</tr>
<tr>
<td>(dollars/bushel)</td>
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^aNominal dollars.
Table 6.2 (continued)

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<tbody>
<tr>
<td>WPP&lt;sub&gt;t&lt;/sub&gt; b (dollars/bushel)</td>
<td>1.18</td>
<td>0.98</td>
<td>0.91</td>
<td>0.94</td>
<td>0.99</td>
<td>1.04</td>
<td>1.08</td>
<td>1.07</td>
<td>1.06</td>
<td>1.03</td>
</tr>
<tr>
<td>CPA&lt;sub&gt;t+1&lt;/sub&gt; (million acres)</td>
<td>83.037</td>
<td>82.654</td>
<td>82.133</td>
<td>81.830</td>
<td>81.178</td>
<td>82.05</td>
<td>83.660</td>
<td>84.444</td>
<td>85.349</td>
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<tr>
<td>BPA&lt;sub&gt;t+1&lt;/sub&gt; (million acres)</td>
<td>7.951</td>
<td>7.406</td>
<td>6.939</td>
<td>6.468</td>
<td>6.000</td>
<td>6.000</td>
<td>6.000</td>
<td>6.000</td>
<td>6.000</td>
<td>6.000</td>
</tr>
<tr>
<td>PRODFG&lt;sub&gt;t+1&lt;/sub&gt; (MMT)</td>
<td>208.899</td>
<td>213.656</td>
<td>215.562</td>
<td>216.639</td>
<td>215.867</td>
<td>218.719</td>
<td>221.645</td>
<td>224.505</td>
<td>227.132</td>
<td>230.026</td>
</tr>
<tr>
<td>SFG&lt;sub&gt;t&lt;/sub&gt; (MMT)</td>
<td>28.287</td>
<td>27.651</td>
<td>28.238</td>
<td>28.023</td>
<td>28.443</td>
<td>27.513</td>
<td>27.391</td>
<td>27.271</td>
<td>27.335</td>
<td>27.231</td>
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<sup>b</sup>Constant 1967 dollars.
Table 6.2 (continued)

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<td>DFEEDFG&lt;sub&gt;t&lt;/sub&gt; (MMT)</td>
<td>127.101</td>
<td>127.633</td>
<td>125.452</td>
<td>126.907</td>
<td>126.224</td>
<td>127.144</td>
<td>125.036</td>
<td>125.868</td>
<td>126.662</td>
<td>127.773</td>
</tr>
<tr>
<td>CEGF&lt;sub&gt;t&lt;/sub&gt; (MMT)</td>
<td>62.872</td>
<td>63.899</td>
<td>67.790</td>
<td>68.754</td>
<td>69.439</td>
<td>70.553</td>
<td>72.854</td>
<td>74.262</td>
<td>75.534</td>
<td>77.125</td>
</tr>
<tr>
<td>CPF&lt;sub&gt;t&lt;/sub&gt;&lt;sup&gt;a&lt;/sup&gt; (dollars/bushel)</td>
<td>2.21</td>
<td>2.67</td>
<td>2.72</td>
<td>3.01</td>
<td>3.15</td>
<td>3.61</td>
<td>3.85</td>
<td>4.13</td>
<td>4.37</td>
<td>4.67</td>
</tr>
<tr>
<td>CPF&lt;sub&gt;t&lt;/sub&gt;&lt;sup&gt;b&lt;/sup&gt; (dollars/bushel)</td>
<td>0.78</td>
<td>0.88</td>
<td>0.83</td>
<td>0.85</td>
<td>0.83</td>
<td>0.88</td>
<td>0.87</td>
<td>0.87</td>
<td>0.85</td>
<td>0.85</td>
</tr>
<tr>
<td>OPF&lt;sub&gt;t&lt;/sub&gt;&lt;sup&gt;a&lt;/sup&gt; (dollars/bushel)</td>
<td>1.25</td>
<td>1.48</td>
<td>1.52</td>
<td>1.68</td>
<td>1.77</td>
<td>2.00</td>
<td>2.14</td>
<td>2.29</td>
<td>2.43</td>
<td>2.61</td>
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</tr>
<tr>
<td>BPF&lt;sub&gt;a&lt;/sub&gt;&lt;sup&gt;t&lt;/sup&gt; (dollars/bushel)</td>
<td>2.05</td>
<td>2.48</td>
<td>2.55</td>
<td>2.83</td>
<td>2.99</td>
<td>3.41</td>
<td>3.64</td>
<td>3.91</td>
<td>4.14</td>
<td>4.44</td>
</tr>
<tr>
<td>GSPF&lt;sub&gt;a&lt;/sub&gt;&lt;sup&gt;t&lt;/sup&gt; (dollars/bushel)</td>
<td>2.24</td>
<td>2.60</td>
<td>2.63</td>
<td>2.89</td>
<td>3.02</td>
<td>3.43</td>
<td>3.66</td>
<td>3.93</td>
<td>4.16</td>
<td>4.49</td>
</tr>
<tr>
<td>WLSTKPRD&lt;sub&gt;t&lt;/sub&gt; (million pounds)</td>
<td>21097.4</td>
<td>20018.2</td>
<td>21152.7</td>
<td>20828.6</td>
<td>21486.8</td>
<td>21327.4</td>
<td>218897.4</td>
<td>22025.0</td>
<td>22360.7</td>
<td>22566.0</td>
</tr>
<tr>
<td>GCAU&lt;sub&gt;t&lt;/sub&gt; (thousand units)</td>
<td>80169.4</td>
<td>80655.7</td>
<td>80324.1</td>
<td>80759.2</td>
<td>80802.0</td>
<td>81300.2</td>
<td>81150.8</td>
<td>81385.8</td>
<td>81669.5</td>
<td>82052.6</td>
</tr>
<tr>
<td>LSTKPI&lt;sub&gt;a&lt;/sub&gt;&lt;sup&gt;t&lt;/sup&gt;</td>
<td>1.989</td>
<td>2.918</td>
<td>2.660</td>
<td>3.289</td>
<td>2.320</td>
<td>4.108</td>
<td>4.081</td>
<td>4.595</td>
<td>4.974</td>
<td>5.524</td>
</tr>
<tr>
<td>LSTKPI&lt;sub&gt;b&lt;/sub&gt;&lt;sup&gt;t&lt;/sup&gt;</td>
<td>1967=1.0</td>
<td>0.703</td>
<td>0.957</td>
<td>0.810</td>
<td>0.930</td>
<td>0.872</td>
<td>1.002</td>
<td>0.924</td>
<td>0.966</td>
<td>0.971</td>
</tr>
<tr>
<td>LSTKPI&lt;sub&gt;c&lt;/sub&gt;&lt;sup&gt;t&lt;/sup&gt;</td>
<td>1967=1.0</td>
<td>0.703</td>
<td>0.957</td>
<td>0.810</td>
<td>0.930</td>
<td>0.872</td>
<td>1.002</td>
<td>0.924</td>
<td>0.966</td>
<td>0.971</td>
</tr>
</tbody>
</table>
Livestock production expands 0.7 percent per year. This is somewhat below annual increase in per capita disposable income, thus, real increases in livestock price are generated.

Stochastic Simulations

Each policy alternative consists of 20 stochastic solutions of the model (Figure 6.1). Randomly generated error terms enter current grain production relations and current period commercial exports. Expected production is generated using mean yields for t+1 as presented in Appendix B. Tables 6.3-6.5 present computed mean and standard deviation of each price in real terms for each crop year under each policy alternative (PA). Simulation results between policy alternatives are directly comparable with one another with one qualification. In the free market, alternative (PA II) 3 out of 20 solutions did not converge in 1981. Thus, mean and standard deviations of PA II are based on 17 observations. Also, PA IV results are based on 19 observations from 1985-87 and 18 observations from 1988-90 due to convergence problems.¹

Mean wheat prices generally follow each other fairly closely over the future period between policy alternatives. Initially, mean wheat prices are lower in the free market (PA II), commercial storage subsidy (PA III), and no set-asides (PA IV) alternatives than the current policy (PA I) alternative. This is caused by the dumping of existing FOR stocks on the market in PAs II and III and lack of wheat set-asides to support prices in PA IV.

¹Convergence problems in PA II and IV suggest that price variability, as measured by calculated standard deviations, is understated for these two policy alternatives.
Figure 6.1. Flow chart of stochastic simulations of the U.S. Grain and Livestock Sector Model: Continuation of current policy alternative

^Based on farmer-owned reserve linear response functions.
Table 6.3. Mean and standard deviation of wheat price under Policy Alternatives I-IV

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1981</td>
<td>1.13</td>
<td>0.60</td>
</tr>
<tr>
<td>1982</td>
<td>0.96</td>
<td>0.80</td>
</tr>
<tr>
<td>1983</td>
<td>0.95</td>
<td>1.13</td>
</tr>
<tr>
<td>1984</td>
<td>1.01</td>
<td>1.08</td>
</tr>
<tr>
<td>1985</td>
<td>1.19</td>
<td>1.35</td>
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<tr>
<td>1986</td>
<td>1.35</td>
<td>1.38</td>
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<tr>
<td>1987</td>
<td>1.35</td>
<td>1.38</td>
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<tr>
<td>1988</td>
<td>1.41</td>
<td>1.49</td>
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<tr>
<td>1989</td>
<td>1.31</td>
<td>1.33</td>
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<tr>
<td>1990</td>
<td>1.22</td>
<td>1.29</td>
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</tbody>
</table>

<sup>a</sup>Based on 18 observations.

<sup>b</sup>Based on 19 observations for 1985-87 and 18 observations for 1988-90.
Table 6.4. Mean and standard deviation of corn price under Policy Alternatives I-IV

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II\textsuperscript{a}</td>
</tr>
<tr>
<td>1981</td>
<td>0.71</td>
<td>0.49</td>
</tr>
<tr>
<td>1982</td>
<td>0.87</td>
<td>0.97</td>
</tr>
<tr>
<td>1983</td>
<td>0.85</td>
<td>0.74</td>
</tr>
<tr>
<td>1984</td>
<td>0.88</td>
<td>0.82</td>
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<tr>
<td>1985</td>
<td>0.82</td>
<td>0.69</td>
</tr>
<tr>
<td>1986</td>
<td>0.81</td>
<td>0.75</td>
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<tr>
<td>1987</td>
<td>0.93</td>
<td>0.90</td>
</tr>
<tr>
<td>1988</td>
<td>0.93</td>
<td>0.80</td>
</tr>
<tr>
<td>1989</td>
<td>0.87</td>
<td>0.80</td>
</tr>
<tr>
<td>1990</td>
<td>0.87</td>
<td>0.85</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Based on 18 observations.

\textsuperscript{b}Based on 19 observations for 1985-87 and 18 observations for 1988-90.
Table 6.5. Mean and standard deviation of livestock price under Policy Alternative I-IV

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Mean</th>
<th></th>
<th></th>
<th></th>
<th>Standard deviation</th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II(^a)</td>
<td>III</td>
<td>IV(^b)</td>
<td></td>
<td>I</td>
<td>II(^a)</td>
<td>III</td>
</tr>
<tr>
<td>1981</td>
<td>0.69</td>
<td>0.66</td>
<td>0.66</td>
<td>0.69</td>
<td>0.016</td>
<td>0.021</td>
<td>0.021</td>
<td>0.016</td>
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<tr>
<td>1982</td>
<td>0.95</td>
<td>0.95</td>
<td>0.95</td>
<td>0.94</td>
<td>0.030</td>
<td>0.037</td>
<td>0.042</td>
<td>0.030</td>
</tr>
<tr>
<td>1983</td>
<td>0.81</td>
<td>0.80</td>
<td>0.82</td>
<td>0.80</td>
<td>0.031</td>
<td>0.028</td>
<td>0.037</td>
<td>0.032</td>
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<tr>
<td>1984</td>
<td>0.94</td>
<td>0.92</td>
<td>0.95</td>
<td>0.92</td>
<td>0.025</td>
<td>0.016</td>
<td>0.021</td>
<td>0.026</td>
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<tr>
<td>1985</td>
<td>0.87</td>
<td>0.85</td>
<td>0.89</td>
<td>0.86</td>
<td>0.023</td>
<td>0.033</td>
<td>0.026</td>
<td>0.023</td>
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<tr>
<td>1986</td>
<td>0.99</td>
<td>0.97</td>
<td>0.99</td>
<td>0.98</td>
<td>0.018</td>
<td>0.022</td>
<td>0.018</td>
<td>0.017</td>
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<tr>
<td>1987</td>
<td>0.93</td>
<td>0.92</td>
<td>0.95</td>
<td>0.92</td>
<td>0.019</td>
<td>0.022</td>
<td>0.022</td>
<td>0.020</td>
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<tr>
<td>1988</td>
<td>0.98</td>
<td>0.95</td>
<td>0.96</td>
<td>0.96</td>
<td>0.022</td>
<td>0.035</td>
<td>0.022</td>
<td>0.021</td>
</tr>
<tr>
<td>1989</td>
<td>0.98</td>
<td>0.96</td>
<td>0.98</td>
<td>0.90</td>
<td>0.026</td>
<td>0.031</td>
<td>0.033</td>
<td>0.025</td>
</tr>
<tr>
<td>1990</td>
<td>1.01</td>
<td>1.00</td>
<td>1.02</td>
<td>1.00</td>
<td>0.019</td>
<td>0.023</td>
<td>0.023</td>
<td>0.018</td>
</tr>
</tbody>
</table>

\(^a\)Based on 18 observations.

\(^b\)Based on 19 observations for 1985–87 and 18 observations for 1988–90.
Variability in annual real wheat prices as measured by the standard deviation averages 0.170 for PA I over 1981-90. In comparison, this figure is 0.732, 0.330, and 0.180 for PAs II, III, and IV, respectively. Wheat price variability, on the average, is over four times greater under the free market alternative (PA II) and two times greater under subsidized commercial storage (PA III) as compared to a continuation of current policy (PA I). Ending of set-aside authority (PA IV) has little effect on wheat price variability when compared to PA I.

Mean corn and livestock prices also follow each other quite closely over the future period between policy alternatives. However, substantial differences exist in price variability. The standard deviation of real corn and livestock prices average 0.143 and 0.023, respectively, for the continuation of current policy (PA I) alternative. In comparison, these figures are 0.198 and 0.027, 0.184 and 0.026, 0.140 and 0.023 for PAs II, III, and IV, respectively. Corn and livestock prices are presented together because of the fundamental relationship between feed grain and livestock markets which has been empirically demonstrated throughout this study.

A number of interesting points are revealed from the above figures. First, in all policy alternatives, wheat prices are substantially more variable than are corn prices. This is partly due to total wheat demand being more inelastic with respect to own price than total feed grain demand. Thus, equal shocks imposed on the wheat and feed grain markets result in larger wheat price fluctuations than corn price fluctuations. Also, the domestic livestock market serves as more of
a shock absorber for the feed grain market than the wheat market. For example, compare results from PA I and II. Wheat price variability increases over 300 percent in moving from a continuation of post-1977 grains policy to a free market situation. Corn price variability increases 38 percent between the same policy alternatives. Livestock price variability increases 17 percent between these policy alternatives. When the feed grain market is subjected to an exogenous increase in current supply or decrease in current demand, corn price is driven down, encouraging grain feeding through an expansion of grain-consuming animal units. Thus, the downward movement in corn price from the initial shock is cushioned. The expansion in current period animal units expands current livestock production and forces down equilibrium prices for finished animals. An opposite chain of events occurs with an exogenous current supply decrease or demand increase in the feed grain market. Since a large portion of total feed grain disappearance is utilized by the domestic livestock market, shocks to the feed grain market, and to a much lesser extent the wheat market, result in larger fluctuations in livestock price than would otherwise be the case. Thus, the domestic livestock market cushions corn price variability by absorbing exogenous shocks which result in increased livestock price variability.

A comparison of results between PA I and PA II suggest that commodity price volatility would increase substantially if commodity programs were scrapped. This is especially true of wheat prices. The mean levels of commodity prices differ very little between these
two alternatives (Figures 6.1-6-3). Thus, grain policy instruments as they have been managed since 1977 and as they have been represented in PA I appear to leave long-run equilibrium prices undisturbed while removing the peaks and valleys generated by random supply and demand shocks imposed on the grain markets.

However, increased price stability is achieved only through substantial cost in terms of government expenditures and government interference in markets. Wheat set-asides are implemented in 63 percent of the simulated conditions over the future period while feed grain set-asides are implemented 58 percent of the time under PA I and farmer-owned grain reserve carryover averages 15.80 and 23.68 MMT for wheat and feed grain, respectively.

Finally, some critics of the farmer-owned reserve program have suggested replacing the program with a simple subsidy to all commercial storage at any price. This alternative is represented in PA III. The annual storage subsidy is set equal to the average subsidy in real terms given to farmers in the FOR program over 1977-80. This preliminary analysis suggests that such a subsidy would result in significantly more price volatility than would exist under a continuation of the current FOR program. Price variability, on the average, increases 94 percent, 29 percent, and 13 percent for wheat, corn, and livestock, respectively, in moving from PA I to PA III. The FOR, as embodied by the linear response functions, add more to the total elasticity of demand for grains than does the subsidy to commercial storage.
However, this is not a strict test of these alternative approaches to government stockpiling. The FOR interest waiver (see Chapter I) encourages farmer participation at prices below the release level. However, this storage incentive is not captured in PA III.
Figure 6.1. Mean and standard deviation of real wheat price from free market (PA II) and current policy (PA I) alternatives.
Figure 6.2. Mean and standard deviation of real corn price from free market (PA II) and current policy (PA I) alternative
Figure 6.3. Mean and standard deviation of aggregate real livestock price market (PA II) and current policy (PA I) alternatives.
CHAPTER VII. SUMMARY

The purpose of this study has been to evaluate post-1977 U.S. grains policy and several proposed alternatives in the context of U.S. and world grain market conditions which are likely to exist in the 1980s. A structural econometric model of the U.S. wheat, feed grain, and livestock markets has been conceptualized and estimated as the basic tool for policy evaluation. In development of the model, emphasis has been given to capturing the historical influence of loan rates, diversion incentives, government stocks, export subsidies, and food aid on the structure and price dynamics of these interrelated markets. The model has focused on explaining movement of equilibrium prices and quantities on a year-to-year basis. Multiplier analysis is used to assess the impact of grain policy instruments on market structure, to examine the relationship between grain and livestock markets, and to analyze dynamic price behavior.

Price instability in the U.S. grain and livestock sector, resulting from potential fluctuations in domestic crop yields and demand for U.S. grain exports over 1981-90, is simulated for four alternative representations of U.S. grains policy. The policy alternatives examined are a continuation of post-1977 grains policy and management strategy (PA I); elimination of grain policy programs (PA II); replacement of the existing farmer-owned reserve program (FOR) with an FOR equivalent subsidy to private commercial storage at any price (PA III); and continuation of post-1977 grains policy without authority to implement acreage set-aside or diversion programs (PA IV).
Alternative policy scenarios can be realistically compared and thus evaluated only from a multi-objective standpoint. Sharples (1980) has enumerated major grain policy objectives as increased grain and livestock price stability (1); protection of farmers from unusually low income years (2); reduction of stress on the federal budget (3); reduction of the role of government in agriculture (4); concern about the ability of the U.S. to respond to emergency needs of grain at home and abroad (5); and assurance that there will be adequate stocks to meet export commitments (6).

The present study is only a partial evaluation of the simulated policy alternatives in that primary emphasis is given to their impact on price instability. However, this objective is one of the most, if not most, important objectives of the six listed because grain price instability has increased so dramatically during the 1970s and because price instability is difficult to quantify.

For the purpose of this study, instability in U.S. grain and livestock farm level prices is defined as originating from nonsystematic or stochastic factors such as weather impacts on domestic crop yields and deviations in trend exports due to weather or other foreign influences. These two sets of factors are not the only stochastic factors which affect the U.S. grain livestock sector over time, but they are the most important.

This study begins with a review of the economic and institutional setting in the U.S. grain markets over the historical sample period (1954–79) in order to provide the basis for a realistic econometric
model. Several major conclusions are derived from conceptualization and estimation of the model.

Estimated elasticities of planted acreage to own price (in real terms) range from .098 in wheat to .193 in grain sorghum. In general, acreage response to price is relatively inelastic. These results are consistent with earlier studies (Houck, 1976 and Gallagher, 1978). Acreage reduction programs, as embodied in effective diversion rates, are significant factors in explaining historical wheat, corn, and grain sorghum planted acreage. Commercial carryover stocks for wheat and feed grain are significantly influenced by lagged commercial stocks, current production, production next year, current price, and government carryover (FOR and CCC carryover stocks). Empirical results suggest that a 1 bushel increase in government carryover displaces commercial carryover .242 and .259 bushels for wheat and feed grain, respectively. This result suggests increases in government carryover of, for example, 10 MMT, increase total carryover approximately 7.5 MMT. Thus, government stock activities have historically influenced market price for grain and livestock by enhancing total carryover. Impact multiplier analysis indicated that a 1 MMT increase in government wheat and feed grain carryover increases current wheat and corn farm prices .16 and .02 dollars per bushel, respectively. Such increases also increase current livestock price .001 and .004 ($P_{1979} = 2.620$), respectively. Thus, while government feed grain carryover has less influence on corn prices than government wheat carryover on wheat prices, the former has a much greater impact on livestock prices.
The estimated elasticity of U.S. feed grain exports with respect to U.S. corn price is .346. This is virtually identical with the estimated price elasticity of U.S. corn exports found by Bredahl, Womack, and Matthews (1978). In this study, the estimated elasticity of U.S. wheat exports with respect to wheat price paid by foreign importers \((WPF_t - WES_t) \times WTWVDOL_t\) is .143. This is less elastic than other studies, for example, Gallagher et al. (1981, pp. 104). This is due partly to the role of the exchange rate \(WTWVDOL_t\). This is a better measure of the exchange rate which reflects the value of the U.S. dollar in terms of currencies from the developing world which imports the bulk of U.S. wheat exports. Other studies typically use the SDR rate which will bias the elasticity upward (Table 2.3). The three equation representation of the domestic livestock market does a good job of explaining price dynamics between the grain and livestock market, given the simplicity of the equations.

In general, the model tracks historical values of the endogenous variables quite well. Root mean square percentage errors are less than 30 percent for endogenous variables with the exception of wheat utilization as feed. Also, the total number of turning points errors in endogenous prices are small relative to the total number of turning points (13 out of 40). Based on its performance over the sample period, this model appears to be well-suited to representing behavior in the U.S. grain livestock sector in the 1980s.

Seemingly unrelated regression and three-stage least square techniques provide estimates of the variance-covariance matrix of deviations.
from trend domestic crop yields and trend U.S. exports. Thus, random demand and supply shocks applied to the model over the future period embody the joint probability distribution of these supply and demand shifters.

Linear response functions relating farmer-owned reserve carryover to real market prices suggest that FOR carryover over the 1977-80 period has been quite price elastic (estimated elasticities are 3.63 and 3.77 for wheat and feed grain). These estimates suggest that the reserve program as managed over 1977-80 has added to the elasticity of total demand for both wheat and feed grain. Thus, the reserve program has significantly enhanced grain price stability.

The stochastic simulation experiments employed in this study provide a measure of mean and variability in real grain and livestock prices in order to compare continuation of post-1977 grains policy with other alternatives. Mean grain and livestock prices generally follow each other quite closely over the 1981-90 future period between the continuation of current policy (PA I) and free market (PA II) alternatives. Wheat, corn, and livestock prices are 331, 38, and 17 percent more volatile, on average, over 1981-90, respectively, in PA II. Thus, grain policy instruments as they have been managed since 1977 appear to stabilize commodity prices significantly compared with the free market alternative while leaving long run equilibrium prices undisturbed.

The FOR program is replaced with a simple subsidy on commercial storage at any price in PA III. The subsidy is set to equal the real value of reserve program's annual storage subsidy over 1977-80. This
preliminary analysis suggests that such a policy change would result in 94, 29, and 13 percent more variability in wheat, corn, and livestock prices, respectively. The FOR, as embodied by the linear response functions, add more to the total elasticity of demand for grains than does the subsidy to commercial storage. Results suggest that lack of set-aside authority (PA IV) add virtually nothing to commodity price variability as compared to a continuation of current grains policy (PA I). However, average FOR carryover is 14 and 8 percent higher for wheat and feed grain without set-aside authority. In addition, lack of set-aside authority results in mean prices of wheat, corn, and livestock to average 11, 7, and 2 percent lower when compared to PA I over the 1981-90 future period.

Finally, in all policy alternatives wheat prices are substantially more variable than corn prices. This is partly due to total wheat demand being more inelastic with respect to own price than total feed grain demand. In addition, the domestic livestock market serves as more of a shock absorber for the feed grain market than the wheat market. Thus, linkages with the domestic livestock market are critical in quantifying differential impacts of policy instruments on the wheat and feed grain markets.
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U.S. Department of Commerce

Webb, Alan J.

Womack, Abner W.

Zellner, A.
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Finally, I would like to thank Mary Shearer for her excellent typing of this thesis and to Mrs. Bishop for her proofreading of the final draft.
Description of Selected Variables

Table 3.1 lists all variables used to estimate the model. Some of these variables require further elaboration than is possible in the space provided in the table. They are presented here in the order they appear in Table 3.1.

\[ WLSTKPRD_t = W_1 \cdot PRDBEEF_t + W_2 \cdot PRDPORK_t + W_3 \cdot PRDCHK_t \]

where

\[ PRDBEEF_t = \text{Beef production, million pounds, crop year basis (USDA, 1973; 1981c).} \]

\[ PRDPORK_t = \text{Pork production, million pounds, crop year basis (USDA, 1973; 1981c).} \]

\[ PRDCHK_t = \text{Total production of broiler meat, ready to cook, million pounds, crop year basis (USDA, 1982b).} \]

\[ W_i = \frac{\bar{p}_i}{\bar{p}_1 + \bar{p}_2 + \bar{p}_3} \quad i = 1, 2, 3 \]

\[ \bar{p}_1 = \text{Average (1970-78) price of choice steers, 900-1100 pounds, Omaha, dollars per cwt., crop year basis (USDA, 1981c).} \]

\[ \bar{p}_2 = \text{Average (1970-78) price of hogs received by farmers, dollars per cwt, crop year basis (USDA, 1982a).} \]

\[ \bar{p}_3 = \text{Average (1970-78) price of frying chicken, ready to cook, dollars per cwt., crop year basis (USDA, 1982b).} \]
**WHEDR}_{t+1}, CEDR}_{t+1}, GSEDR}_{t+1} = Effective diversion rates for wheat, corn, and sorghum, respectively. Pre-1974 values for these variables can be found in sources listed in Table 3.1. From 1974-80, set-asides were implemented in only 1978 and 1979. Given program provisions, Gallagher (1981) calculates per bushel diversion incentives to equal:

<table>
<thead>
<tr>
<th>Year</th>
<th>WHEDR}_{t+1}</th>
<th>CEDR}_{t+1}</th>
<th>GSEDR}_{t+1}</th>
</tr>
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<tr>
<td>1977</td>
<td>1.05</td>
<td>0.17</td>
<td>0.41</td>
</tr>
<tr>
<td>1978</td>
<td>1.05</td>
<td>0.13</td>
<td>0.33</td>
</tr>
</tbody>
</table>

These values reflect maximum deficiency payment on planted acreage per bushel for these crop years.

**CESP}_{t+1}, FOESP}_{t+1}, SBESP}_{t+1}, COTESP}_{t+1} = Effective support prices for corn, oats, soybeans, and cotton. Pre-1974 values for these variables can be found in sources listed in Table 3.1. From 1974-80, the corn and cotton effective support prices are calculated as follows (Gallagher, 1981):

\[
\text{ESP}_{t+1} = 0.8*\text{TP}_{t+1} + 0.2*LR_{t+1}
\]

where

- \( \text{ESP}_{t+1} \) = Effective support price
- \( \text{TP}_{t+1} \) = Target price
- \( LR_{t+1} \) = Loan rate
Effective support prices for soybeans and oats equal their loan rates over this period (Gallagher, 1981).

The wheat and corn trade-weighted value of the U.S. dollar, 1970=1.0, crop year basis. The annual values of these variables were calculated from monthly data based on the wheat and corn crop years. The indexes are based on monthly foreign currency values of the U.S. dollar of all countries which import U.S. wheat or corn. Country weights are based on U.S. import market share for fiscal years (Oct.-Sept.) 1976-78 (Stallings, 1981).

\[ W_{TWDOL_t}, CT_{WDOL_t} = \text{wheat and corn trade-weighted value of the U.S. dollar, 1970=1.0, crop year basis.} \]

\[ W_{TWDOL_t}, CT_{WDOL_t} = \text{wheat and corn trade-weighted value of the U.S. dollar, 1970=1.0, crop year basis.} \]

Country weights are based on U.S. import market share for fiscal years (Oct.-Sept.) 1976-78 (Stallings, 1981).

\[ SPAM_t = \begin{cases} 
GSPA_t & \text{if } t \leq 1960 \\
\text{Average } GSPA_t \text{ over } 1954-60 & \text{otherwise} 
\end{cases} \]

\[ AWWM_t = \begin{cases} 
WWPA_t \text{ (winter wheat planted acres, million acres) if } t \leq 1960 \\
\text{average } WWPA_t \text{ over } 1954-60 & \text{otherwise} 
\end{cases} \]

\[ RFC_t = \text{Pasture and range feed conditions. Indicates current supply of feed for grazing on nonirrigated pastures and ranges relative to that expected from existing stands under very favorable weather conditions, RFC=100 (USDA, 1973; 1981c). Crop year figure is calculated by taking the average of April 1 and December 1 values.} \]
APPENDIX B
<table>
<thead>
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<td>$/bu.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>RES&lt;sub&gt;t&lt;/sub&gt;</td>
<td>$/bu.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>2.440</td>
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<td>1967=1.0</td>
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<td>3.807</td>
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<td>3755.5</td>
<td>3821.0</td>
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<td>WPOPNU&lt;sub&gt;t&lt;/sub&gt;</td>
<td>millions</td>
<td>4160.2</td>
<td>4213.8</td>
<td>4269.5</td>
<td>4326.7</td>
<td>4385.1</td>
<td>4444.1</td>
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<td>4626.1</td>
<td>4687.5</td>
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<td>475.787</td>
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<td>VCC&lt;sub&gt;t+1&lt;/sub&gt;</td>
<td>$/acre</td>
<td>114.82</td>
<td>119.27</td>
<td>123.71</td>
<td>128.16</td>
<td>132.60</td>
<td>137.05</td>
<td>141.49</td>
<td>145.94</td>
<td>150.38</td>
<td>154.83</td>
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<td>VCSB&lt;sub&gt;t+1&lt;/sub&gt;</td>
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<td>59.62</td>
<td>59.94</td>
<td>60.44</td>
<td>61.08</td>
<td>61.66</td>
<td>62.34</td>
<td>63.02</td>
<td>63.71</td>
<td>64.40</td>
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<td>6.34</td>
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<td>$/ton</td>
<td>186.25</td>
<td>192.16</td>
<td>198.08</td>
<td>204.00</td>
<td>209.92</td>
<td>215.83</td>
<td>221.75</td>
<td>227.67</td>
<td>233.59</td>
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*Deflated by CPILF<sub>t</sub>.*
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<td>MMT</td>
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<td>0</td>
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<td>RFC(_t)</td>
<td>1967=100</td>
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<td>UOA(^b)/metric ton</td>
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<td>162.65</td>
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<td>MMT</td>
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<td>MMT</td>
<td>448.23</td>
<td>459.40</td>
<td>473.64</td>
<td>487.67</td>
<td>499.35</td>
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<td>526.35</td>
<td>536.58</td>
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<tr>
<td>EWRTFGU(_t)</td>
<td>MMT</td>
<td>780.85</td>
<td>796.91</td>
<td>812.96</td>
<td>829.02</td>
<td>845.07</td>
<td>861.13</td>
<td>877.18</td>
<td>893.24</td>
<td>909.30</td>
<td>925.35</td>
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<td>YLDC(_{t+1})</td>
<td>bu./ac.</td>
<td>86.24</td>
<td>87.15</td>
<td>88.00</td>
<td>88.77</td>
<td>89.48</td>
<td>90.12</td>
<td>90.70</td>
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<td>YLDCS(_{t+1})</td>
<td>bu./ac.</td>
<td>38.45</td>
<td>38.45</td>
<td>38.45</td>
<td>38.45</td>
<td>38.45</td>
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<td>bu./ac.</td>
<td>43.07</td>
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</tr>
</tbody>
</table>

\(^b\) European Community units of account.

\(^c\) The cotton effective support rate is expressed in real terms deflated by IPPF\(_{t+1}\).

\(^d\) USDA (1980e).

\(^e\) Mean values obtained when error term is suppressed.
Instrument Sets Used in Estimating The Model

As is often the case in relatively large econometric models, the total number of exogenous variables in the system exceeds the total number of data points available. Thus, there are insufficient degrees of freedom to estimate the unrestricted first-stage, reduced form equations of the simultaneous block of the model. As can be seen from Chapter III, this is a problem with the model used in the current study. To alleviate this problem, the first-stage equations are redefined to obtain a set of equations which can be estimated. This is done by selecting only the exogenous variables that are most closely related to the endogenous variable in the equation. The instrument set used with each dependent variable is shown in Table C.1.
<table>
<thead>
<tr>
<th>Group number</th>
<th>Dependent variables</th>
<th>Instrument set</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$SFG_t$, $SW_t$, $DFEEDFG_t$, $DFOODFG_t$,</td>
<td>$PCD_I_t$, $SFGGOV_t$, $SWGOV_t$, $CTWVDOL_t$,</td>
</tr>
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<td>$DFEEDW_t$, $GSPF_t$, $BPF_t$, $OPF_t$,</td>
<td>$WTVVDOL_t$, $SBPF_t$, $CEDR_{t+1}$, $GSED_R_{t+1}$,</td>
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<td></td>
<td>$GSPA_{t+1}$, $BPA_{t+1}$, $OPA_{t+1}$</td>
<td>$WHEDR_{t+1}$, $GESP_{t+1}$, $LPRDDEV_t$, $WSUPNUS_t$,</td>
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<td></td>
<td>$CCOMEXP_t$, $GOVW_t$, $IPPF_{t+1}$, $GPILF_t$,</td>
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<td>$WPOPNUS_t$, $COTESP_{t+1}$, $D66_{t+1}$, $D6272_t$,</td>
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<td>$D73_t$, $RPHOU_t$</td>
</tr>
<tr>
<td>2</td>
<td>$CPA_{t+1}$</td>
<td>Same as 1 including: $VCC_{t+1}$, $VCSB_{t+1}$</td>
</tr>
<tr>
<td>3</td>
<td>$WPA_{t+1}$</td>
<td>Same as 1 including: $AWM_{t+1}$</td>
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<td></td>
<td>Same as 1 excluding: $CTWVDOL_t$,</td>
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<tr>
<td></td>
<td></td>
<td>$CCOMEXP_t$, $D66_{t+1}$, $LPRDDEV_t$</td>
</tr>
<tr>
<td>4</td>
<td>$CEFG_t$, $CEW_t$, $LSTKPI_t$,</td>
<td>Same as 1 including: $CPEEC_t$</td>
</tr>
<tr>
<td></td>
<td>$WLINKPRD_t$, $GCAU_t$</td>
<td>Same as 1 excluding: $D66_{t+1}$, $D6272_t$, $D73_t$,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$GSED_R_{t+1}$</td>
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