Potential long-term agricultural impacts of the Russian grain embargo

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Potential Long-Term Agricultural Impacts of the Russian Grain Embargo

CARD Report 97

THE CENTER FOR
AGRICULTURAL AND RURAL DEVELOPMENT
IOWA STATE UNIVERSITY, AMES, IOWA 50011
POTENTIAL LONG-TERM AGRICULTURAL IMPACTS
OF THE RUSSIAN GRAIN EMBARGO

by

Burton C. English, Raymond Joe Schatzer,
Roland K. Roberts, and Earl O. Heady

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The Authors
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Late in 1979, the Russians mounted an offensive in Afghanistan. This action was perceived as a direct threat to U.S. security by the President of the United States. A course of nonmilitary response to this threat was planned. One component of this plan, announced on January 4, 1980, called for an embargo of high-technology goods and all agricultural commodities except the quantities of corn and wheat agreed to by previous treaty.

Agricultural programs proposed to help alleviate the burdens imposed upon farmers by the embargo were developed and announced during the following 15 days. The programs, designed to distribute the burden among all U.S. citizens, included: (a) increasing the corn reserve by 400 to 500 million bushels; (b) purchasing wheat and placing it in the international emergency reserve; (c) purchasing contractual obligations of U.S. grain exporters affected by the embargo through the Commodity Credit Corporation (CCC); (d) increasing the corn loan, release, and call prices to $2.10, $2.63, and $3.05 per bushel, respectively, and the respective wheat rates to $2.50, $3.75, and $4.63; and (e) waiving the first year interest costs on the first 13 million metric tons of corn entering the reserve after the embargo and increasing storage payments $0.15 per bushel.

In effect, these programs were a two-step approach to help corn farmers absorb the impact of the embargo. The first was to increase the incentives for storing corn in farmer-held reserves; the second was to
reimburse grain companies for costs incurred in offsetting embargoed sales contracts to Russia. For wheat, the government offered to purchase the amount affected and deliver it to needy countries.

Historical Perspective

The Des Moines Register, on January 5, reported that President Carter, rejecting the advice of key agriculturalists, stated he would deny Russia 17 million tons of corn and wheat it planned to purchase. He also indicated that he was determined to: (a) minimize any adverse impact on the American farmer resulting from this action; (b) alleviate hunger in poor countries; and (c) massively increase the use of grain for gasohol production [Risser, Anthan, and Paul, 1980].

Allen Grant, president of the American Farm Bureau Federation, said that throwing 17 million metric tons of grain back on the market will depress prices. He added, "Despite precautions of the President and Secretary of Agriculture say they are taking to insulate this military-economic tactic, there is no truly effective way to insulate the markets from this impact." Following this point of view, he called for:

(a) development of new export markets with a full implementation of the Trade Development Acts of 1974 and 1978; (b) restoration of the CCC export credit funds scheduled to be cut in half and provide short term CCC credits to countries desiring them; (c) an increase in PL 480 shipments; and (d) establishment of a crash research program to develop new uses and markets for farm commodities [Orr, 1980]. On the same day, January 7, the government called for a two day shutdown of commodity markets.
increased the reserve's release and call prices, and pledged to purchase all of the wheat affected by the embargo [Risser, 1980].

Duncan of the Federal Reserve Bank in Kansas City stated that the embargo could create lower feed grain costs which could, in turn, slow the expected cut in pork and poultry production [Anonymous, 1980]. Thus, the consumer food prices may rise less than anticipated. He added, however, that the long run impacts of this embargo could be severe. If the Soviets slaughter livestock then future Soviet demand would be reduced.

On January 8, it was reported that the USDA would buy the contractual obligations (Approximately $2.5 billion worth) of the firms with contracts to sell the grain and soybeans to the Soviets. This grain would be held in storage and released at a later date [Cohen and Ackland, 1980].

On January 9, it was announced that the loan rate on corn and wheat was increased to $2.10 and $2.50, respectively. This increase and the corresponding increases in the release and call prices were designed to keep grain from flooding the market. Another move to help the farmers contemplating in holding grain reserves was to waive the first-year interest costs on the next 13 million tons of corn entering the reserve, and increase the storage payments from $0.25 to $0.265 per bushel [Risser, 1980a].

On January 11, 1980, the feed grain policy was clarified. It was announced that corn in the government's physical possession would not be sold until the U.S. average corn farm price reached $3.15 a bushel.

In addition, the embargoed export contracts purchased by the Commodity
Credit Commission would not be retendered at a U.S. average corn farm price of $2.40 per bushel (the preembargo price) [Waterloo, 1980].

On February 4, it was reported in Feedstuffs [Kopperud, 1980], that the embargoed quantities included 11.528 million metric tons of corn, 4.738 million metric tons of wheat, 0.71 million metric tons of soybeans, 0.03 million metric tons of soybean oil, and .4 million metric tons of soybean meal. On February 15, information from Dr. Wisner\(^1\) indicated that 16,075,029 metric tons of corn, soybeans, and wheat were included in the embargo. (Note: This figure does not include the quantity of soybean oil or meal embargoed.) Splicing these two sources together, an estimated 11.96 million tons of feed grains, 166.76 million bushels of wheat, and 44.77 million bushels of soybeans (including products) were embargoed.

On January 28, 1980, Dan Huber, an executive for Cargill, Inc., expected that approximately 1/3 of the total quantity embargoed would find other markets and that approximately a 8.4 million ton shortfall in corn grain exports could occur as a result of the embargo [Anonymous, 1980b].

Since little is known about the impacts of the embargo on future exports to the Soviet Union and on other countries' reactions to the embargo, several alternatives are examined reflecting different export levels. Several factors influence export levels that occur due to an embargo of the type placed on the Soviet Union. Two of these factors are redirection of trade opportunities, and increased efforts in the development of long-term contracts.

\(^1\)Information provided by the Reuter Wire Service, February 15, 1980.
Prices following an embargo of this type normally decline once the policy is announced. This occurs as a result of reduced expectations in the demand for commodities. Thus, a shift of the demand curve toward the origin (D') occurs and since the supply of agricultural commodities is fixed, the price declines (Figure 1).

Figure 1. Demand adjustment as a result of an embargo
Following a decrease in commodity prices, other countries tend to buy increased quantities of commodities. Countries not supporting the embargo sell more to the USSR and less to other nation's. Thus, a redirection of trade occurs.

In the Russian grain embargo, Canada, the European Community nations, and Australia agreed not to increase their exports to the Soviet Union. The Soviet Union redirected its trade to Argentina; thus increasing the Argentina feed grain price. Additionally, the Soviet Union sharply reduced its grain exports to Eastern Europe and small increases in Soviet purchases from several minor grain exporting countries, also, occurred. This forced other countries to seek other markets with lower feed grain prices. Thus, a shift of the D' demand curve occurred toward the original demand curve. How much of a shift will occur, where will the final demand curve lie and where the future demand curves rest are questions that require some speculation.

Study's Objectives and Alternatives

This study uses an econometric model as a tool to help analyze the potential longer term impacts of the grain embargo (imposed on the Soviet Union) on the agricultural sector of the United States. The model, as explained in the following chapter, is not a model designed to analyze short-term effects of agricultural market disturbances. For an analysis of this type to occur, a model using at a minimum quarterly data would be required. Rather, this study examines changes in the agricultural sector that occur as a result of the embargo, and the longer term impacts of these results.
The alternatives used in this study are designed to reflect these factors and to provide a range of future possibilities. While it is recognized that a redirection of trade will develop as a result of the embargo, it can not be inferred that a total redirection of trade will take place before the initial year of the embargo is completed. Thus, the question as to how much redirection-of-trade will occur must be projected. In the addition, the alternatives can be examined and analyzed. The alternatives include a Base level of exports which assumes no embargo (Base), a level of exports reflecting the decrease resulting from the embargo for one year only (I), a level of exports reflecting the decrease resulting from the embargo for the entire period of the analysis (II), a level of exports that assumes that the Base level of exports will be reached in three years after the embargo is imposed (III), and finally, a level of exports that assumes the Base level of exports is reached in three years and that in the fourth, fifth, and sixth years exports will increase due to increased emphasis placed on expanding exports as a result of the embargo.

Each of these alternatives are run assuming that the grain that goes into farmer storage (1/3 the embargoed amount) is not released until prices are greater than 150 percent of the real loan rate for feed grains. Embargoed wheat and soybeans are assumed to be used in the PL-480 program. Thus, the initial embargoed quantities of wheat and soybeans and 1/3 of

\[\text{In this alternative it is assumed that to minimize the agricultural impacts of an embargo, the government places an increased emphasis on increasing exports to other countries.}\]
CHAPTER II. THE MODEL

The national agricultural econometric simulation model (NAES) used in this analysis was developed at the Center for Agricultural and Rural Development (CARD). This chapter contains a general overview of the CARD-NAES model. Linkages among important economic variables are examined and the feed grain sector is shown in order to illustrate the flow of the model. Special characteristics of the other sectors, modifications to the estimated equations, and adjustments for analysis of the alternatives also are presented in this chapter.

There are 11 submodels in the CARD-NAES model including five major crop commodity sectors -- feed grains, wheat, soybeans, cotton, and tobacco; and five livestock commodity sectors -- beef, pork, lamb and mutton, chicken, and turkey. The final submodel aggregates components from each of the submodels and sums those results with the exogenously determined variables for the rest of the U.S. agricultural sector. Each of these submodels is divided into three sections: pre-input, input, and output sections. These three model sections represent the processes involved in the agricultural planning, production, and marketing decisions.

The pre-input section determines the stocks of such fixed resources as machinery, land and buildings, and on-farm commodity inventories. Levels of the variable inputs such as fertilizer, seed, machinery services, real estate services, and labor requirements are determined variables. Production, commodity prices, and income estimates resulting from the resource levels committed in the pre-input and input section are obtained from the output section.
Generally, the model's structure is recursive, but there are portions of the model which fail to meet all the recursiveness criteria. For a model to be recursive, two conditions must prevail. First, the matrix of coefficients for endogenous variables must be triangular. If this condition prevails, the structural equations of the model can be solved sequentially without the use of reduced form equations or iterative techniques. Secondly, the variance-covariance matrix of structural equation disturbances must be diagonal [Johnston, 1972]. Thus, the disturbance term of any one equation must not be correlated with the disturbance of any other equation in the model.

Portions of the output section do not meet the first criteria. These portions, therefore, are block recursive. There also are portions of the model that do not meet the second criterion. These violations imply certain statistical estimation techniques are more appropriate than others. The equations and the statistical information for the equations used pertinent in the model are shown in Appendices A and B.

**Statistical Methods**

Annual time series data are used to estimate the structural parameters of the model using regression techniques. Most equations are estimated from 1949 through 1976 data with portions of the livestock sub-models using 1953 through 1976 data.

Six regression techniques are used to estimate the model's parameters. Ordinary least squares is used for those equations that are

---

1 The term "block recursive" indicates that both simultaneous and recursive portions are represented.
recursive. The recursive equations with autocorrelated errors are estimated by autoregressive least squares. Two-stage least squares is used to estimate the farm-retail margin equations in the beef, pork, chicken, and turkey submodels as they are determined simultaneously with their respective farm prices. Three-stage least squares or autoregressive three-stage least squares are used on equations which are not simultaneous, but have disturbances correlated with disturbances of other equations in the model [Roberts and Heady, 1979].

Feed Grain Submodel

The feed grain submodel is typical of the crop submodels. Thus, it is employed to illustrate the general linkages among the important crop submodel variables and between the submodels. A detailed presentation of the output section of the livestock submodels is found in Roberts and Heady [1979], with the pre-input and input sections described in more detail in Schatzer, Roberts, Heady, and Gunjal [1980]. The equations used in the model are presented along with statistical information in Appendices A and B from the crop and livestock submodels, respectively.

Feed grain pre-input section

Figure 2 is a schematic diagram of the pre-input section with definitions of the variables appearing in Appendix C. The pre-input section determines the levels of physical assets committed to the production of feed grains. Harvested acreage, machinery purchases, machinery stocks, on-farm commodity stocks, and land and building value per harvested acre are estimated through regression techniques, with the machinery and
Figure 2. Schematic diagram of the feed grain pre-input sector.
commodity stock averages, total land and building value, and stocks of physical assets determined through identities.

Feed grain harvested acreage (FG-AC) is determined first with lagged price ratios for feed grains (FG-PR), soybeans (SB-PR), and wheat (WT-PR3) used to capture competition among the commodities for land. A time trend (TIME) and a feed grain base program dummy variable (D6178) along with the feed grain diversion program (FG-ACDIV) are also included in the equation. The index of the per acre price of land and buildings (FG-PRLA) for feed grains is estimated using a time trend (TIME), and lagged FG-PRLA as explanatory variables. The total value of land and buildings (FG-VALA) is then derived by multiplying the feed grain harvested acreage by the price of land.

On-farm stocks (FG-STK) is determined by a free market dummy variable (FREE1), its lagged value, and a dummy variable for the 1970 corn blight (BLIGHT). The on-farm grain stock average is derived by summing current and lagged values of FG-STK and dividing by two.

U.S. motor supplies price and machinery purchase indices (MSPI and MHPI, respectively), dummy variables representing the feed grain diversion program (FG-ACDIV) and the Vietnam War (DG871), lagged feed grain prices (FG-PR), and the lagged machinery purchases (FG-MPUR) are the variables included in the estimation of machinery purchases. These purchases then are used to determine the per acre stock of machinery (FG-MSTK/FG-AC) along with the log time (LOGTIME) and the FG-AC. The average stock of machinery (FG-MSTKAVE) is then computed by dividing the sum of the current and lagged stocks by two.
The final variable computed in the pre-input section is the stock of physical assets. It is formed by summing the values of land and buildings, on-farm feed grains, stock average, and the machinery stock average.

**Feed grain input section**

Endogenous variables estimated in the pre-input sector determine the variable input expenditures in the feed grain input sector. The flow of these variables is shown in Figure 3 with variable input expenditures expressed in constant dollars. The variables determined in the input section include real estate taxes (FG-RETX), real estate expenditures (FG-REEX), miscellaneous inputs (FG-MISC), fertilizer (FG-FERT), seed (FG-SEED), fuel oil and repairs (FG-FOR), machinery (FG-MACH), man-hours of labor (FG-LABR), and interest on feed grain stocks (FG-INT). Real estate, miscellaneous inputs, per acre fertilizer, seed, fuel oil and repairs, and machinery expenses and labor are computed through econometrically estimated equations with real estate taxes, fertilizer, and interest on commodity stocks determined by identities.

The value of land and buildings from the pre-input sector is used to derive real estate taxes and expense. The real estate taxes are estimated by multiplying the exogenously determined feed grain real estate tax rate (FG-TXRT) by the estimated value of land and buildings used in feed grain production. The estimated value of land and buildings along with the log of time are the explanatory variables used in determining the real estate expense for feed grain production. Miscellaneous input
Figure 3. Schematic diagram of the feed grain input sector
expense (FG-MISC), is determined as a function of farm supplies price index (FSPI), the square root of time (SQRTIME), time, and the stock of physical assets.

The fertilizer price index (FTPI), a free market dummy variable, the quantity of feed grain harvested acreage, the lagged feed grain price and time are used to determine the per harvested acre use of fertilizer (FG-FERT/PG-AC). To find the total expense of fertilizers the harvested feed grain acres are multiplied by the per acre quantity of fertilizer used by feed grains.

Fuel, oil and repairs expense (FG-FOR) is derived using the change in the machinery price index (DMSPI), a free market dummy variable (FREE2), the estimated quantity of harvested feed grain acreage, and the square root to time. Machinery Expense is determined using lagged machinery expense, the exogenously determined interest rate (INTRT), and the stock of machinery from the pre-input section.

Miscellaneous, seed, fuel, oil and repairs, and machinery expenses along with labor are divided by harvested acreage to obtain per harvested acre estimates (FG-MISC/FG-AC, FG-SEED/FG-AC, FG-FOR/FG-AC, FG-MACH/FG-AC, EG-LABR/FG-AC). These variables along with fertilizer per harvested acre are used by the feed grain output section to estimate feed grain yield per acre in tons per acre.

Feed grain output section

A schematic diagram of the feed grain output section is shown in Figure 4. The price received by farmers (FG-PR), feed grain commercial
Figure 4. Schematic diagram of the feed grain output sector
demand (FG-CDEM), and the gross income from feed grain production (FG-GINC) are determined by econometric equations, while production (FG-PRD), supply (FG-SUPPLY), total noninventory demand (FG-CDEM), and end-of-year stocks (FG-TIWV) are determined through identities. A yield per harvested acre is also determined from a production function which uses estimated elasticities of production for six inputs from the input section.

The production function to estimate year-to-year changes in crop yield is presented in equation 1:

\[
FY_t = FYB_t \cdot \left[ 1.0 + \sum \left\{ E_i \cdot \left( \frac{I_{it} - B_{it}}{B_{it}} \right) \right\} \right]
\]

(1)

where:

- \( FY \) is the per harvested acre feed grain yield;
- \( FYB_t \) is the Base Run per harvested acre feed grain yield in year (t);
- \( E_i \) is the elasticity of production of the ith input;
- \( I_{it} \) is the predicted level of the ith input in year (t); and
- \( B_{it} \) is the Base Run level of the ith input in year (t).

The input elasticities of production are estimated from factor share data using methodology by Tyner and Tweeten [1965]. Per acre Base input use and yields are obtained from a Base run which projects crop yields. These crop yields and input quantities are then exogenous inputs into subsequent model alternatives. In these subsequent simulations, yields will vary about the Base according to the above equation. Thus, Base yields are projected exogenously. Changes in input expenditures and acres harvested in the various alternatives result in changing the Base yield.
Harvested acreage is multiplied by feed grain yield to reflect annual production. Production, imports (FG-IMPTS), and beginning inventories (FG-TINV) are summed to derive total supply which then is used to determine the feed grain price.

The recursive structure of the output section complies with the biological production process of most agricultural commodities. Price uncertainty exists at the time when farmers plant their crops. Thus, an expected price is used when making their planting decisions. In this model, lagged prices are assumed to be the expected price. As a result, supply is fixed in the current year and the current year's price is adjusted so that the market will clear. At the estimated price level, the quantity supplied equals the total quantity demanded (total quantity demanded equals the sum of domestic requirements (FG-CDEM), exports (FG-EXPTS), and ending inventories (FG-TINV)). The domestic demand is estimated econometrically as a function of the current year's price, while exports are determined exogenously and ending inventories are determined exogenously and ending inventories are determined using an identity equaling commercial demand plus exports, less supplies.\(^1\) The feed grain loan rate (FG-LR), and exogenous export levels are also required variables and are price determined.

The feed grain commercial demand equation includes three variables -- time, (TIME), livestock price (LF-PR), and a dummy variable reflecting

\(^1\)Inventories can never be less than nor equal to 0. If they are less than, 11.2 million tons for feed grains, movement up the demand curve occurs. This results in a higher farm price for feed grains.
the free market years of 1974 to 1976. The livestock price is a weighted average price and allows the livestock sector to influence commercial demand.

Gross feed grain income is the last variable determined within the feed grain submodel. Gross income for feed grain production is equal to the cash receipts of feed grain sales. Thus, the value of production is simply the price of feed grains times the estimated production.

Policy Simulations and Assumptions

A Base run and four alternatives are examined. Each of these alternatives has a different assumption concerning the impact of the Russian grain embargo on the agricultural sector. The policy changes and their impacts are analyzed over the 1977-2000 period with all dollar figures expressed in 1978 dollars.

A more detailed description of the assumptions used in the analysis follows. The assumptions associated with the Base are important and are therefore dealt with in great detail. The assumptions of each of the other four alternatives deviate from those of the Base in that one or more variables are altered to simulate different alternative futures.

Assumptions and modifications for the Base

The Base provides a base for 1979-2000 with which the alternatives can be compared. It is made by setting the exogenous variables of the model equal to their most likely levels for the 1979-3000 period and by modifying some of the coefficients of the statistically estimated equations.
Model adjustments and modifications

The equations presented in Appendices A and B are the estimated econometric equations and the identities which represent the structure of the model based on data from the historical sample period. Adjustments and modifications of the estimated equations are made to account for assumed changes in consumer tastes and preferences, technological improvements and other trend forces. These adjustments and modifications are important in providing a meaningful base run for an intermediate or distant future period of analysis where tastes and preferences and technological growth rates are likely to change from the historical sample period.

Several time trends are modified in the pre-input section of the model. The trend in the livestock purchases equation is assumed to increase by only 0.5 percent per year beginning with 1978. The trend variables in the feed grain, soybean, and cotton acreage equation are assumed respectively to be constant at the 1976 level, increase by 0.85 percent per year beginning with 1978, and increase at 0.5 percent per year beginning with 1978. The time trend in the "other acreage" equation of the U.S. aggregate submodel increases at 0.35 percent per year beginning with 1977. The trend variable for livestock value of land and buildings and cotton machinery purchases are held constant at their 1977 levels. The price of land equations for feed grains, wheat, and soybeans have trends which are assumed to increase by 0.5 percent per year starting with 1977.
Trend variables in five equations of the input section are adjusted. The trends for the livestock labor and fuel, oil, and repairs equations are assumed constant at 1976 values. The feed grain, wheat, and cotton fertilizer expense equations include time trends which are assumed to increase by 0.75 percent per year after 1976.

Modifications also are made in the output section of the model. Three time trends are modified in the livestock submodels. The trend variables in the beef production and pork farm-retail margin equations are assumed to be constant at 1978 and 1977 levels, respectively. The trend variable for lamb production is assumed to increase at one-half the rate that occurred during the sample period. The lamb production time trend is estimated with a negative coefficient. Therefore, the reduced rate of growth in the time trend translates into a reduced rate of decline in lamb and mutton production. This step is taken to prevent negative lamb and mutton production which otherwise would occur after only a few years.

Another important modification in the livestock submodels is based upon an assumption that the income elasticities of demand for the five livestock and poultry commodities will not remain constant over the entire analysis period. It is assumed that after 1980, consumers will demand progressively smaller increases in consumption of each of the five commodities for each dollar increase in personal disposable income. In order to capture the effect of this assumption, the rate of increase in personal disposable income is tapered off after 1980. The impact of slower growth
in income is calculated differently for each commodity. In general, income elasticities of demand are assumed to decline most rapidly for those commodities with the highest levels of per capita consumption. The growth rate in personal disposable income coefficient declines fastest for beef and is followed by pork, lamb, chicken, and turkey in descending order.

In addition, it is assumed that cattle producers and feeders will respond differently to price incentives after 1990 than they previously have. To reflect this, the coefficient for BFPEC in the beef production equation is reduced gradually from 54.7 in 1990 to 27.4 in 2000. This assumption is made to account for possible resource limitations (e.g., pasture) which might develop as cattle numbers increase in response to higher beef price to feed costs ratios in the future.

Other modifications of the retail price equations are made to provide more realistic projections. The coefficient for personal disposable income is reduced from 0.1732 to 0.1600 for pork. The estimated farm-retail margin for turkey appears to increase at an unrealistically rapid rate because of the large coefficient for the three-year moving weighted average of the wage rate of meat manufacturing employees. The result is a farm price which appears too low. Therefore, the coefficient is reduced from 27.9653 to 25.5500.

Some equations of the output section of the crop submodels also require modification. The time trend in the feed grain commercial demand equation is modified so that the time trend increases 0.8 per year after 1977 instead of 1.0. Also, the constant term in the feed grain commercial
demand equation is assumed to be 60 percent of its estimated value. These two assumptions were made because it seemed feed grain commercial demand was increasing too fast. Per capita disposable income in the cotton lint commercial demand equation after 1990 grows as one-half of its previous growth rate. This effectively incorporates as assumption that the income elasticity of cotton commercial demand is lower in the 1990s as compared with the sample period and the 1980s. Soybean exports are assumed to have less of an effect upon the soybean price for 1979-2000 than during the sample period because soybean price seemed to be increasing too fast. This assumption is incorporated by lowering the coefficient for soybean exports in the price equation by 25 percent.

These changes appeared logical for this analysis. Other variations also could be used. Individuals wishing to test other alternatives can request to do so through CARD.

The projected levels of exogenous variables

Another important step in the application of the model to the analysis of the Russian embargo is to determine and project the levels of the variables which are exogenous to the model. This section deals with the assumptions relating to the exogenous variables of the model and the levels at which they are set.

Exports and imports for both livestock and crop commodities are projected using trend variables or by assuming that they remain constant. Ordinary least squares (OLS) or autoregressive least squares (ALS) are used to estimate the trend coefficients.
The following equations are used to project livestock imports and exports and poultry net exports. The figure in the parentheses are t values for the respective variables. The value of $R^2$, the mean square error (MSE), Durbin Watson (DW), and estimated autoregressive parameter ($\hat{\rho}$) also are shown.

\[ B-\text{IMP}_t = 123.8902 + 76.5643 \text{TIME}, \quad (5.837) \]
\[ \text{ALS, } R^2 = .8670, \quad \text{MSE} = 49142.4550, \quad \text{DW} = 1.5608. \]

\[ B-\text{EXP}_t = 28.6993 + 4.217 \text{TIME}, \quad (9.241) \]
\[ \text{OLS, } R^2 = .7952, \quad \text{MSE} = 239.5221, \quad \text{DW} = 1.449. \]

\[ P-\text{IMP}_t = 13.7807 + 15.2609 \text{TIME}, \quad (2.136) \]
\[ \text{ALS, } R^2 = .9527, \quad \text{MSE} = 874.6217, \quad \text{DW} = 1.1795. \]

\[ P-\text{EXP}_t = 35.0471 + 7.7096 \text{TIME}, \quad (5.521) \]
\[ \text{OLS, } R^2 = .5808, \quad \text{MSE} = 2242.4922, \quad \text{DW} = 1.0958. \]

\[ L-\text{IMP}_t = 35.25 \text{ which is the 1973-76 average.} \]

\[ L-\text{EXP}_t = .1023 + .3531 \text{TIME}, \quad (5.413) \]
\[ \text{ALS, } R^2 = .8494, \quad \text{MSE} = 1.0972, \quad \text{DW} = 1.9666. \]

\[ C-\text{NEXP}_t = -118.9969 + 229.3105 \text{LOGTIME}, \quad (5.358) \]
\[ \text{ALS, } R^2 = .7510, \quad \text{MSE} = 2231.9151, \quad \text{DW} = 1.080. \]

\[ T-\text{NEXP}_t = -25.7649 + 34.8693 \text{LOGTIME}, \quad (3.900) \]
\[ \text{ALS, } R^2 = .8494, \quad \text{MSE} = 71.8139, \quad \text{DW} = 1.8087. \]
The definitions of most of the above variables and symbols are found in Appendix C. These equations are estimated from annual time series for 1953-76. The data sources for these variables are found in Roberts and Heady [1979, 1980].

Table 1 shows the projected levels of livestock commodity imports, for 1980, 1990, and 2000. Averages of actual observations for 1972-76 are also presented for comparison. Beef imports are projected to increase from, 2,372.2 million pounds in 1980 to 3,907.6 million pounds in 2000. Pork imports are expected to reach 824.3 million pounds by 2000 as compared with 493.4 million pounds in 1972-76. Lamb and mutton imports are assumed constant at 1973-76 average levels.

Table 1. Projected beef, pork, and lamb and mutton imports for 1980, 1990, and 2000, with actual 1972-76 average imports for comparison

<table>
<thead>
<tr>
<th>Commodity</th>
<th>1972-76a</th>
<th>1980</th>
<th>1990</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef (mil. lbs.)</td>
<td>1.879.0</td>
<td>2,372.2</td>
<td>3,131.9</td>
<td>3,907.6</td>
</tr>
<tr>
<td>Pork (mil. lbs.)</td>
<td>493.4</td>
<td>499.5</td>
<td>668.6</td>
<td>824.3</td>
</tr>
<tr>
<td>Lamb and mutton (mil. lbs.)</td>
<td>35.3b</td>
<td>35.3</td>
<td>35.3</td>
<td>35.3</td>
</tr>
</tbody>
</table>


bA four-year average for 1973-76.

Table 2 indicates the projected levels of livestock and poultry exports and net exports. Beef exports are projected to be 231.1 million pounds in 2000 which is 102.9 million pounds higher than the 1972-76 average. Pork exports are projected to drop below the 1972-76 average
in 1980 but to increase rapidly thereafter to reach 405.1 million pounds in 2000. Lamb and mutton exports increase from 9.7 million pounds in 1980 to 16.7 million pounds in 2000. Chicken net exports are projected to increase to 481.9 million pounds in 2000 while turkey net exports increase to 82.7 million pounds.

Table 2. Projected beef, pork, lamb and mutton exports and chicken and turkey net exports for 1980, 1990, and 2000, with actual 1972-76 average exports for comparison

<table>
<thead>
<tr>
<th>Commodity</th>
<th>1972-76(^a) (million pounds)</th>
<th>1980</th>
<th>1990</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>128.2</td>
<td>146.8</td>
<td>189.0</td>
<td>231.1</td>
</tr>
<tr>
<td>Pork</td>
<td>291.4</td>
<td>250.9</td>
<td>328.0</td>
<td>405.1</td>
</tr>
<tr>
<td>Lamb and mutton</td>
<td>7.2</td>
<td>9.7</td>
<td>13.2</td>
<td>16.7</td>
</tr>
<tr>
<td>Chicken</td>
<td>273.6</td>
<td>390.3</td>
<td>429.3</td>
<td>481.9</td>
</tr>
<tr>
<td>Turkey</td>
<td>52.6</td>
<td>64.7</td>
<td>74.6</td>
<td>82.7</td>
</tr>
</tbody>
</table>

\(^a\)SOURCE: [Economics, Statistics, and Cooperatives Service, 1979].

Crop imports are assumed to be constant over the 1979-2000 period. Imports of 0.4 million tons, 2.0 million bushels, and 0.05 million bales are assumed for feed grains, wheat, and cotton lint, respectively. Soybean and cottonseed imports are assumed to be zero. The above assumptions are based upon 1972-76 averages for feed grain and cotton lint imports and a 1963-76 average for wheat imports [Economics, Statistics, and Cooperatives Service, 1976 and 1977, and U.S. Department of Agriculture, 1978].
Crop exports are projected by time trends and two dummy variables. The dummy variables take into account apparent structural shifts in the levels of exports. Exports of feed grains, wheat, and soybeans took a dramatic jump in 1972 and seem to have maintained these high levels.

The export (EXPTS_t), trend (TIME), and postwar dummy (WAR2) variables are defined in Appendix C. DUM1 is a dummy variable with 1972-78 equal one and 1949-71 equal zero. DUM2 is a dummy variable with 1977-78 equal one and zero otherwise. These two variables account for effects such as the devaluation of the U.S. dollar and changes in both foreign and domestic government policy. The following equations are used to project crop exports.

\[
\text{FG-EXPS}_t = 1.3124 + 17.7277 \ DUM1 + 13.6004 \ DUM2 + 1.0885 \ TIME, \quad (10)
\]

\[
\text{OLS, } R^2 = .9646, \quad \text{MSE} = 13.2085, \quad DW = 1.6122.
\]

\[
\text{WT-EXPTS}_t = 196.4143 + 353.5923 \ DUM1 + 16.7191 \ TIME, \quad (11)
\]

\[
\text{ALS, } R^2 = .8577, \quad \text{MSE} = 13818.1281, \quad DW = 2.1739.
\]

\[
\text{SB-EXPTS} = -96.9637 + 66.3656 \ \text{WAR2} + 56.9442 \ DUM1, \quad (12)
\]

\[
+ 149.3029 \ DUM2 + 21.2192 \ TIME, \quad (4.631) \quad (13.522)
\]

\[
\text{OLS, } R^2 = 9.735, \quad \text{MSE} = 1441.7286, \quad DW = 1.7123.
\]

\[
\text{CT-EXPTS} = 4.5 \quad \text{which is the 1972-76 average for cotton.} \quad (13)
\]
For the purpose of projection from 1979-2000, DUM1 and DUM2 are set equal to one under the assumption that crop exports will remain at a higher level through 2000. WAR2 is set equal to zero and the time trend is increased by one unit per year up to 52 in 2000.

Table 3 displays projected levels of crop exports with 1972-76 averages of actual observations for comparison. Of the four crops, soybean exports are projected to increase the most. They reach 1,062.3 in 2000 which is 108 percent higher than the 1972-76 average. The projected level of feed grain exports for 2000 is 60 percent higher than 1972-76. Wheat exports are estimated to increase by 38 percent over the same period. Cotton exports are constant at 4.76 million bales because of the lack of correlation with trend or dummy variables.

Table 3. Projected levels of feed grain, wheat, soybean, and cotton lint exports for 1980, 1990, and 2000, with actual 1972-76 average exports for comparison

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed grain (mil. tons)</td>
<td>47.3</td>
<td>53.9</td>
<td>64.7</td>
<td>75.6</td>
</tr>
<tr>
<td>Wheat (mil. bu.)</td>
<td>1,098.6</td>
<td>1,201.6</td>
<td>1,362.0</td>
<td>1,511.5</td>
</tr>
<tr>
<td>Soybeans (mil. bu.)</td>
<td>511.7</td>
<td>638.7</td>
<td>850.5</td>
<td>1,062.3</td>
</tr>
<tr>
<td>Cotton lint (mil. bales)</td>
<td>4.5</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
</tr>
</tbody>
</table>


ᵇNo embargo is assumed.
Crop yields are projected exogenously as linear functions of time using 1949-1976 as a sample period. Ordinary and autoregressive least squares (OLS and ALS, respectively) are used to estimate the equations which follow.

\[
\begin{align*}
\text{FC-}Y_t &= 0.6690 + 0.0498 \text{TIME,} \quad \text{(14)} \\
\text{WT-}Y_t &= 15.6801 + 6255 \text{TIME,} \quad \text{(15)} \\
\text{SB-}Y_t &= 20.0293 + 0.2746 \text{TIME,} \quad \text{(16)} \\
\text{CT-}Y_t &= 22.30 + 0.1989 \text{LOGTIME,} \quad \text{(17)}
\end{align*}
\]

OLS, \( R^2 = 0.9224 \), MSE = 0.0147, DW = 1.4314.

OLS, \( R^2 = 0.8647 \), MSE = 4.3016, DW = 1.3877.

OLS, \( R^2 = 0.6948 \), MSE = 2.3271, DW = 1.5888.

ALS, \( R^2 = 0.7768 \), MSE = 0.0060, DW = 1.7475.

Feed grain and wheat yields are assumed to deviate from the above trends during the 1990s. An assumption is made that after 1990 gains from technological advances will occur more slowly than in the past. To account for this, the time trend variable increases at one-half unit per year instead of one unit per year after 1990. Feed grain yields in the Base increase by 41 percent from 1981 to 2000 and wheat yields increase 33 percent over the same time period. Soybean and cotton yields increase by 18 and 8 percent, respectively. As is noted previously, the Base yields change for the various alternatives analyzed. The change is based on input expenditures.
Military consumption of livestock commodities is the last group of exogenous variables which are projected by estimated econometric equations. The equations presented below are used to project military consumption of livestock and poultry.

\[
B_{\text{MILCONS}}_t = 33.7430 + 0.2037 M_{\text{IPOP}}_t, \quad \rho = 0.7647, \quad (2.728) \\
\text{ALS, } R^2 = 0.8754, \text{ MSE } = 2467.5413, \text{ DW } = 1.4620.
\]

\[
P_{\text{MILCONSt}} = -6.3338 + 0.0798 M_{\text{IPOP}}_t, \quad \rho = 0.9006, \quad (3.702) \\
\text{ALS, } R^2 = 0.9128, \text{ MSE } = 337.1776, \text{ DW } = 2.2077.
\]

\[
L_{\text{MILCONS}}_t = 1.0 \text{ which is the value of the variable for 1974, } 1975, 1976.
\]

\[
C_{\text{MILCONS}}_t = -1.4465 + 0.0300 M_{\text{IPOP}}_t, \quad \rho = 0.8540, \quad (2.880) \\
\text{ALS, } R^2 = 0.8672, \text{ MSE } = 64.1501, \text{ DW } = 2.1077.
\]

\[
T_{\text{MILCONS}}_t = 52.2126 + 7.4795 \text{ LOGTIME} + 0.0257 M_{\text{IPOP}}_t, \quad (4.234) (7.829) \\
\text{OLS, } R^2 = 0.7471, \text{ MSE } = 39.7913, \text{ DW } = 1.4905.
\]

These equations are estimated with 1953-76 annual data. MILPOP is the military population in thousands and it is assumed to be constant at 2,123 which is the post-Vietnam War average (1974-76 average).

Table 4 shows increases in military consumption of all livestock and poultry commodities except lamb and mutton. These increases are due to the high levels of the estimated autoregressive parameters ($\rho$s) even though military population is held constant. Military consumption of turkey increases because it has a positive log time trend.
Another exogenous set of variables includes government policy variables which are set at anticipated levels. These variables are difficult to project because their levels are determined by the government which offers, modifies, adds to, or eliminates national agricultural policy legislation without much forewarning. For the Base, only government policies which have influenced the agricultural sector in the past are used. These policy variables are set at levels which are anticipated for the 1979-2000 period.

Crop loan rates are assumed to remain constant in real terms at levels which have prevailed over the most recent past. Loan rates are set at $2.08 per bushel for corn, $2.46 per bushel for wheat, $4.50 per bushel for soybeans, and $.48 per pound for cotton lint.

Table 4. Projected levels of military consumption for beef, pork, lamb and mutton, chicken, and turkey for 1980, 1990, and 2000, with actual 1974-76 averages for comparison

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>239.7</td>
<td>277.8</td>
<td>288.1</td>
<td>289.0</td>
</tr>
<tr>
<td>Pork</td>
<td>94.0</td>
<td>90.5</td>
<td>99.7</td>
<td>103.6</td>
</tr>
<tr>
<td>Lamb and mutton</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Chicken</td>
<td>35.3</td>
<td>44.3</td>
<td>51.4</td>
<td>53.2</td>
</tr>
<tr>
<td>Turkey</td>
<td>17.0</td>
<td>27.5</td>
<td>29.6</td>
<td>31.3</td>
</tr>
</tbody>
</table>

above loan rates are expressed in 1978 dollars and represent a 1977-78 average for corn, a 1976-78 average for wheat, and the 1978 value for soybeans, and the 1978 value for cotton lint. The cottonseed loan rate is assumed to be zero as it has been since 1971.

Most other government program variables except feed grain, wheat and cotton government payments are set equal to zero over the analysis period. Government payments are assumed to be constant at $224.55, $324.06, and $110.67 million for feed grains, wheat and cotton [18], respectively. These figures are 1974-77 average values expressed in 1978 dollars. Also, the free market dummy variables (FREE1 and FREE2) are included at a level of 0.5 instead of one in most cases. The exceptions occur in the wheat food demand, commercial demand and government inventory equations and the soybean harvested acreage equation where the value of one is retained throughout the analysis period. The free market dummy variables generally are included at values less than one because it is felt that forces which caused shifts in some crop market variables during the mid-1970s will be partially dissipated in the years ahead. The wheat low loan rate dummy (LLRDUM) is continued at a level of one to the year 2000 allowing the quantity of wheat supplies to have an added effect upon the price of wheat.

Other important exogenous variables are either assumed to be constant or to increase at assumed rates. Those remaining variables which are assumed to be constant are RFC (range feed conditions in 17 western states) which take on a value of 76.64 (1953-76 variable mean), and the
byproduct allowances for beef, pork, and lamb which are set at their 1953-76 variable means in 1978 dollars of 9.91, 7.12, and 14.44 cents per pound, respectively. The polyester price is assumed to be constant at its 1972-76 average of 57.77 cents per pound in 1978 dollars.

Table 5 gives projected levels of certain other important exogenous variables. The Consumer Price Index 1967 = 100 (CPI) is assumed to grow at President Carter's original guideline rate of 5.75 percent per year and the index of prices paid by farmers 1967 = 100 (IPPBF) is assumed to increase at a rate of 6 percent because it traditionally has increased faster than CPI.

Growth rates for personal disposable income in 1967 dollars (INC), personal disposable income per capita in 1967 dollars (PINC), and civilian population (POP) are taken from the OBERS projections [U.S.

Table 5. Assumed levels of other important exogenous variables for 1980, 1990, and 2000, with 1976 actual values for comparison

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI (1967 = 100)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>170.5</td>
<td>218.6</td>
<td>382.5</td>
<td>668.8</td>
</tr>
<tr>
<td>IPPBF (1967 = 100)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>201.0</td>
<td>259.6</td>
<td>464.8</td>
<td>832.4</td>
</tr>
<tr>
<td>INC (b'il. $)&lt;sup&gt;a,d&lt;/sup&gt;</td>
<td>693.1</td>
<td>791.7</td>
<td>1,124.2</td>
<td>1,596.3</td>
</tr>
<tr>
<td>PINC ($)&lt;sup&gt;a,d&lt;/sup&gt;</td>
<td>3,222.0</td>
<td>3,573.8</td>
<td>4,714.4</td>
<td>6,311.2</td>
</tr>
<tr>
<td>POP (mil.)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>213.0</td>
<td>222.0</td>
<td>224.5</td>
<td>262.3</td>
</tr>
<tr>
<td>W(MA4)&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>2.95</td>
<td>3.05</td>
<td>4.40</td>
<td>3.58</td>
</tr>
</tbody>
</table>

<sup>a</sup>SOURCE: [Bureau of Economic Analysis, 1977].

<sup>b</sup>SOURCE: [U.S. Department of Agriculture, 1976].

<sup>c</sup>SOURCE: [Bureau of Census, 1976].

<sup>d</sup>These variables are deflated by CPI (1967 = 100).
Water Resources Council, 1974]. Disposable income and disposable income per capita are assumed to grow at the same rate as personal income and personal income per capita. Military population is subtracted from the OBERS population projections to arrive at civilian population which is used in this study. The annual time series for INC, PINC, and POP are derived from the OBERS projections by calculating annual growth rates. For example, growth rates in population between 1980 and 1985 were calculated by the following formula:

$$1 + r = \text{antilog} \left( \frac{\ln \text{POP}_{85} - \ln \text{POP}_{80}}{5} \right)$$

$$= \text{antilog} \left( \frac{\ln 234.52 - \ln 223.53}{5} \right) = 1.009645$$

(23)

This growth rate is assumed to hold between 1980 and 1985. New growth rates are calculated between 1985 and 1990 and between 1990 and 2000. The annual growth rates of personal and per capita personal income are calculated in the same fashion.

The three year moving average of the hourly wage rate of meat manufacturing employees deflated by CPI (W MA4)) is assumed to grow at a rate of 0.81 percent per year which is the 1961-67 average rate of growth in this variable.

Other assumptions relating to the Base

In the model, the quantity supplied equals the quantity demanded. In the livestock submodels, civilian consumption is determined by an identity which embodies this requirement. The same condition is imposed
upon the crop commodities by the total inventory identity which requires that total ending inventory to be equal to supply minus noninventory demand.

An additional restriction placed upon the crop submodels is that ending inventories cannot fall below assumed pipeline levels. Government inventories are constrained to be greater than or equal to zero and total inventories are restricted to be greater than two-thirds of their historical lows for 1962-77. These lower bounds on total inventories are assumed to be 11.2 million tons, 164.9 million bushels, 19.8 million bushels, and 1.9 million bales for feed grains, wheat, soybeans, and cotton, respectively.

Adjustments of the Base simulation for the alternatives analyzed

For all alternatives, it is assumed that feed grain and soybean exports decrease in the initial year of the embargo by 1/3 of the amount on contract for purchase by Russia. For wheat, the entire embargoed quantity is reduced from exports as it is assumed that wheat is removed from the market and used for other purposes not affecting future markets through for example the PL-480 program. Thus, exports for all alternatives are reduced by 3.95 million tons of feed grains, 14.77 million bushels of soybeans, and 166.75 million bushels of wheat. Additionally, it is assumed that the feed grains can reenter the market; thus coming out of storage when the corn price is equal to 150 percent of the loan rate. The 3.95 million tons of feed grains, if this corn price is attained, is added to the total inventory (PTINV) equation

\[ PTINV = PSUPPLY - PTDEM + 3.95 \]
This has the effect of depressing the market as inventories, in the year in which the corn is released, increase the quantities available for consumption in the next year. Finally, for Alternatives I, II, III, and IV it is assumed that in the 2nd year of the embargo, wheat is treated similarly to feed grains and soybeans.

Export alternatives

All of the alternatives examine different assumptions about how the export market reacts after the embargo. Each of the four alternatives requires subtraction of the amount soybeans, wheat, and feed grains affected by the grain embargo from the Base level exports in the first year. The quantity subtracted in the initial year is derived based on the assumption that 2/3 of the quantity embargoed will still be exported to other countries for reasons expounded upon in Chapter I. The entire quantity of embargoed wheat is subtracted from the Base export level as the wheat is placed in the PL 480 program. Levels of exports for feed grains, soybeans, and wheat are reflected in Table 6.

The adjustments in the export level of feed grains, soybeans, and wheat are made through the equation

\[
NWEXP_j = BEXP_j - \sum_{j=1}^{3} \frac{EMB_j}{NYR_j} \times (I - 31)
\]

where:

NWEXP is the new export level; BEXP is the base export level; EMB is quantity of embargoed quantity; NYR is the number of years the impact of the embargo is felt; and I is an index of the year where I = 31 indicates that the model is in the 1979 growing season.
Table 6. Projected exports for feed grains, wheat, soybeans, cotton lint, and tobacco for growing seasons 1980-2000

<table>
<thead>
<tr>
<th>ALTERNATIVE</th>
<th>BASE</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>YEAR</strong></td>
<td>FEED GRAINS (MIL. TCNS)</td>
<td>WHEAT (MIL. BUSHELS)</td>
<td>SOYBEANS (MIL. BUSHELS)</td>
<td>COTTON LINT (MIL. BALES)</td>
<td>TOBACCO (MIL. POUNDS)</td>
</tr>
<tr>
<td>1980</td>
<td>67.47</td>
<td>63.53</td>
<td>67.47</td>
<td>64.84</td>
<td>64.84</td>
</tr>
<tr>
<td>1981-1985</td>
<td>70.74</td>
<td>66.79</td>
<td>70.74</td>
<td>70.47</td>
<td>72.05</td>
</tr>
<tr>
<td>1986-1990</td>
<td>76.18</td>
<td>72.23</td>
<td>76.18</td>
<td>76.18</td>
<td>80.12</td>
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<tr>
<td>1991-1995</td>
<td>81.62</td>
<td>77.68</td>
<td>81.62</td>
<td>81.02</td>
<td>85.57</td>
</tr>
<tr>
<td>1996-2000</td>
<td>87.06</td>
<td>83.12</td>
<td>87.06</td>
<td>87.06</td>
<td>91.01</td>
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<tr>
<td>1979-2000</td>
<td>77.81</td>
<td>73.87</td>
<td>77.81</td>
<td>77.45</td>
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</tr>
<tr>
<td>1980</td>
<td>129.30</td>
<td>1066.96</td>
<td>129.30</td>
<td>1192.24</td>
<td>1192.24</td>
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<tr>
<td>1981-1985</td>
<td>1283.56</td>
<td>1061.23</td>
<td>1283.56</td>
<td>1279.85</td>
<td>1302.09</td>
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<td>1986-1990</td>
<td>1367.87</td>
<td>1145.33</td>
<td>1367.87</td>
<td>1367.87</td>
<td>1423.45</td>
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<tr>
<td>1991-1995</td>
<td>1451.47</td>
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<td>1451.47</td>
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<tr>
<td>1996-2000</td>
<td>1535.67</td>
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<td>1535.67</td>
<td>1535.67</td>
<td>1590.65</td>
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<tr>
<td>1979-2000</td>
<td>1392.06</td>
<td>1172.25</td>
<td>1392.06</td>
<td>1392.06</td>
<td>1424.91</td>
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<tr>
<td>1980</td>
<td>788.30</td>
<td>773.52</td>
<td>788.30</td>
<td>778.45</td>
<td>778.45</td>
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<tr>
<td>1981-1985</td>
<td>851.55</td>
<td>837.18</td>
<td>851.55</td>
<td>850.97</td>
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</tr>
<tr>
<td>1986-1990</td>
<td>958.05</td>
<td>943.28</td>
<td>958.05</td>
<td>958.05</td>
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</tr>
<tr>
<td>1991-1995</td>
<td>1064.15</td>
<td>1049.37</td>
<td>1064.15</td>
<td>1064.15</td>
<td>1078.92</td>
</tr>
<tr>
<td>1996-2000</td>
<td>1170.24</td>
<td>1155.47</td>
<td>1170.24</td>
<td>1170.24</td>
<td>1185.02</td>
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<tr>
<td>1979-2000</td>
<td>989.89</td>
<td>975.11</td>
<td>989.89</td>
<td>988.54</td>
<td>999.95</td>
</tr>
<tr>
<td>1980</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
</tr>
<tr>
<td>1981-1985</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
</tr>
<tr>
<td>1986-1990</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
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</tr>
<tr>
<td>1991-1995</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
</tr>
<tr>
<td>1996-2000</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
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<td>4.76</td>
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<td>1979-2000</td>
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<tr>
<td>1981-1985</td>
<td>701.52</td>
<td>701.52</td>
<td>701.52</td>
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<td>701.52</td>
</tr>
<tr>
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This equation is used in all six of the alternatives. Throughout all alternatives, EMB for feed grains, soybeans, and wheat equals 3.95 million tons, 14.77 million bushels, and 166.75 million bushels, respectively. The BEXP is as stated in equations 9, 10, and 11.

**Base Alternative:** This alternative is the Base run and assumes that the embargo did not take place. Thus, all of the other alternatives are compared to this simulated run.

**Alternative I:** The one year continued alternative assumes that a parallel shift downward of the projected base exports occurs during the entire period of analysis. This assumption requires a modification in equation (24). The modification was made by setting \((EMB/NYR) = 0\) and letting \(I = 31, 32, \ldots, 52\). This modification results in the subtraction of 3.95, 14.77, and 166.75 for feed grains, soybeans, and wheat, respectively, from the base level of exports for the 1979-2000 growing seasons.

**Alternative II:** This alternative assumes that the export levels for the commodities impacted by the embargo recover after the 1979 growing season. Thus, the level of exports in the second year following the embargo is at the Base level of exports for the affected commodities. The variables in equation (24) are \(NYR = 1\) and \(I = 31\), thus the equation collapses to

\[
NWEXP_j = BEXP_j - EMB_j; \tag{25}
\]

for the growing 1979 season and for the 1980 growing seasons and beyond

\[
NWEXP_j = BEXP_j.
\]
Alternative III: This alternative assumes the export levels reach the Base levels in the 1982 growing season. Thus, variables in equation (24) are adjusted so that NYR = 3 and I = 31, 32, 33, and 34 for the 1979, 1980, 1981, and 1982 growing seasons.

Alternative IV: This alternative is somewhat different from the other alternatives in that exports increase above the level of exports established in the Base Run. For the first three growing seasons after the embargo, the exports are as those in Alternative III. However, the next three growing seasons reflect increasing exports above the Base run. This is done by using equation 24 and setting I = 31, 32, 33, 34, 35, and 36. Once I = 37, then NWEXP_j = BEXP_j + EMB_j. This results in a parallel shift upward in the projected export level by the embargoed amount for the 1985-2000 growing seasons.
CHAPTER III. GRAIN EMBARGO RESULTS

Direct and indirect impacts occur throughout the agricultural sector as a result of the Russian grain embargo. The direct impacts occur in the feed grain, soybean, and wheat sectors, while the indirect impacts occur in all sectors included in the model with the exception of the tobacco sector.¹

Factors analyzed in this chapter include production of beef, pork, poultry, feed grains, wheat, soybeans, and cotton, the estimated farm price of the mentioned commodities, estimated inventories for feed grains, wheat, and soybeans, and average U.S. agricultural farm output expenditures, gross income, and net income. Some additional variables for the feed grain sector are analyzed including per acre fertilizer expenditures and end-of-year machinery stock. These variables are analyzed for all of the alternatives mentioned in Chapter II.

Agricultural Production

Agricultural production is divided into two areas — livestock and crop commodities. For the purpose of this report, livestock commodities examined include beef, pork, and poultry, while the crop commodities include feed grains, soybeans, wheat, and cotton.

¹As previously mentioned, the tobacco sector is independent of all other sectors in the model used in the analysis.
Livestock production

In the Base Run, average annual production between 1979 and 2000 is 32.25, 13.80, and 14.36 billion pounds carcass weight for beef, pork, and ready-to-cook chicken, respectively [Table 7]. As the embargo is prolonged, the production of these commodities increases from the Base, resulting from the impact that the embargo has on commodity prices.

The largest increases from the Base in the livestock commodity production occur when the embargo is continued throughout the period of analysis. An annual average production increase of 532, 336, and 159 million pounds occurs for beef, pork, and chicken, respectively.

As mentioned before, Alternative IV actually requires an increase in the overall production of feed grains. This increase results in a decrease (115, 130, and 55 million pounds respectively for beef, pork, and chicken) in livestock production when compared to the Base run. Thus, the increased exports act to decrease the production for the remainder of the period of analysis. For pork production, an annual average increase of 107 million pounds occurs during the 1981-1985 period and a very slight increase in poultry production occurs during this same period. For both pork and poultry production, a decrease is seen over the remainder of the analytic period.

Crop production

The initial impact of the grain embargo is to increase the amount of land used in production of feed grains (120 thousand acres) and to decrease the acres used to produce soybeans and wheat (60 and 120 thousand
Table 7. Estimated average beef, pork, lamb, chicken, and turkey production by alternative for growing seasons 1980-2000

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acres, respectively). There is virtually no change in the cotton acres in production [Table 8]. However, in examining the production of these commodities, feed grain, soybeans, and wheat production decreases while cotton production shows a modest increase [Table 9]. The decrease in feed grain production reflects a decrease in input use other than land.

Feed grains: The Base projects an average of 97 million acres harvested each year during the period of analysis ranging from a high of 100 million acres in the 1980 growing season to an average annual 95 million acres during the period 1991-1995. The same trend of decreasing acres harvested in the period 1980-1995 occurs throughout all embargo alternatives. When compared to the Base all of the alternatives reflect an increase in acres harvested during the 1980 growing season.

Feed grain production decreases throughout the period of analysis for Alternatives I, II, and III. Only Alternative IV reflects an increase in production. The largest decrease of 3.38 million tons per year in feed grain production occurs when the export levels are continuously restricted over the entire period (Alternative I).

Two input variables reflecting farmers' reactions in input usage are per acre fertilizer expenditures and machinery expenses used in crop production [Tables 10, 11]. The impact of the grain embargo has an immediate effect on the amount of fertilizer applied on each acre in feed grains. Approximately $0.26 per acre less is spent on fertilizer than in the Base. Additionally, less fertilizer is used in the first four embargo alternatives than in the Base with an average annual fertilizer expenditures during the period of analysis declining $2.76 per acre under Alternative I. The
Table 8. Estimated average harvested acreage for feed grains, wheat, soybeans, cotton, and tobacco by alternative for growing seasons 1980-2000

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Table 9. Estimated average feed grains, wheat, soybean, cotton lint, and tobacco production by alternative for growing seasons 1980-2000

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Table 10. Estimated U.S. crop fertilizer and lime expenses per harvested acre for feed grains, wheat, soybeans, cotton, and tobacco by alternative for growing seasons 1980-2000

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other alternatives show somewhat more modest changes with Alternative IV showing the only annual average increase in fertilizer expenses when compared to the Base.

Per acre machinery costs for feed grains decrease slightly ($0.05/acre) during the initial year of the embargo. As might be expected, machinery expenses' decreases are much larger in the longer term analysis since a large portion of the machinery expense for next year is already in position this year. Thus, in Alternative I when compared to the Base, an average annual decrease during the entire period of the study of $1.68 per acre occurs [Table 11]. While feed grain machinery expense declines, labor expense increases only slightly in Alternative I [Table 12]. The other alternatives show similar patterns but with much less impact on machinery expense. These results illustrate the farmers' response to prices. For feed grain farmers, an increase in acreage and decreases in other inputs represents their response to the depressed prices that occur as a result of increasing inventories and less demand.

As one might expect, with a decrease in input use, yields decline. The crop yields solved in the model are shown in Table 13.

Soybeans: The impacts of the grain embargo on soybean acres harvested and production are minimal [See Tables 8 and 9]. The Base projects that the average annual acres harvested during the period of analysis is 73.6 million acres. The trends of the impacts are not similar to that of feed grains in that soybean annual average acreage increases only in Alternative IV. The other alternatives show either a slight
Table 12. Estimated U.S. crop labor per harvested acre for feed grains, wheat, soybeans, cotton, and tobacco by alternative for growing seasons 1980-2000

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Table 13. Estimated U.S. crop yields for feed grains, wheat, soybeans, cotton lint, and tobacco by alternative for growing seasons 1980-2000

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<td><strong>COTTON LINT (BALES/ACRE)</strong></td>
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decrease of 20 thousand acres, or no change at all. Only when exports are extended above the Base level (Alternative IV), does soybean acreage increase.

Average production changes in the same direction. Thus, unlike the feed grain situation where in some instances production decreased although acreage increased, soybean acreage and soybean production act in unison. The initial impact of the embargo is to reduce production by 2.1 million bushels in the 1980 growing season. Even though trade is reduced by 14.8 million bushels, the farmers response is to reduce production by only 2.1 million bushels. In Alternative I where a reduction in the Base level of exports of 14.8 million bushels is assumed throughout the period of analysis, production declines by an average of 3.62 million bushels or a 0.15 percent decrease in total production during the 20 years. The largest annual five year decrease for this alternative occurs during the 1996-2000 growing seasons where the average decrease in production is 16.31 million bushels. As might be expected after examining these results, little change occurs in input usage or yields as a result of the embargo.

Since the embargo decreased total demand by 0.8 percent after the expected redirection of trade occurs, it should be expected that soybean farmers would not see much of a long-term impact.

Wheat: An average of 58.8 million acres of wheat are planted during each growing season within the period of analysis ranging from a five year average low of 57.7 to a high of 59.7 million acres during the 1991-1995 and 1981-1985 growing seasons, respectively [See Table 8]. There is very little long run impact on wheat acreage harvested resulting
from the grain embargo. Only Alternative IV shows an increase in the
harvested acres of 25 thousand acres. The largest decrease in harvested
wheat acres of 2,810 thousand acres occurs in Alternative I.

The farmers initial response to the embargo is to decrease wheat
production almost 5 million bushels during the 1980 growing season [See
Table 9]. The continued embargo throughout the 21 years of analysis
(Alternative I) has the largest impact on wheat production with a decrease
of more than 168 million bushels. The other alternatives, with the
exception of Alternative IV, show a modest decrease in production.
Alternative IV projects an average wheat production increase of over 19
million bushels per year in the analysis.

Cotton production: Cotton is not directly affected by the grain
embargo. Thus, changes in production only occur through the interrela-
tionships between the affected commodities and cotton. The average
change in production is less than 230 thousand bales plus and minus in
either direction [See Table 9]. The grain embargo has little impact
on national cotton production. One interesting result, however, is that
Alternatives I, II, and III show an increase in cotton production where
as Alternative IV shows a slight decline of 60 thousand bales. This
illustrates a possible response by the farmers to depressed agricultural
prices. In areas where climate permits, additional acres are planted
in cotton that were previously in feed grains, soybeans, or wheat.
Crop and Livestock Prices

The grain embargo has a large impact on agricultural prices. Prices analyzed in this section include beef, pork, poultry, feed grain, soybeans, wheat, and cotton.

**Beef price**

The average Base beef price during the 1980-2000 growing seasons is $134.55 per carcass cwt.\(^2\) ranging from a five year average low of 128.53 in the 1986-1990 growing season to a high of 142.68 during the years 1996-2000 [Table 14]. There is only a slight increase of $0.01 per carcass cwt. in the first year following the embargo; however, there are much larger longer-term impacts over the span of the analysis, when compared to the Base the carcass beef price changes -8.98, -0.79, -1.38, and 2.04 dollars per cwt. for Alternatives I, II, III, and IV respectively.

As the price of grain decreases, livestock production increases and the price of livestock decreases as supplies build.

**Pork price**

The five year average carcass pork price in the Base run ranges from $88.03 to $81.09 with an average price over the 21 years of 84.42 [Table 14]. In all of the runs where total grain exports are less than the Base (Alternatives I, II, and III), the average annual carcass pork prices are less than the Base while Alternative IV has a higher price.

\(^1\)All prices in this section are in 1978 dollars.

\(^2\)Hundredweight.
Table 14. Estimated U.S. livestock and Poultry farm prices by alternative for growing seasons 1980-2000

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ALTERNATIVE</th>
<th>BEEF ( /POUND)</th>
<th>PORK ( /POUND)</th>
<th>LAMB ( /POUND)</th>
<th>CHICKEN ( /POUND)</th>
<th>TURKEY ( /POUND)</th>
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</thead>
<tbody>
<tr>
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<td>140.46</td>
<td>57.39</td>
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<td>140.46</td>
<td>57.29</td>
<td>57.29</td>
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<tr>
<td>1986-1990</td>
<td>III</td>
<td>140.65</td>
<td>87.07</td>
<td>143.75</td>
<td>35.04</td>
<td>57.29</td>
</tr>
<tr>
<td>1991-1995</td>
<td>IV</td>
<td>130.92</td>
<td>82.02</td>
<td>140.75</td>
<td>35.04</td>
<td>57.29</td>
</tr>
<tr>
<td>1996-2000</td>
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<td>131.40</td>
<td>82.09</td>
<td>138.28</td>
<td>35.04</td>
<td>57.29</td>
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<tr>
<td>1979-2000</td>
<td></td>
<td>131.18</td>
<td>83.07</td>
<td>135.89</td>
<td>35.04</td>
<td>57.29</td>
</tr>
</tbody>
</table>
The decrease (increase) illustrates the farmers' response to input costs. As feed costs decrease, the farmers increase their production. As production increases, movement down the demand curve occurs and lower prices result. The largest average decrease ($7.15 per cwt.) occurs when the embargo is continued throughout the analysis [Alternative I].

**Poultry price**

As with other livestock prices, the poultry price is less for the alternatives reflecting lower exports. In the Base, five year average poultry prices range from $31.39 to $38.20 per ready-to-cook (rtc) cwt. with the annual average price of $34.61 per rtc cwt. [See Table 14]. As exports decrease, the price for poultry decreases with the lowest price occurring in Alternative I. The price response in the poultry sector is much more rapid than the other livestock commodities, due primarily to biological conditions inherent in poultry production but not in other livestock types.

**Feed grain price**

In the Base run, real feed grain prices decrease over time from a high of $82.20 per ton in 1980 to an average low of $67.03 per ton during the years 1991-1995 with an average price of $72.73 per ton over the span of the analysis [Table 15]. In the first year after the embargo, prices range from $80.63 per ton in Alternative II to $79.38 per ton in Alternative I; decreases of $1.67 per ton to $2.92 per ton, respectively. The average price over the entire 21 year period ranges from $76.89 per ton in Alternative IV to a low of $63.85 per ton under Alternative I with the Base price at $72.73 per ton.
Table 15. Estimated U.S. crop prices received by farmers by alternative for growing seasons 1980-2000

<table>
<thead>
<tr>
<th>YEAR</th>
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<th>II</th>
<th>III</th>
<th>IV</th>
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<tr>
<td>FEED GRAINS ($/TON)</td>
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<td>72.07</td>
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<td>SOYBEANS ($/BUSHEL)</td>
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<td>128.30</td>
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</table>
Soybean price

The soybean price is moderately affected when the embargo is imposed. (A decrease when compared to the Base of $0.26 per bushel occurs under Alternative I). An average per bushel decrease of $1.06 is projected under Alternative I. Thus, over the entire period of analysis assuming the average per acre yield of 31.39 bushels per acre a decrease in gross receipts of nearly $700 per acre over the 21 year time span or an average of $33.27 per acre per year.

Wheat price

The base indicates an average wheat price of $2.20 per bushel over the period of analysis with five year average prices ranging from $2.53 to $2.02 per bushel during the respective 1981-1985 and 1991-1995 time periods [Table 15]. Only two of the alternatives have greatly affected wheat prices -- I and IV with average prices of $1.60 and $2.34 per bushel, respectively. In the initial year following the embargo, wheat prices for all alternatives are depressed, with Alternatives I, II, and III being depressed throughout the analysis.

Cotton price

The grain embargo initially decreases the cotton price with results indicating a $0.03 per cwt. decrease in the 1980 growing season [Table 15]. The average Base price is $56.06 per cwt. with the alternatives showing modest changes with the maximum increase of $0.36 per cwt. for the Alternative IV and a decrease of $2.63 per cwt. for Alternative I.
Inventories

Another aspect of the embargo is its effect on the inventories of feed grains, soybeans, and wheat. It must be emphasized that with feed grain inventories, it is assumed that a minimum of 11.2 million tons must be available for the next year's use.¹ (Historically, this is 2/3 of the lowest quantity in the past 30 years.) Thus, even though 11.2 million tons are available for use, the model assumes that these must be maintained and not consumed; thus, movement up the demand curve is assumed and the market is cleared. This occurs only in the last three years of Alternative IV's solution.

The Base run projects that average inventories will be 42.0 million tons, 142.3 million bushels, and 796.9 million bushels for feed grains, soybeans, and wheat, respectively [Table 16]. In comparing all alternatives with the Base, the average annual end-of-year inventories increase the most for Alternative I and decrease the most for Alternative IV for feed grains, soybeans, and wheat. Feed grain inventories increase to an overall average of 61.35 tons per year in Alternative I an average increase of 19.32 tons. To put this in perspective in the past 20 years, the largest corn grain inventories held by the U.S. farmers, commercial firms, and government totalled 2,016 million bushels or 56.45 million tons [U.S. Department of Agriculture, 1978].

¹ Minimum inventories are required so that feeding, processing, and exports can be maintained until new crop supplies are readily available.
Table 16. Estimated U.S. crop total ending inventories by alternative for growing seasons 1980-2000

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ALTERNATIVE</th>
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<th>II</th>
<th>III</th>
<th>IV</th>
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<td>FEED GRAINS (MIL. TONS)</td>
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<tr>
<td>1986-1990</td>
<td>11.07</td>
<td>13.91</td>
<td>11.20</td>
<td>11.29</td>
<td>10.83</td>
<td></td>
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<tr>
<td>1596-2000</td>
<td>5.47</td>
<td>8.68</td>
<td>3.34</td>
<td>5.38</td>
<td>4.38</td>
<td></td>
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<tr>
<td></td>
<td>T03 ACCU (MIL. POUNDS)</td>
<td></td>
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</tr>
<tr>
<td>1981-1985</td>
<td>4474.59</td>
<td>4474.59</td>
<td>4474.59</td>
<td>4474.59</td>
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<tr>
<td>1986-1990</td>
<td>5103.93</td>
<td>5103.93</td>
<td>5103.93</td>
<td>5103.93</td>
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<tr>
<td>1996-2000</td>
<td>5264.60</td>
<td>5264.60</td>
<td>5264.60</td>
<td>5264.60</td>
<td>5264.60</td>
<td></td>
</tr>
<tr>
<td>1979-2000</td>
<td>4554.98</td>
<td>4954.98</td>
<td>4954.98</td>
<td>4954.98</td>
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Farm Income

The analysis of the Russian Grain Embargo would not be complete without examining agricultural's input expenditures, gross receipts, and finally net income. Aggregate farm input expenditures do not significantly change when comparing the Base to other alternatives. The Base run indicates that an average of $113 billion is spent annually on inputs by U.S. agriculture [Table 17]. Less than a plus (minus) 1 percent change is seen throughout the alternative.

Gross income fluctuates widely with Alternative I projecting a decrease from the Base of $9.0 billion. Additionally, Alternative IV tends to increase the gross income received by U.S. farmers by a very slight margin.

With input expenditures remaining relatively constant and gross income fluctuating, as might be expected, net income also fluctuates. In the Base, U.S. agriculture has a net income of $30.1 billion per year over the entire span of the analysis with a range of $26.7 billion to $35.8 billion in the 1986-1990 and 1996-2000 periods, respectively.

However, a decrease in net income when compared to the Base of 27.6, 1.9, and 3.3 percent is projected for Alternatives I, II, and III. Net farm income increases, however, for the other alternative. The increase for Alternative IV is $2.77 billion or a 9.2 percent increase in net farm income.

1 Note that this section includes all of U.S. agriculture with projections of expenses and income for the exogenous commodities.
Table 17. Estimated aggregate U.S. income variables by alternative for growing seasons 1980-2000

<table>
<thead>
<tr>
<th>YEAR</th>
<th>BASE</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
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<tr>
<td>1980</td>
<td>1062.34</td>
<td>1062.34</td>
<td>1062.34</td>
<td>1062.34</td>
<td>1062.34</td>
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<tr>
<td>1981-1985</td>
<td>1053.46</td>
<td>1053.76</td>
<td>1053.73</td>
<td>1053.75</td>
<td>1053.75</td>
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<tr>
<td>1986-1990</td>
<td>1040.85</td>
<td>1041.08</td>
<td>1041.07</td>
<td>1041.14</td>
<td>1041.14</td>
</tr>
<tr>
<td>1991-1995</td>
<td>1028.91</td>
<td>1029.02</td>
<td>1029.03</td>
<td>1029.05</td>
<td>1029.05</td>
</tr>
<tr>
<td>1996-2000</td>
<td>1017.68</td>
<td>1017.72</td>
<td>1017.72</td>
<td>1017.76</td>
<td>1017.76</td>
</tr>
<tr>
<td>1979-2000</td>
<td>1038.04</td>
<td>1038.04</td>
<td>1038.04</td>
<td>1038.04</td>
<td>1038.04</td>
</tr>
</tbody>
</table>

ACREAGE IN FARMS (MIL. ACRES)

PRODUCTION EXPENSES (MIL. DOLLARS)

GROSS INCOME (MIL. DOLLARS)

NET INCOME (MIL. DOLLARS)
CHAPTER IV. CONCLUSIONS

The purpose of this report is not to question the embargo policy but rather to illustrate some of the potential longer-term impacts that might occur in the agricultural sector of the United States. Pending the alternative examined, the Russian grain embargo may or may not have significant long-term impacts on U.S. agriculture.

This analysis examines four alternatives, reflecting different export assumptions. The alternatives are developed to reflect different assumptions following the embargo. One might speculate that (a) the embargo would be lifted and the Soviet Union will readily enter the U.S. grain market (Alternative II) or (b) due to lower prices, other countries might gradually increase their purchases of U.S. agricultural commodities (Alternative III), or (c) the embargo would be extended indefinitely (Alternative I), or lastly (d) as a result of the increasing purchases by other countries, when the embargo is lifted and the Soviet Union enters the market the other countries will not leave (Alternative IV). These alternatives are designed to provide parameters to allow the reader to form their opinions as to the likely impacts of the embargo.

Alternative I and Alternative II are included in the analysis as extreme possibilities. The actual impacts will likely lie between these alternatives. The worst situation, as far as U.S. agriculture is concerned, is Alternative I. This alternative projects a large decrease in net
farm income. Inventories increase 46 percent for feed grains, 57 percent for soybeans and 45 percent for wheat when compared to the Base. These inventories and the decrease in net farm income indicate that greater government presence would be required in the agricultural sector. Because of the large impacts encountered and the projected low prices, it would seem that this alternative is very unlikely. Prices are depressed to such an extent that other countries are likely to enter the U.S. market thus increasing exports and prices and decreasing inventories.

It seems unlikely at this time that the embargo would be lifted after one year of enforcement. Even if it were, the Soviet Union has found other grain markets and would be unlikely to enter the U.S. market with the same strength that it had before the embargo. It, therefore, seems unlikely that the Alternative II with its minimal impacts would result.

Livestock production increases under the embargo alternatives due to the depressed feed grain prices. In addition, livestock prices fall as more livestock is available for consumption. Thus, a movement down the demand curve occurs.

Finally, it is difficult to examine the exact impacts of the Russian Grain Embargo using an exogenous export sector. Thus, this analysis, while using a model positive in nature may not predict all of the "real" impacts of the Grain Embargo. Rather, it examines some possible alternatives and projects the impacts based on the assumptions made for these alternatives. In addition, the model is not capable of analyzing short term fluctuations as a result of the grain embargo. Quarterly models should be used to analyze the short term impact on the agricultural sector.
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APPENDIX A. CROP EQUATIONS

(1) \[ \frac{\partial}{\partial t} \left( \rho \vec{v} \right) + \nabla \cdot (\rho \vec{v} \otimes \vec{v}) = -\nabla p + \nabla \cdot \tau + \rho \vec{g} \]

(2) \[ \rho \vec{E} = \vec{E}_{0} + \nabla \phi \]

(3) \[ \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = 0 \]

(4) \[ \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = 0 \]

(5) \[ \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = 0 \]
Feed Grain Submodel

Feed Grain Pre-input Equations

\[ \text{FG-AC}_t = 145.3231 - 0.7730 \times \text{TIME}_t - 214.869 \times \text{SB-PR}^2_{t-1} / \text{FG-PR}^2_{t-1} \]  
\[ - 0.2039 \times \text{FG-ACDIV}_t - 157.184 \times \text{WPRD}^3_{t-1} / \text{FG-PR}^2_{t-1} - 8.4538 \times \text{D}6170_{t} \text{, SLS.} \]  
\[ (5.77) \]  
\[ (1.72) \]  
\[ (2.13) \]  
\[ (4.09) \]  
\[ (3.37) \]  

\[ \text{FG-STK}_t = 7360.8227 - 518.2067 \times \text{BLIGHT}_t - 550.3262 \times \text{FREE}_1^t \]  
\[ - 49.5848 \times \text{FG-PR}^t_{t-1} - 0.2906 \times \text{FG-STK}^t_{t-1} \text{, SLS.} \]  
\[ (2.35) \]  
\[ (2.83) \]  
\[ (5.77) \]  
\[ (1.50) \]  

\[ \text{FG-STKAVE}_t = (\text{FG-STK}_t + \text{FG-STK}^t_{t-1}) / 2, \]  
\[ (3) \]  

\[ \text{FG-MPUR}_t = 4816.5781 - 24242.0890 \times \text{MHPI}^t_{t-1} / \text{FG-PR}^t_{t-1} - 2280.3414 \times \text{MSPI}_t \]  
\[ - 0.0841 \times \text{FG-MSTK}^t_{t-1} - 6.7694 \times \text{FG-ACDIV}_t - 170.4906 \times \text{D}6871_{t} \]  
\[ + 0.4409 \times \text{FG-MPUR}^t_{t-1}, \text{ OLS,} \]  
\[ (1.79) \]  
\[ (3.18) \]  
\[ (1.82) \]  
\[ (2.10) \]  
\[ (3.37) \]  

\[ R^2 = .738, \text{ MSE} = 15088.5363, \text{ DW} = 2.4348. \]  

\[ \text{FG-MSTK}_t / \text{FG-AC}_t = 15.6306 + 3.5614 \times \text{LOGTIME}_t + 0.9604 \times \text{FG-MPUR}_t / \text{FG-AC}_t \]  
\[ (1.76) \]  
\[ (2.06) \]  
\[ + 0.5959 \times \text{FG-MSTK}^t_{t-1} / \text{FG-AC}^t_{t-1}, \text{ OLS,} \]  
\[ (3.79) \]  

\[ R^2 = .8973, \text{ MSE} = 10.6270, \text{ DW} = 2.0670. \]  

\[ \text{FG-MSTK}_t = (\text{FG-MSTK}_t / \text{FG-AC}_t) \times \text{FG-AC}_t. \]  
\[ (6) \]  

\[ \text{FG-MSTKAVE}_t = (\text{FG-MSTK}_t + \text{FG-MSTK}^t_{t-1}) / 2. \]  
\[ (7) \]
\[
\text{FG-PRLA}_t = 0.1401 + 0.0206 \cdot \text{TIME}_t + 0.4329 \cdot \text{FG-PRLA}_{t-1}, \quad \text{OLS,} \quad R^2 = 0.9563, \quad \text{MSE} = 0.0036, \quad \text{DW} = 1.7534.
\]

\[
\text{FG-VALA}_t = 290.84 \cdot \text{FG-AC}_t \cdot \text{FG-PRLA}_t.
\]

\[
\text{FG-SPA}_t = \text{FG-STKAVE}_t + \text{FG-MSTKAVE}_t + \text{FG-VALA}_t.
\]

Feed Grain Input Equations

\[
\text{FG-FERT}_t / \text{FG-AC}_t = 1.0876 + 0.4964 \cdot \text{TIME}_t - 2.8310 \cdot \text{FREE1}_t + 0.0225 \cdot \text{FG-SPA}_t / \text{FG-AC}_t - 335.1750 \cdot \text{FTPI}_t / \text{FG-PR}_t, \quad \text{OLS,} \quad R^2 = 0.9776, \quad \text{MSE} = 0.8037, \quad \text{DW} = 1.728.
\]

\[
\text{FG-FERT}_t = (\text{FG-FERT}_t / \text{FG-AC}_t) \cdot \text{FG-AC}_t.
\]

\[
\text{FG-SEED}_t = -71.3643 + 4.6976 \cdot \text{TIME}_t + 2.1510 \cdot \text{FG-AC}_t, \quad 3SLS.
\]

\[
\text{FG-LABR}_t = -159.465 + 3441.7385 \cdot \text{RECTIME}_t + 5.0908 \cdot \text{FG-AC}_t \quad \text{(5.23)} \quad \text{(9.94)}
\]

\[
+ 0.2232 \cdot \text{FG-LABR}_{t-1} \quad \text{(2.82)}
\]

ALS, \( R^2 = 0.9975, \) MSE = 266.9506, DW = 1.7560, \( \hat{\rho} = 0.4750. \)

\[
\text{FG-MACH}_t = -1310.7563 + 12639.7847 \cdot \text{INTRT}_t + 0.3825 \cdot \text{FG-MSTKAVE}_t \quad \text{(11.98)} \quad \text{(14.13)}
\]

\[
- 0.6050 \cdot \text{FG-MACH}_{t-1}, \quad 3SLS. \quad \text{(6.64)}
\]

\[
\text{FG-REEX}_t = -266.5778 - 102.1867 \cdot \text{LOGTIME}_t + 0.099 \cdot \text{FG-VALA}_t, \quad 3SLS, \quad \text{(1.73)} \quad \text{(19.99)}
\]

\( \hat{\rho} = 0.5327. \quad \text{(3.72)} \)
$FG-\text{FOR}_t = -14.4494 + 40.6780 \times \text{SQRTTIME}_t + 135.4207 \times \text{FREE2}_t$ \hfill (17) \\
- 793.8837 \times \text{DMSPi}_t + 7.8323 \times \text{FG-AC}_t$, OLS, \\
$R^2 = 0.8872, \text{MSE} = 1227.1215, \text{DW} = 2.0786.$

$FG-\text{MISC}_t = 1999.8751 + 65.0083 \times \text{TIME}_t - 414.4160 \times \text{SQRTTIME}_t$ \hfill (18) \\
+ 0.0179 \times \text{FG-SPA}_t - 1231.0886 \times \text{FSPI}_t$, 3SLS. \\
$R^2 = 0.8872, \text{MSE} = 1227.1215, \text{DW} = 2.0786.$

$FG-\text{INT}_t = \text{INTRT}_t \times \text{FG-STKAVE}_t$. \hfill (19) \\
$FG-\text{RETX}_t = \text{FG-VALA}_t \times \text{FG-TXRT}_t$. \hfill (20)

Feed Grain Output Equations

$FG-\text{PRO}_t = \text{FG-AC}_t \times \text{FG-Y}_t$. \hfill (21) \\
$FG-\text{SUPPLY}_t = \text{FG-PRO}_t + \text{FG-TINV} _{t-1} + \text{FG-IMPTS}_t$. \hfill (22)

$FG-\text{PR}_t = 87.5643 + 6.5147 \times \text{FG-LR}_t + 19.5067 \times \text{FREE1}_t$ \hfill (23) \\
- .2624 \times \text{FG-SUPPLY}_t + .1629 \times \text{FG-EXPTS}_t$, 3SLS. \\
$R^2 = 0.9922, \text{MSE} = .0011, \text{DW} = 1.7785.$

$CNPR_t = -0.0475 - .0298 \times \text{FG-PR}_t$, OLS \hfill (24) \\
$R^2 = .9922, \text{MSE} = .0011, \text{DW} = 1.7785.$

$FG-\text{CDEM}_t = 64.7607 - 15.5395 \times \text{FREE2}_t - .9118 \times \text{FG-PR}_t$ \hfill (25) \\
+ 1.4090 \times \text{LV-PR}_t + 3.0271 \times \text{TIME}_t$, 3SLS. \\
$R^2 = 0.9922, \text{MSE} = .0011, \text{DW} = 1.7785.$
\[
\text{FG-TDEM}_t = \text{FG-CDEM}_t + \text{FG-EXPTS}_t. \tag{26}
\]

\[
\text{FG-TINV}_t = \text{FG-SUPPLY}_t - \text{FG-TDEM}_t. \tag{27}
\]

\[
\text{FG-GINV}_t = 4.9073 + 17.4081*\text{FG-LR}_t - 0.4945*\text{FG-PR}_t + 0.8439*\text{FG-TINV}_t, \text{ OLS} \tag{28}
\]

\[
R^2 = 0.8156, \text{ MSE} = 95.5288, \text{ DW} = 1.3432.
\]

\[
\text{FG-CINV}_t = \text{FG-TINV}_t - \text{FG-GINV}_t. \tag{29}
\]

\[
\text{FG-CRPTS}_t = -3990.0923 + .5982*(\text{FG-PRO}_t*\text{FG-PR}_t) + 798.3541*\text{LOGTIME}_t, \text{ ALS} \tag{30}
\]

\[
\hat{\rho} = -.4375, R^2 = .9430, \text{ MSE} = 166507.8824, \text{ DW} = 2.2995.
\]

\[
\text{FG-GINC}_t = \text{FG-CRPTS}_t + \text{FG-GPAY}_t. \tag{31}
\]
Wheat Submodel

Wheat Pre-input Equations

\[
\begin{align*}
WT-AC_t &= 115.8103 - 0.9643 \times WT-ACDIV_t - 0.6298 \times WT-SBAR_t \\
&\quad - 16.259 \times WT-ACATDUMY_t + 6.5580 \times WT-VOLPG_t - 4.5885 \times B-PR_{t-1} / WT-PR_{t-1}' \\
\hat{\rho} &= -0.5561, \text{ A3SLS.} \\
&\quad (2.50)
\end{align*}
\]

\[
\begin{align*}
WT-STK_t &= 5457.1445 - 573.2523 \times \text{LOGTIME}_t - 636.5228 \times WT-PR_{t-1} \\
&\quad + 270.4343 \times WPRD2_t - 221.5677 \times WPRD1_t - 743.3794 \times WT-ACATDUMY_t \\
&\quad - 806.1548 \times DALLOT_t - 446.2281 \times WARI_t + 485.3619 \times D6771_t, \text{ ALS,} \\
R^2 &= 0.8087, \text{ MSE} = 17408.3822, \text{ DW} = 2.4171, \hat{\rho} = -0.2724. \\
&\quad (2.04)
\end{align*}
\]

\[
\begin{align*}
WT-STKAVE_t &= (WT-STK_t + WT-STK_{t-1}) / 2. \\
R^2 &= 0.9428, \text{ MSE} = 743.7564, \text{ DW} = 2.1655.
\end{align*}
\]

\[
\begin{align*}
WT-MPUR_t &= 825.9541 - 176.7295 \times \text{MHPI}_t / WT-PR_{t-1} - 881.8595 \times \text{MSPI}_t \\
&\quad + 9.6818 \times WT-AC_t - 49.2587 \times D6771_t + 0.267 \times WT-MPUR_{t-1}', \text{ OLS,} \\
R^2 &= 0.8673, \text{ MSE} = 5.4735, \text{ DW} = 2.1427.
\end{align*}
\]
WT-MSTK\_t = (WT-MSTK\_t / WT-AC\_t) * WT-AC\_t. 
\( t \)

\( (37) \)

WT-MSTKAVE\_t = (WT-MSTK\_t + WT-MSTK\_t-1) / 2. 
\( t \)

\( (38) \)

WT-PRLA\_t = 0.5064 + 0.0303*TIME\_t, OLS. 
\( t \)

\( (18.10) \)

\( R^2 = 0.9291, MSE = 0.0046, DW = 1.4307. \)

WT-VALA\_t = 170.78*WT-AC\_t * WT-PRLA\_t. 
\( t \)

\( (40) \)

WT-SPA\_t = WT-STKAVE\_t + WT-MSTKAVE\_t + WT-VALA\_t. 
\( t \)

\( (41) \)

Wheat Input Equations

WT-FERT\_t/WT-AC\_t = 2.0999 + 0.1206*TIME\_t + 1.7243*FREE2\_t - 3.0248* 
\( t \)

\( (42) \)

\( R^2 = .9836, MSE = 0.0479, DW = 2.2668, \hat{\rho} = 0.5301. \)

\( (2.88) \)

WT-FERT\_t = (WT-FERT\_t/WT-AC\_t) * WT-AC\_t. 
\( t \)

\( (43) \)

WT-SEED\_t = -2.0703 + 1.3185*TIME\_t + 1.9207*WT-AC\_t 
\( (7.57) \)

\( (17.14) \)

- 23.2261*WT-SDPI\_t-1 / WT-PR\_t-1, ALS, 
\( (1.52) \)

\( R^2 = .9274, MSE = 37.5475, DW = 1.3537, \hat{\rho} = -0.3950. \)

\( (2.05) \)

WT-LABR\_t = -4.5198 + 24.7487*RECTIME\_t + 3.4897*WT-AC\_t, \hat{\rho} = 0.9206, 
\( (0.925) \)

\( (11.11) \)

\( (17.21) \)

ALS, \( R^2 = 0.9764, MSE = 86.5211, DW = 1.8211. \)
\[
\text{WT-MACH}_t = -387.1321 + 4281.9571 \times \text{INTRT}_t + 0.3379 \times \text{WT-MSTKAVE}_t - 0.6526 \times \text{WT-MACH}_{t-1}, \quad 3SLS. \tag{46}
\]
\[
\text{WT-REEX}_t = -165.4441 + 85.2690 \times \text{FREE1}_t + 0.0654 \times \text{WT-VALA}_t + 0.3040 \times \text{WT-REEX}_{t-1}, \quad \text{OLS}, \tag{47}
\]
\[
R^2 = 0.9947, \quad \text{MSE} = 538.6407, \quad \text{DW} = 1.4573.
\]
\[
\text{WT-FOR}_t = -170.8472 + 32.4349 \times \text{LOGTIME}_t - 203.5928 \times \text{DMSPI}_t + 5.9219 \times \text{WT-AC}_t + 0.0404 \times \text{WT-MSTKAVE}_t, \quad 3SLS. \tag{48}
\]
\[
R^2 = 0.9945, \quad \text{MSE} = 122.8464, \quad \text{DW} = 1.8423.
\]
\[
\text{WT-MISC}_t = 367.2454 + 0.0176 \times \text{WT-SPA}_t - 295.1356 \times \text{FSPI}_t + 11.0078 \times \text{TIME}_t - 63.1004 \times \text{LOGTIME}_t, \quad \text{OLS}, \tag{49}
\]
\[
R^2 = 0.9945, \quad \text{MSE} = 122.8464, \quad \text{DW} = 1.8423.
\]
\[
\text{WT-INT}_t = \text{INTRT}_t \times \text{WT-STKAVE}_t. \tag{50}
\]
\[
\text{WT-RETX}_t = \text{WT-VALA}_t \times \text{WT-TXRT}_t. \tag{51}
\]

Wheat Output Equations
\[
\text{WT-PRO}_t = \text{WT-AC}_t \times \text{WT-Y}_t. \tag{52}
\]
\[
\text{WT-SUPPLY}_t = \text{WT-PRO}_t + \text{WT-TINV}_{t-1} + \text{WT-IMPTS}_t. \tag{53}
\]
WT-PR

\[ WT-PR_t = 3.0669 + 1.1901*FREE1_t + 0.1748*WT-LR_t - 0.0007*WT-SUPPLY_t \]

\[ (11.091) \quad (1.191) \quad (6.812) \]

- 0.004*(WT-SUPPLY_t*LLRDUM_t) + 0.0005*WT-EXPTS_t, OLS, (54)

\[ t (11.091) \quad t (1.191) \quad t (6.812) \]

\[ R^2 = .9494, \text{ MSE} = .0211, = 1.5199. \]

WT-CDEM

\[ WT-CDEM_t = 43.8028 + 42.8935*FREE1_t + 4.4422*LV-PR_t - 95.0363*WT-PR_t \]

\[ (2.178) \quad (3.391) \quad (4.948) \]

\[ + 0.5140*WT-CDEM_{t-1}, 3SLS. \]

\[ (4.481) \]

WT-FOOD

\[ WT-FOOD_t = 464.1740 + 20.5026*FREE1_t + 15.914*WAR1_t \]

\[ (4.051) \quad (3.731) \]

- 15.4144*(WT-PR_t + WT-MC_t) + 0.301*PINC_t, 3SLS

\[ (4.324) \quad (7.503) \]

WT-TDEM

\[ WT-TDEM_t = WT-CDEM_t + WT-FOOD_t + WT-EXPTS_t \]

\[ (57) \]

WT-TINV

\[ WT-TINV_t = WT-SUPPLY_t - WT-TDEM_t. \]

\[ (58) \]

WT-GINV

\[ WT-GINV_t = -206.7987 - 267.1816*FREE1_t - 146.4695*WAR1_t \]

\[ (2.853) \quad (1.301) \]

+ 102.5850*WT-LR_t + 0.6076*WT-TINV + 0.3306*WT-GINV_t, 3SLS.

\[ (2.107) \quad (5.132) \quad (3.290) \]

\[ (t-1) \]

WT-CINV

\[ WT-CINV_t = WT-TINV_t - WT-GINV_t. \]

\[ (60) \]

WT-CRPT

\[ WT-CRPT_t = -184.7690 + 0.9022*(WT-PRO_t*WT-PR_t) + 64.9603*LOGTIME_t, \]

\[ (53.465) \quad (3.327) \]

\[ ALS, \rho = -0.5900, R^2 = .9826, \text{ MSE} = 14407.9551, \text{ DW} = 1.9117. \]

\[ (3.491) \]

WT-GINC

\[ WT-GINC_t = WT-CRPTS_t + WT-GPAY_t. \]

\[ (62) \]
Soybean Submodel

Soybean Pre-input Equations

\[ SB-AC_t = 19.1834 + 1.151*TIME_t - 0.5257*FG-PR2_t - 0.5257*FG-PR2_{t-1} - 6.5210*WT-PR2_{t-1}/SB-PR2_{t-1} + 6.4088*FREE1_t - 0.3368*CT-PR2_t - 0.3368*CT-PR2_{t-1}/SB-PR2_{t-1}, \]
\[ p = .3847, A3SLS. \]  
\[ t (5.81) (2.29) (2.24) \]

\[ SB-STK_t = -212.6959 - 167.3345*FREE2_t + 32.5409*SB-AC_t, 3SLS. \]
\[ (2.00) (15.82) \]

\[ SB-STKAVE_t = (SB-STK_t + SB-STK_{t-1})/2. \]
\[ (65) \]

\[ SB-MPUR_t = 105.7644 - 10.3203*TIME_t - 1.8638*US-SBAR_t + 21.2162*SB-AC_t, 3SLS. \]
\[ (2.23) (1.68) (9.41) \]

\[ SB-AC_t - 428.7303*MSPI_t - 101.19726*D6872_t, \]
\[ p = .7104, ALS, \]
\[ (3.87) (5.22) (4.72) \]

\[ R^2 = .9917, MSE = 498.0861, DW = 2.430. \]

\[ SB-MSTK/SB-AC_t = 15.89 + 3.2268*LOGTIME_t + 1.0213*SB-MPUR/SB-AC_t, \]
\[ (2.83) (1.78) \]

\[ 0.5886*SB-MSTK_{t-1}/SB-AC_{t-1}, \]
\[ (3.77) \]

\[ OLS, R^2 = .8885, MSE = 9.0892, DW = 2.009. \]

\[ SB-MSTK_t = (SB-MSTK_t/SB-AC_t)*SB-AC_t, \]
\[ (68) \]

\[ SB-MSTKAVE_t = (SB-MSTK_t + SB-MSTK_{t-1})/2. \]
\[ (69) \]

\[ SB-PRLA_t = 0.1454 + 0.0150*TIME_t + 0.5747*SB-PRLA_t, OLS, \]
\[ (2.52) (3.40) \]

\[ R^2 = 0.9635, MSE = 0.0029, DW = 1.9346. \]
\[
SB-\text{VALA}_t = 257.28*SB-\text{AC}_t*SB-\text{PRLA}_t. \tag{71}
\]

\[
SB-\text{SPA}_t = SB-\text{STKAVE}_t + SB-\text{MSTKAVE}_t + SB-\text{VALA}_t. \tag{72}
\]

**Soybean Input Equations**

\[
SB-\text{FERT}_t/\text{SB-AC}_t = 2.8278 - 0.7455*\log \text{TIME}_t - 1.0116*\text{FTP}_t^* + \]
\[
0.0001*SB-\text{SPA}_t + 0.4793*SB-\text{FERT}_{t-1}/SB-\text{AC}_{t-1}, \text{ OLS},
\]
\[
(2.87) (4.31)
\]
\[
R^2 = 0.9775, \text{ MSE} = 0.0201, \text{ DW} = 2.021.
\]

\[
SB-\text{FERT}_t = (SB-\text{FERT}_t/\text{SB-AC}_t)*\text{SB-AC}_t. \tag{74}
\]

\[
SB-\text{SEED}_t = -0.3732 + 3.8223*SB-\text{AC}_t, \hat{\beta} = 0.5129,
\]
\[
(44.54) (2.83)
\]
\[
\text{ALS, } R^2 = 0.9971, \text{ MSE} = 7.9656, \text{ DW} = 1.909.
\]

\[
SB-\text{LABR}_t = 8.5398 + 5.3640*SB-\text{AC}_t - 0.0145*SB-\text{MSTKAVE}_t, \hat{\beta} = 0.6194,
\]
\[
(14.93) (4.40)
\]
\[
\text{ALS, } R^2 = 0.9967, \text{ MSE} = 9.7823, \text{ DW} = 2.189.
\]

\[
SB-\text{MACH}_t = -323.9498 + 4061.3693*\text{INTRT}_t + 0.3003*SB-\text{MSTKAVE}_t + \]
\[
18.3581*SB-\text{PR}_{t-1} - 0.4835*SB-\text{MACH}_{t-1}, \text{ 3SLS},
\]
\[
(5.74) (15.22) (2.81) (5.17)
\]

\[
SB-\text{REEX}_t = 122.2919 - 242.3817*\log \text{TIME}_t + 0.0910*SB-\text{VALA}_t + \]
\[
0.1392*SB-\text{REEX}_{t-1}, \text{ ALS, } R^2 = 0.9965, \text{ MSE} = 7.021191,
\]
\[
(2.27) (15.22)
\]
\[
\text{DW} = 1.3545, \hat{\beta} = 0.7069.
\]
\[
(7.64)
\]
SB-FOR$_t$ = -4.5460 + 32.5356*FREE1$_t$ - 309.8208*DMSP$_t$ + 0.0483*SB-MSTKAVE$_t$ + 4.5689*SB-AC$_t$, OLS, $R^2$ = 0.9971, MSE = 62.4146, DW = 1.7259.

SB-MISC$_t$ = 340.6862 - 59.6356*LOGTIME$_t$ + 0.0265*SB-SPA$_t$ - 236.4487*FSPI$_{t-1}$, 3SLS.

SB-INT$_t$ = INTRT$_t$ *SB-STKAVE$_t$.

SB-RETX$_t$ = SB-VALA$_t$ *SB-TXRT$_t$.

Soybean Output Equations

SB-PRO$_t$ = SB-AC$_t$ *SB-Y$_t$.

SB-SUPPLY$_t$ = SB-PRO$_t$ + SB-TINV$_{t-1}$ + SB-IMPTS$_t$.

SB-PR$_t$ = .3402 + .9715*FREE1$_t$ - .9978*SB-LPRDUM + .4376*SB-LR$_t$ + .0066*SB-EXPTS$_t$ - .0021*SB-SUPPLY$_t$ + .6035*SB-PR$_{t-1}$, OLS, $R^2$ = .9130, MSE = .0454, DW = 2.229.

SB-CDEM$_t$ = -220.6619 + .9820*FG-CDEM$_t$ - 53.5980*SB-PR$_t$ + 6.5507*LV-PR$_t$ + 23.7674*TIME$_t$ + .2160*SB-CDEM$_{t-1}$, OLS, $R^2$ = .9884, MSE = 727.2567, DW = 1.7223.

SB-TDEM$_t$ = SB-CDEM$_t$ + SB-EXPTS$_t$. 

(79) (80) (81) (82) (83) (84) (85) (86) (87)
\[ SB-TINV_t = SB-SUPPLY_t - SB-TDEM_t. \]  \hfill (88)

\[ SB-GINC_t = -7.3341 + 0.9449 \times (SB-PRO_t \times SB-PR_t), \]  \hfill (89)

\( OLS, R^2 = 0.9538, \ MSE = 114026.4368, \ DW = 2.1548. \)

\[ \text{OLS, } R^2 = 0.9538, \ MSE = 114026.4368, \ DW = 2.1548. \]
Cotton Submodel

Cotton Pre-input Equations

\[
CT-AC_t = 28.2464 - 0.4401*TIME_t + 0.045*CS-PR_{t-1} \quad (90)
\]

\[
- 67.3709*WT-PR_{t-1}/CT-PR_{t-1} - 1.2907*FG-PR_{t-1}/CT-PR_{t-1} - 0.7476*CT-ACDIV_t \quad (4.81)
\]

\[
- 1.0308*CT-SBAR_t - 4.2782*CT-ACATDUMY_t, \text{ 3SLS.} \quad (5.58)
\]

\[
CT-STK_t = 615.8468 - 73.4139*CT-EXPTS_t - 66.2233*CT-CDEM_{t-1} - 645.7145*UAR_t + 50.8904*CT-AC_t + 0.2765*CT-STK_{t-1}, \text{ 3SLS.} \quad (4.49)
\]

\[
CT-STKAVE_t = (CT-STK_t + CT-STK_{t-1})/2. \quad (92)
\]

\[
CT-MPUR_t = 228.7502 + 95.6780*RECTIME_t + 10.7344*CT-AC_t \quad (93)
\]

\[
-210.3078*MSPI_t - 26.4005*D6872_t, \text{ OLS,} \quad (4.12)
\]

\[
R^2 = 0.9561, \text{ MSE = 209.5368, DW = 1.2044.} \quad (93)
\]

\[
CT-MSTK_t/CT-AC_t = 42.0571 - 29.5692*RECTIME_t + 1.1085*CT-MPUR_t/CT-AC_t \quad (94)
\]

\[
+ 0.4381*CT-MSTK_{t-1}/CT-AC_{t-1}, \text{ OLS,} \quad (2.34)
\]

\[
R^2 = 0.8735, \text{ MSE = 9.6407, DW = 2.1541.} \quad (94)
\]

\[
CT-MSTK_t = (CT-MSTK_t/CT-AC_t)*CT-AC_t. \quad (95)
\]

\[
CT-MSTKAVE_t = (CT-MSTK_t + CT-MSTK_{t-1})/2. \quad (96)
\]
\[
\text{CT-PRLA}_t = 0.1549 + 0.1175 \times \text{LOGTIME}_t + 0.5346 \times \text{CT-PRLA}_{t-1}, \text{ OLS}\]  
\[
R^2 = 0.8629, \text{ MSE} = 0.0054, \text{ DW} = 1.9407. \tag{97}
\]

\[
\text{CT-VALA}_t = 664.45 \times \text{CT-AC}_t \times \text{CT-PRLA}_t. \tag{98}
\]

\[
\text{CT-SPA}_t = \text{CT-STKAVE}_t + \text{CT-MSTKAVE}_t + \text{CT-VALA}_t. \tag{99}
\]

**Cotton Input Equations**

\[
\text{CT-FERT}_t / \text{CT-AC}_t = 6.5864 + 0.2437 \times \text{TIME}_t + 0.0089 \times \text{CT-GINC}_{t-1} / \text{CT-AC}_{t-1}\]  
\[
- 3.1127 \times \text{FPI}_t, \text{ OLS}, R^2 = .9477, \text{ MSE} = 0.3488, \text{ DW} = 1.5751. \tag{100}
\]

\[
\text{CT-FERT}_t = (\text{CT-FERT}_t / \text{CT-AC}_t) \times \text{CT-AC}_t. \tag{101}
\]

\[
\text{CT-SEED}_t = 0.7802 + 0.6347 \times \text{CT-AC}_t - 59.1641 \times \text{SDPI}_t / \text{CT-PR}_{t-1}, \text{ OLS}, \tag{102}
\]
\[
R^2 = 0.9492, \text{ MSE} = 0.7673, \text{ DW} = 2.423. \tag{13.99}
\]

\[
\text{CT-LABR}_t = 63.7005 + 53.2678 \times \text{CT-AC}_t - 0.5471 \times \text{MSTKAVE}_t \]  
\[
+ 0.7895 \times \text{CT-LABR}_{t-1}, \text{ ALS}, R^2 = .9910, \text{ MSE} = 2507.002, \text{ DW} = 2.115, \tag{103}
\]
\[
\hat{\beta} = -0.3675. \tag{6.43}
\]

\[
\text{CT-MACH}_t = -26.2499 + 1158.1303 \times \text{INTR}_t + 0.3434 \times \text{MSTKAVE}_t \]  
\[
- 0.8986 \times \text{CT-MACH}_{t-1}, \text{ ALS}, \hat{\beta} = 0.6201, R^2 = .9863, \text{ MSE} = 48.8038, \text{ DW} = 1.6733. \tag{104}
\]

\[
\text{CT-REEX}_t = 25.4965 + 79.9518 \times \text{FREE1}_t - 1086.1061 \times \text{RECTIME}_t \]  
\[
+ 0.0638 \times \text{CT-VALA}_t, \text{ ALS}, R^2 = 0.9674, \text{ MSE} = 415.6218, \text{ DW} = 1.2479, \hat{\beta} = 0.4721. \tag{105}
\]
\[
\text{CT-FOR}_t = 84.2675 + 1.0262 \times \text{CT-PR2}_t - 31.4514 \times \text{WAR1}_t
\]
\[
+ 60.0157 \times \text{MSPI}_t + 10.4066 \times \text{CT-AC}_t, \text{OLS, } R^2 = .9778, \text{MSE} = 68.8256, \text{DW} = 1.2387.
\]
\[
\text{CT-MISC}_t = 549.4612 + 0.0508 \times \text{CT-SPA}_t - 670.1221 \times \text{FSP}_t, \text{ALS, } R^2 = 0.9741, \text{MSE} = 283.8612, \text{DW} = 1.245.
\]
\[
\text{CT-INT}_t = \text{INTR}_t \times \text{CT-STKAVE}_t.
\]
\[
\text{CT-RETX}_t = \text{CT-VALA}_t \times \text{CT-TXRT}_t.
\]

Cotton Output Equations

\[
\text{CT-PRO}_t = \text{CT-AC}_t \times \text{CT-Y}_t.
\]
\[
\text{CT-SUPPLY}_t = \text{CT-PRO}_t + \text{CT-TINV}_t - 1 + \text{CT-IMPTS}_t.
\]
\[
\text{CT-PR}_t = 14.7807 + 7.1163 \times \text{FREE2}_t - 0.5298 \times \text{CT-SUPPLY}_t + 0.9396 \times \text{CT-LR}_t
\]
\[
+ 14.0982 \times \text{CT-PRDUM}_t, \text{OLS, } R^2 = .8711, \text{MSE} = 11.5117, \text{DW} = 1.4197.
\]
\[
\text{CT-CDEMP}_t = e^{(-4.6099 - 0.2493 \times \text{FREE2}_t)} \times \text{PINC}_t \times 0.7089 \times \text{CT-PR}_t \times -0.2101
\]
\[
\text{POLYPR}_t = 0.4140 \times \text{CT-CDEMP}_t - 0.3442 \times \text{PINC}_t, \text{3SLS.}
\]
\[
\text{CT-TDEMt} = \text{CT-CDEMP}_t \times \text{POPt}/100.
\]
\[
\text{CT-TINVt} = \text{CT-SUPPLY}_t - \text{CT-TDEMt}.
\]
\[ CT-\text{GINV}_t = -3.9860 + .0414*CT-\text{LR}_t + .8727*CT-\text{TINV}_t, \quad \text{OLS}, \]  
\[ R^2 = .8953, \quad \text{MSE} = 1.7296, \quad \text{DW} = 1.4615. \]  

\[ CS-\text{PRO}_t = 155.7182 + 397.34*CT-\text{PRO}_t - 13.1610*\text{TIME}_t, \quad \text{ALS}, \]  
\[ R^2 = .9946, \quad \text{MSE} = 6470.1763, \quad \text{DW} = 2.1038. \]  

\[ CS-\text{SUPPLY}_t = CS-\text{PROD}_t + CS-\text{TINV}_{t-1} + CS-\text{IMPTS}_t. \]  

\[ CS-\text{PR}_t = 43.3551 - .0083*CS-\text{SUPPLY}_t + 23.8197*SB-\text{PR}_t \]  
\[ + .2336*CS-\text{LR}_t - 1.1466*\text{TIME}_t, \quad \text{OLS}, \quad R^2 = .8016, \quad \text{MSE} = 76.8677, \quad \text{DW} = 2.0129. \]  

\[ CT-\text{CRPTS}_t = 520.5813 + .8640*(480.0*CT-\text{PRO}_t - .01*CT-\text{PR}_t \]  
\[ + .001*CS-\text{PRO}_t \cdot CS-\text{PR}_t) - 15.309*\text{TIME}_t, \quad \text{OLS}, \]  
\[ R^2 = .9693, \quad \text{MSE} = 27291.0902, \quad \text{DW} = 1.9947. \]  

\[ CT-\text{GINC}_t = CT-\text{CRPTS}_t + CT-\text{GPAY}_t. \]
Tobacco Submodel

Tobacco Pre-input Equations

\[
\text{TB-AC}_t = -0.2959 + 0.003192 \times \text{TB-PR}_t - 0.0004 \times \text{TB-BMQUOTA}_t + 0.0009 \times \text{TB-ACALL}_t - 0.0023 \times \text{US-SBAR}_t + 0.2527 \times \text{TB-AC}^{-1}_t, \quad \text{3SLS.} \\
(1.55) \quad (11.02) \quad (12.01) \quad (2.48) \quad (3.49)
\]

\[
\text{TB-STK}_t = -592.7473 + 6.1061 \times \text{TIME}_t + 0.0749 \times \text{TB-PRO}_t + 4.5506 \times \text{TB-SPPR}_t + 205.8004 \times \text{TB-AC}_t, \quad \text{OLS, } R^2 = .7396, \text{ MSE} = 480.9461, \text{ DW} = 2.1749. \\
(1.92) \quad (4.09) \quad (5.14) \quad (12.01)
\]

\[
\text{TB-STKAVE}_t = (\text{TB-STK}_t + \text{TB-STK}_{t-1})/2. \\
(125)
\]

\[
\text{TB-MPUR}_t = 7.8900 + 0.1030 \times \text{TIME}_t - 0.0145 \times \text{TB-MPUR}_{t-1} - 257.0488 \times \text{MHPI}_{t-1} / \text{TB-PR}_{t-1} - 2.008 \times \text{D6771}_t + .9694 \times \text{TB-MPUR}_{t-1}, \quad \text{OLS, } R^2 = .8223, \text{ MSE} = 1.7837, \text{ DW} = 2.5335. \\
(1.05) \quad (1.44) \quad (0.67) \quad (2.69) \quad (7.51)
\]

\[
\text{TB-MSTK}_t / \text{TB-AC}_t = 18.3263 + 2.8021 \times \text{TB-MPUR}_t / \text{TB-AC}_t + 0.8514 \times \text{TB-MSTK}_{t-1} / \text{TB-AC}_{t-1}, \quad \text{OLS, } R^2 = .9512, \text{ MSE} = 126.1453, \text{ DW} = 2.42. \\
(2.10) \quad (15.22)
\]

\[
\text{TB-MSTK}_t = (\text{TB-MSTK}_t / \text{TB-AC}_t) \times \text{TB-AC}_t. \\
(128)
\]

\[
\text{TB-MSTKAVE}_t = (\text{TB-MSTK}_t + \text{TB-MSTK}_{t-1})/2. \\
(129)
\]

\[
\text{TB-PRLA}_t = 0.2505 + 0.0117 \times \text{TIME}_t + 0.4973 \times \text{TB-PRLA}_{t-1}, \quad \text{OLS, } R^2 = .9074, \text{ MSE} = 0.0035, \text{ DW} = 2.1784. \\
(2.62) \quad (2.69)
\]
TB-VALAt = 5517.31*TB-ACt*TB-PRLAt.  \hspace{1cm} (131)

TB-SPA_t = TB-STKAVE_t + TB-MSTAKVE_t + TB-VALAt.  \hspace{1cm} (132)

Tobacco Input Equations

\[ \begin{align*}
TB-FERT_t/TB-AC_t &= 56.2722 + 20.2848*FREE2_t - 32.4237*FTPI_t \\
&\quad + 0.0365*TB-GINC_{t-1}/TB-AC_{t-1}, \text{ OLS, } R^2 = 0.9677, \text{ MSE } = 7.4452, \text{ DW } = 1.7251. \\
&\quad (7.33) \\
TB-FERT_t &= (TB-FERT_t/TB-AC_t)*TB-AC_t. \hspace{1cm} (134)
\end{align*} \]

\[ \begin{align*}
TB-LABR_t &= 9.0766 - 360.8480*RECTIME_t + 545.8050*TB-AC_t \\
&\quad - 1.074*TB-MSTKAVE_t + 0.5067*TB-LABR_{t-1}, \text{ A3SLS, } \hat{\rho} = 0.5820. \\
&\quad (7.62) \hspace{1cm} (3.13)
\end{align*} \]

\[ \begin{align*}
TB-MACH_t &= -52.6363 + 412.0239*INTRT_t + 0.1063*TB-MSTKAVE_t \\
&\quad + 0.3516*TB-PR_{t-1}, \text{ OLS, } R^2 = 0.9397, \text{ MSE } = 2.3987, \text{ DW } = 1.524. \\
&\quad (12.97) \hspace{1cm} (15.14) \hspace{1cm} (3.66)
\end{align*} \]

\[ \begin{align*}
TB-REEX_t &= -193.5813 + 53.0365*FREE1_t + 1783.6082*INTRT_t \\
&\quad + 0.0612*TB-VALAt + 0.3397*TB-REEX_{t-1}, \text{ OLS, } R^2 = 0.9734, \text{ MSE } = 240.2803, \\
&\quad DW = 1.9068. \\
&\quad (4.02) \hspace{1cm} (15.14) \hspace{1cm} (4.98) \hspace{1cm} (9.67)
\end{align*} \]

\[ \begin{align*}
TB-FOR_t &= 18.5850 + 11.3891*FREE2_t - 37.2682*DMSPI_t + 22.0035*TB-AC_t \\
&\quad + 0.0791*TB-MSTKAVE_t, \text{ 3SLS.} \\
&\quad (4.50) \hspace{1cm} (2.89) \hspace{1cm} (6.28) \hspace{1cm} (3.48)
\end{align*} \]

\[ \begin{align*}
TB-MISC_t &= 194.4117 + 0.0238*TB-SPA_t - 200.5288*FSPI_t \\
&\quad + 43.2485*RECTIME_t, \text{ OLS, } R^2 = 0.9880, \text{ MSE } = 11.2605, \text{ DW } = 1.3394. \\
&\quad (25.66) \hspace{1cm} (24.65) \hspace{1cm} (3.96)
\end{align*} \]
TB-INT_t = INTRT_t * TB-STKAVE_t. (140)

TB-RETX_t = TB-VALA_t * TB-TXRT_t. (141)

Tobacco Output Equations

TB-PRO_t = TB-AC_t * TB-Y_t. (142)

TB-SUPPLY_t = TB-PRO_t + TB-TINV_t-1. (143)

TB-PR_t = 39.555 + 4.8201*FREE2_t - 0.0087*TB-SPPR_t + 0.5134*TB-EXPTS_t - 0.2931*TIME_t, OLS, $R^2 = 0.4501$, MSE = 5.9787, DW = 2.1174. (144)

TB-CDEMt/POP_t = 5.3105 + 0.8718*WAR2_t - 0.0048*TB-PR - 0.00087*TINCt + 1.0685*RECTIME_t + 0.6241*TB-CDEMt/POP_t-1, OLS, $R^2 = 0.9863$, MSE = 0.0264, DW = 2.3748. (145)

TB-CDEM_t = (TB-CDEMt/POP_t)*POP_t. (146)

TB-TDEMt = TB-CDEM_t + TB-CDEM_t. (147)

TB-TINV_t = TB-SUPPLY_t - TB-TDEMt. (148)

TB-CINV_t = TB-TINV_t. (149)

TB-CRPTS_t = 233.4022 + 0.8922*(TB-PRO_t*TB-PR_t*0.01) - 2.4311*TIME_t, OLS, $R^2 = 0.9023$, MSE = 2072.2858, DW = 2.3018. (150)

TB-GINC_t = TB-CRPTS_t. (151)
APPENDIX B. LIVESTOCK EQUATIONS
Livestock Submodel

Livestock Preinput Equations

\[
LV-LPUR_t = 639.5835 + 6.147 \times FG-SUPPLY_{t-1} + 74.1419 \times TIME_t, \quad OLS, \quad (1)
\]

\[
R^2 = .9197, \; MSE = 58113.1784, \; DW = 1.3299.
\]

\[
LV-STK_t = 1467.5647 + 40.7284 \times LV-PR_{t-1} + 1.0189 \times LV-LPUR_t + .6494 \times LV-STK_{t-1}, \quad OLS, \quad (2)
\]

\[
R^2 = .9732, \; MSE = 85838.4375, \; DW = 1.2879.
\]

\[
LV-STKAVE_t = (LV-STK_t + LV-STK_{t-1})/2. \quad (3)
\]

\[
LV-MPUR_t = 936.5957 - 10186.6274 \times MHPI_l / LV-PR_{t-1} - 215.9982 \times MSPI_t - 0.079 \times LV-MSTK_{t-1} + 7.2932 \times TIME_t + 0.4280 \times LV-MPUR_{t-1}, \quad OLS, \quad (4)
\]

\[
R^2 = .7365, \; MSE = 865.8877, \; DW = 1.7208.
\]

\[
LV-MSTK_t = 682.7686 - 73.6072 \times WAR + 1.6384 \times LV-MPUR_t + 0.6979 \times LV-MSTK_{t-1}, \quad A3SLS, \; \hat{\beta} = -0.3448. \quad (5)
\]

\[
LV-MSTKAVE_t = (LV-MSTK_t + LV-MSTK_{t-1})/2. \quad (6)
\]

\[
LV-VALA_t = 5312.1353 + 391.1038 \times TIME_t + 0.5272 \times LV-CR_{t-1} + 0.7400 \times LV-VALA_{t-1}, \quad A3SLS, \; \hat{\beta} = -0.5382 \quad (7)
\]

\[
LV-SPA_t = LV-STKAVE_t + LV-MSTKAVE_t + LV-VALA_t. \quad (8)
\]
Livestock Input Equations

\[ \text{LV-FEED}_t = 1276.7910 + 44.6507 \times \text{LV-PR}_{t-1} - 42.9096 \times \text{FG-PR}_{t-1} \]
\[ + 187.1906 \times \text{TIME}_t, \beta = 0.5394, \text{ALS}, R^2 = 0.9737, \text{MSE} = 73512.3021, \text{DW} = 1.6325. \]
\[ (3.01) \quad (4.66) \quad (10.07) \quad (2.38) \]

\[ \text{LV-LABR}_t = 494.4836 - 21.2336 \times \text{TIME}_t + 5.4576 \times \text{LV-PR}_{t-1} \]
\[ + 0.8319 \times \text{LV-LABR}_{t-1}, \text{OLS}, R^2 = 0.9992, \text{MSE} = 1439.1507, \text{DW} = 1.7135. \]
\[ (10.44) \]

\[ \text{LV-MACH}_t = -215.9964 + 4077.470 \times \text{INTRT}_t + 0.1622 \times \text{LV-MSTKAVE}_t \]
\[ + 0.5246 \times \text{LV-PR}_{t-1} - 0.1172 \times \text{LV-MACH}_{t-1}, \text{3SLS}. \]
\[ (11.74) \]

\[ \text{LV-REEX}_t = -1074.6218 + 470.8330 \times \text{FREE1}_t + 351.2973 \times \text{WAR1}_t \]
\[ + 0.0682 \times \text{LV-VALA}_t + 0.3871 \times \text{LV-REEX}_{t-1}, \text{A3SLS}, \beta = 0.5353. \]
\[ (2.07) \]

\[ \text{LV-FOR}_t = 276.9356 - 11.0033 \times \text{TIME}_t + 80.3938 \times \text{SQRTTIME}_t \]
\[ + 55.9642 \times \text{FREE2}_t - 284.7389 \times \text{DSPI}_t + 0.0440 \times \text{LV-MSTKAVE}_t, \text{3SLS}. \]
\[ (1.86) \]

\[ \text{LV-MISC}_t = 2663.8469 + 0.0183 \times \text{LV-SPA}_t - 2396.8675 \times \text{FSPI}_t \]
\[ - 296.8367 \times \text{LOGTIME}_t + 0.4168 \times \text{LV-MISC}_{t-1}, \text{OLS}, R^2 = 0.9958, \text{MSE} = 2863.2479, \text{DW} = 1.5281. \]
\[ (7.23) \quad (8.64) \quad (5.01) \]

\[ \text{LV-INT}_t = \text{INTRT}_t \times \text{LV-STKAVE}_t. \]
\[ (15) \]

\[ \text{LV-RETX}_t = \text{LV-VALA}_t \times \text{LV-TXRT}_t. \]
\[ (16) \]
Beef Output Equations

\[ B_{-FC_t} = 0.047 * FG_{-PR_t} + 0.127 * SB_{-PR_t} \]  \hspace{1cm} (17)

\[ B_{-PRODt} = 13317.0781 + 54.7070 * B_{-FP(MA3)}_{t-1} / B_{-FC(MA3)}_{t-2} - 172.8341 * RFC_{t} - 2633.0070 * PFDUM_{t} \]  \hspace{1cm} (18)

\[ + 0.9755 * B_{-PROD_{t-1}}, \quad R^2 = 0.9909, \quad MSE = 185850.3934, \quad DW = 1.8202, \quad OLS. \]  \hspace{1cm} (24.844)

\[ B_{-INVt} = -277.9914 + 0.0252 * B_{-PRODt} + 0.0177 * PLCT_{-PRODt} \]  \hspace{1cm} (19)

\[ - 86.9550 * LOGTIME_{t-4} + 126.2508 * PFDUM_{t} - 0.2574 * B_{-INV_{t-1}}, \quad R^2 = 0.9266, \quad MSE = 802.3171, \quad DW = 1.8171, \quad OLS. \]

\[ B_{-CCONS_t} = B_{-PRODt} + B_{-INV_{t-1}} + B_{-IMP_{t-1}} - B_{-INV_t} - B_{-EXP_{t-1}} - B_{-MILCONS_{t}}, \]  \hspace{1cm} (20)

\[ B_{-RP_t} = 111.9256 - 0.0066 * B_{-CCONS_t} - 0.0003 * P_{-CCONSt} + 0.1104 * INC_{t} \]  \hspace{1cm} (21)

\[ + 2.4529 * TIME_{t-4} + 0.1945 * B_{-RP_{t-1}}, \quad R^2 = 0.9100, \quad MSE = 3.0868, \quad DW = 2.0125, \quad OLS. \]  \hspace{1cm} (3.990)

B-FRM Structural Equation

\[ B_{-FRMt} = -12.0518 - 0.1713 * B_{-DFP} + 16.4042 * W(MA4)_{t} \]  \hspace{1cm} (22)

\[ - 0.0004 * B_{-PROD(MA4)}_{t} + 1.1343 * B_{-BYPROD_{t}}, \quad MSE = 0.7524, \quad DW = 1.6240, \quad 2SLS. \]  \hspace{1cm} (2.671)

B-FRM Reduced Form Equation

\[ B_{-FRMt} = -14.5434 - 0.2067 * B_{-RP_{t}} + 0.2067 * B_{-FP_{t-1}} \]  \hspace{1cm} (23)

\[ + 19.7956 * W(MA3)_{t} - 0.0005 * B_{-PROD(MA4)}_{t} + 1.1621 * B_{-BYPROD_{t}}. \]
B-FP \_t = B-RP \_t - B-FRM \_t + B-BYPROD \_t. \quad (24)

B-CR \_t = -898.4590 + 1.4443(B-PROD \_t *B-FP \_t), \ \hat{\beta} = .4197, \quad (6.999) \quad (20.002)

R^2 = .8814, \text{MSE} = 86981.0704, \text{DW} = 1.6509, \text{ALS},

Pork Output Equations

P-FC \_t = .043*FG-PR \_(t-1) + .308*SB-PR \_(t-1). \quad (26)

P-PROD \_t = 2554.6797 + 97.0674*P-FP \_t - 1390.6426*P-FC \_t - 1, \quad (3.989) \quad (4.070)

- 1690.7600*PFDUM \_t + .8025*P-PROD \_(t-1), \quad (2.376) \quad (5.853)

R^2 = .7815, \text{MSE} = 390885.2745, \text{DW} = 2.0737, OLS.

P-INV \_t = -161.2783 + .0506*P-PROD \_t + .0191*BLCT-PROD \_t \quad (3.760) \quad (3.715)

- 274.9488*LOGTIME \_t^4 + 64.0776*PFDUM \_t + .2028*P-INV \_(t-1), \quad (5.034) \quad (1.107)

R^2 = .7056, \text{MSE} = 2008.6004, \text{DW} = 1.8127, OLS.

P-CCONS \_t = P-PROD \_t + P-INV \_(t-1) + P-IMP \_t - P-EXP \_t - P-MILCONS \_t. \quad (29)

P-RP \_t = 102.0800 - .0064*P-CCONS \_t - .0024*B-CCONS \_t \quad (14.017) \quad (4.654)

+ .1732*INC \_t - 3.7407*LOGTIME \_t^4 + .1616*P-RP \_(t-1), \quad (9.365) \quad (2.206) \quad (2.558)

R^2 = .9552, \text{MSE} = 2.8883, \text{DW} = 2.0100, OLS.

P-FRM Structural Equation

P-FRM \_t = 5.5844 - .1087*P-\Delta PP \_t + 16.9263*W(MA3) \_t \quad (4.684) \quad (5.938)

- .0041*P-PROD(MA3) \_t - .2654*TIME \_t^4, \text{MSE} = .7381, \text{DW} = 2.4252, 2SLS. \quad (3.918) \quad (2.569)
P-FRM Reduced Form Equation

\[ P_{-FRM_t} = 6.2655 - 0.1219*P_{-RP_t} - 0.1219*P_{-BYPROD_t} + 0.1219*P_{-FP_{t-1}} \]
\[ + 18.9905*W(MA4)_t - 0.0016*P_{-PROD(MA4)_t} - 0.2978*TIME_{t-4} \]  
\[ (32) \]

\[ P_{-FP_t} = P_{-RP_t} - P_{-FRM_t} + P_{-BYPROD_t}, \]  
\[ (33) \]

\[ P_{-CR_t} = 66.6524 + 0.7496*P_{-PROD(FP_t)}, \]  
\[ \hat{\rho} = 0.8082, \]  
\[ (25.055) \]  
\[ R^2 = 0.9790, \text{ MSE} = 8927.1690, \text{ DW} = 2.1501, \text{ ALS}. \]  
\[ (34) \]

Lamb Output Equations

\[ L_{-FC_t} = FG_{-PR_{t-1}}. \]  
\[ (35) \]

\[ L_{-PROD_t} = 56.0480 + 95.9382*L_{-FP(MA3)_{t-1}} / L_{-FC(MA3)_{t-1}} \]  
\[ - 6.4792*TIME_{t-4} + 0.8401*L_{-PROD_{t-1}}, \]  
\[ R^2 = 0.9572, \text{ MSE} = 808.7077, \text{ DW} = 1.3252, \text{ OLS}. \]  
\[ (2.284) \]  
\[ (36) \]

\[ L_{-INV_t} = -60.7161 + 0.0498*L_{-PROD_t} + 0.0015*BPCT_{-PROD_t} \]  
\[ - 3.2665*LOGTIME_{t-4} - 0.5172*L_{-INV_{t-1}}, \]  
\[ R^2 = 0.7724, \text{ MSE} = 3.1482, \text{ DW} = 2.0581, \text{ OLS}. \]  
\[ (5.463) \]  
\[ (2.672) \]  
\[ (4.762) \]  
\[ (37) \]

\[ L_{-CCONS_t} = L_{-PROD_{t+1}} + L_{-INV_{t-1}} + L_{-IMP_{t-1}} - L_{-INV_t} - L_{-EXP_{t}} - L_{-MILCONS_{t}}. \]  
\[ (38) \]

\[ L_{-RP_t} = 63.9403 - 0.0171*L_{-CCONS_t} - 0.0017*P_{-CCONS_t} \]  
\[ - 0.0006*B_{-CCONS_t} + 0.0573*INC_{t} + 0.4682*L_{-RP_{t-1}} \]  
\[ R^2 = 0.9507, \text{ MSE} = 4.4568, \text{ DW} = 2.1614, \text{ OLS}. \]  
\[ (2.050) \]  
\[ (2.646) \]  
\[ (1.044) \]  
\[ (2.413) \]  
\[ (2.672) \]  
\[ (39) \]

\[ L_{-FRM_t} = 19.8530 - 0.0125*L_{-PROD(MA4)} + 0.7137*L_{-FRM_{t-1}} \]  
\[ R^2 = 0.8585, \text{ MSE} = 2.2817, \text{ DW} = 1.6616, \text{ OLS}. \]  
\[ (2.865) \]  
\[ (5.846) \]  
\[ (40) \]
L-\text{FP}_t = L-\text{RP}_t - L-\text{FRM}_t + L-BY\text{PROD}_t \quad (41)

L-\text{CR}_t = -7.1480 + 1.1412*(L-\text{PRODT}_t*L-\text{FP}_t), \quad \hat{\beta} = 0.5635, \quad (7.876) \quad (2.907)

R^2 = 0.9336, \text{ MSE} = 203.7050, \text{ DW} = 1.8380, \text{ ALS.}

\text{Chicken Output Equations}

C-\text{FC}_t = 0.033*\text{FG-PR}_t - 1 + 0.730*\text{SB-PR}_t - t \quad (43)

C-\text{PROD}_t = 2546.2349 + 40.8683*\text{C-FP}_t - 482.6930*\text{C-FC}_t \quad (3.721) \quad (6.052)

+ 255.1748*\text{TIME}_t - 4 + 2.333*\text{C-PROD}_t - 1, \quad R^2 = 0.9950, \text{ MSE} = 21318.9312, \text{ DW} = 1.8543, \text{ OLS.}

C-\text{RP}_t = 77.9181 - 0.0069*\text{C-CCONSt}_t - 0.0010*\text{B-CCONSt}_t - 0.0013*\text{P-CCONSt}_t \quad (4.268) \quad (2.227) \quad (3.231)

- 0.0130*\text{T-CCONSt}_t + 0.1718*\text{INC}_t - 9.6243*\text{LOGTIME}_t - 4, \quad (2.267) \quad (8.607) \quad (8.632)

R^2 = 0.9871, \text{ MSE} = 2.1015, \text{ DW} = 2.4683, \text{ OLS.}

C-\text{CCONSt}_t = C-\text{PROD}_t + C-\text{INV}_t - 1 - C-\text{INV}_t - 4 - C-\text{NEXP}_t - C-\text{MILCONSt}_t. \quad (46)

C-\text{FRM Structural Equation}

C-\text{FRM}_t = 9.1250 + 0.1815*\text{C-FP}_t + 0.0027*\text{C-PROD}_t - 0.9038*\text{TIME}_t - 4 \quad (6.128) \quad (4.146) \quad (5.405)

\text{MSE} = 0.4306, \text{ DW} = 1.4581, \text{ 2SLS.}

C-\text{FRM Reduced Form Equation}

C-\text{FRM}_t = 7.732 + 0.1536*\text{C-RP}_t + 0.0023*\text{C-PROD}_t - 0.7649*\text{TIME}_t - 4 \quad (48)

C-\text{FP}_t = C-\text{RP}_t - C-\text{FRM}_t. \quad (49)
C-CR_t = 18.2104 + 0.8786*(C-PROD_t*C-FP_t), \beta = 0.9207, \\
(23.924) (7.202) \\
R^2 = 0.9773, \text{ MSE} = 1570.8668, \text{ DW} = 1.4875, \text{ ALS.}

Turkey Output Equations

T-FC_t = 0.039*FG-PR_{t-1} + 0.458*SB-PR_{t-1}. \\
(51)

T-PROD_t = 738.1287 + 37.8253*T-FP_{t-1}/T-FC(MA2)_t \\
(2.358) \\
- 1.0016*T-INV_{t-1} + 440.4804*LOGTIME_{t-4} + 0.6514*T-PROD_{t-1}, \\
(1.778) (2.410) (2.139) \\
R^2 = 0.9329, \text{ MSE} = 7159.9737, \text{ DW} = 2.3180, \text{ OLS.}

T-INV_t = -209.5561 + 0.3732*T-PROD_t - 18.4195*TIME_{t-4} \\
(7.376) (6.300) \\
+ 49.3820*PFDUM_t + 0.5125*T-INV_{t-1}, \\
(1.824) (4.648) \\
R^2 = 0.8696, \text{ MSE} = 619.4089, \text{ DW} = 2.2782, \text{ OLS.}

T-CCONS_t = T-PROD_t + T-INV_{t-1} - T-INV_t - T-NEXP_t - T-MILCONS_t. \\
(54)

T-RP_t = 93.1779 - 0.0261*T-CCONS_t - 0.0024*B-CCONS_t \\
(2.577) (2.940) \\
- 0.0113*T-CCONS_t + 0.1018*INC_t, \text{ R}^2 = 0.8892, \text{ MSE} = 6.6734, \text{ DW} = 2.0632, \text{ OLS.} \\
(1.467) (2.995)

T-FRM Structural Equation

T-FRM_t = -22.9909 - 0.1815*T-\Delta FP_t + 22.8894*W(MA4)_t \\
(2.744) (1.723) \\
- 7.3387*LOGTIME_t, \text{ MSE} = 2.2555, \text{ DW} = 2.5344, \text{ 2SLS.} \\
(1.710)
T-FRM Reduced Form Equation

\[ T-\text{FRM}_t = -28.0893 - 0.2218 \times T-RP_t + 0.2218 \times T-FP_{t-1} + 27.9653 \times W(\text{MA4})_t - 8.9661 \times \text{LOGTIME}_{t-4}. \]  

(57)

\[ T-\text{FP}_t = T-\text{RP}_t - T-\text{FRM}_t. \]  

(58)

\[ T-\text{CR}_t = -33.5058 + 1.0621 \times (T-\text{PROD}_t \times T-\text{FP}_t), \]  

(10.740)

\[ R^2 = 0.8650, \text{ MSE } = 725.0636, \text{ DW } = 2.0161, \text{ OLS}. \]  

(59)
APPENDIX C. DEFINITIONS OF VARIABLE CODE NAMES
Harvested acreage (million acres).

Tobacco acreage allotment (million acres).

Acreage allotment dummy with 1.0's in years allotments were in effect.

Acres diverted from production under crop commodity programs (million acres).

The sum of the production of beef, lamb and mutton, chicken, and turkey in millions of pounds.

Dummy variable for corn blight in 1970.

The sum of the production of beef, pork, chicken, and turkey in millions of pounds.


Amount paid to farmers in cents per pound for byproducts not sold as meat at the retail level deflated by the Consumer Price Index 1967 = 100.

Civilian consumption in millions of pounds of carcass weight or ready-to-cook weight meat.

Total domestic crop year demand for all uses, except wheat which excludes food demand (same units as production)

Privately owned ending crop year inventory (same units as production).

Average crop year price received by farmers for corn (dollars per bushel)

The Consumer Price Index with 1967 = 100.

Cash receipts in thousands of dollars from the sale of a livestock commodity deflated by the Consumer Price Index 1967=100.

Cash receipts from the sale of crops (million dollars) deflated by CPI.

Price of cotton seed deflated by index of prices paid by farmers.

Domestic demand for cotton per capita multiplied by 100 (bales).

Feed grain base dummy with 1961-1970 = 1 and 0 otherwise.

Dummy variable = 1.0 for years 1967-1971.

Dummy variable = 1.0 for years 1968-1971.

Dummy variable = 1.0 for years 1968-1972.

Dummy variable for wheat allotment program with 1.0's for 1971-1973.

Change in index of motor supplies price.

Exports in millions of pounds of carcass weight meat.

Crop year exports (same units as production).

A weighted average feed grain and soybean price per hundred pounds of feed for the commodity deflated by the index of prices paid by farmers with 1967 = 100. These variables are taken as proxies for feed costs.

Purchased livestock feed (million 1967 dollars).

Fertilizer and lime expense (million 1967 dollars).

Crop year demand for wheat as food (million bushels).

Machinery fuel, oil and repairs expense (million 1967 dollars).
Gross farm value for beef (choice), pork and lamb (choice), and farm value for chicken and turkey deflated by the index of prices paid by farmers with 1967 = 100. Gross farm value and farm value are prices paid to farmers for a quantity of live animal or bird equivalent to one pound of retail cuts or ready-to-cook bird.

Free market dummy variable with 1.0's for 1973-76.

Free market dummy variable with 1.0's for 1974-1976.

The farm-retail margin in cents per pound of meat sold at the retail level for the ith commodity deflated by the Consumer Price Index 1967 = 100.

Average number of acres per farm.

Index of farm supplies price deflated by GNP deflator (1967 = 100).

Index of fertilizer price deflated by GNP deflator (1967 = 100).

Cash receipts plus government payments (million dollars).

Government owned ending crop year inventory (same units as production).

Government payments to farmers under crop programs (million dollars).

Gross National Product deflator index (1967 = 100).

Imports in millions of pounds of carcass weight meat.

Crop year imports (same units as production).

Personal disposable Income (billion dollars).

End-of-year stocks in millions of pounds of carcass weight for beef, pork, and lamb and mutton and ready-to-cook weight for chicken and turkey.

Interest rate paid by farmers on new farm loans.

The index of prices paid by farmers with 1967 = 100.

Man-hour requirements (million man-hours).

Dummy accounting for low wheat loan rates with 1964-76 = 1 and 0 otherwise.

Natural log of TIME variable.

Soybean low price dummy with 1975 = 1 and 0 otherwise.

Livestock purchased by farmers (million 1967 dollars).

Crop government program loan rate (same units as price except FG which is the corn loan rate in dollars per bushel).

Weighted average livestock and poultry farm price (formed by weighting the farm prices for beef, pork, lamb, chicken, and turkey by their respective productions in millions of pounds).

A two-year equally-weighted moving average of the accompanying variable.

A three-year equally-weighted moving average of the accompanying variable.

A three-year, weighted, moving average of the accompanying variable where the weights are 1/4, 1/2, and 1/4.

Machinery interest and depreciation (million 1967 dollars).

Payment by wheat processors for marketing certificates (dollars per bushel).

Index of machinery price deflated by GNP deflator (1967 = 100).
Military consumption in millions of pounds of carcass weight or ready-to-cook weight meat.

Miscellaneous expenses including pesticides, small hand tools, binding materials, electricity, telephone, etc. (million 1967 dollars).

Machinery purchased (million 1967 dollars).

Index of motor supplies price deflated by GNP deflator (1967 = 100).

Ending calendar year stock of machinery on farms (million 1967 dollars).

Average of beginning and ending calendar year stock of machinery on farms (million 1967 dollars).

Net exports in millions of pounds of ready-to-cook meat.

A dummy variable with 1973 = 1 and 0 otherwise to account for the effects of the 1973 price freeze.

Per capita disposable income (dollars).

The sum of the production of pork, lamb and mutton, chicken, and turkey in millions of pounds.

Polyester price (cents per pound).

U.S. civilian population (million).

Average crop year price received by farmers deflated by the implicit GNP deflator (LV, dollars per hundred weight; FG, dollars per ton; WT and SB, dollars per bushel; and TB, cents per pound). All prices and incomes are deflated by the Consumer Price Index 1967 = 100 when used in the output sector.

PR variable deflated by index of prices paid by farmers instead of GNP.

Dummy with 1973 = 1 and 0 otherwise.

Index of price of land and buildings per acre (index 1967 = 1.0).

Crop production (FG, million short tons; W and SB, million bushels; CT, million bales; and CS, million short tons).

Production in millions of pounds of carcass or ready-to-cook weight meat.

Reciprocal of TIME variable.

Real estate expense including interest on land and farm buildings and depreciation repairs and maintenance on farm buildings (million 1967 dollars).

Real estate taxes (million 1967 dollars).

An index of range feed conditions in 17 western states. RFC ranges from 49 or below indicating very bad to 100 and over indicating excellent range feed conditions.

The retail price in cents per pound of the commodity deflated by the Consumer Price Index 1967 = 100.

Acreage withheld from production under the Soil Bank Acreage Reserve program (million acres).

Purchased plus home-grown seed for individual crops (million 1967 dollars).
SDPI  Index of seed prices deflated by the implicit GNP deflator (1967 = 100).
SQRTIME  Square root of the TIME variable.
SPA  Stock of physical assets defined as the sum of STKAVE, MSTKAVE, and VALA (million 1967 dollars).
SPPR  Average support price levels deflated by the implicit GNP deflator (same units as price).
STK  End of year commodity stock on farms (million 1967 dollars).
STKAVE  Average of beginning and end of year commodity stock on farms (million 1967 dollars).
SUPPLY  Beginning crop year supply defined as the sum of production, carry-in stocks, and imports (same units as production).
t  Current year.
TDEM  Total domestic crop year demand for all uses plus exports (same units as production).
TINV  Ending crop year inventory (same units as production).
TXRT  Tax rate per dollar value of land and buildings.
VALA  Value of farmland and buildings (million 1967 dollars).
VOLPG  Dummy variable for voluntary wheat programs with 1.0's for 1965-1970.
W  The wage rate in dollars per hour for meat manufacturing employees deflated by the Consumer Price Index 1967 = 100.
WAR1  Post war dummy variable for World War II with 1.0's for 1949-1951.
WAR2  Post war dummy variable for World War II with 1.0's for 1949-1952.
WPRD1  Wheat price dummy, PR, with price equal to zero for 1953-1963.
WPRD2  Wheat price dummy, PR, with price equal to zero for 1949-1972.
WPRD3  Wheat price dummy, PR2, with price equal to zero for 1949, 1953-1962.
Y  Crop yield per harvested acre (FG and CS, short tons; W and SB, bushels; and CT, bales).

List of Prefixes

B  Beef
C  Chicken
CS  Cottonseed
CT  Cotton Lint or Cotton Total
FG  Feed Grain
L  Lamb and Mutton
LV  Livestock Total
P  Pork
SB  Soybean
T  Turkey
TB  Tobacco
WT  Wheat
US  United States Total
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