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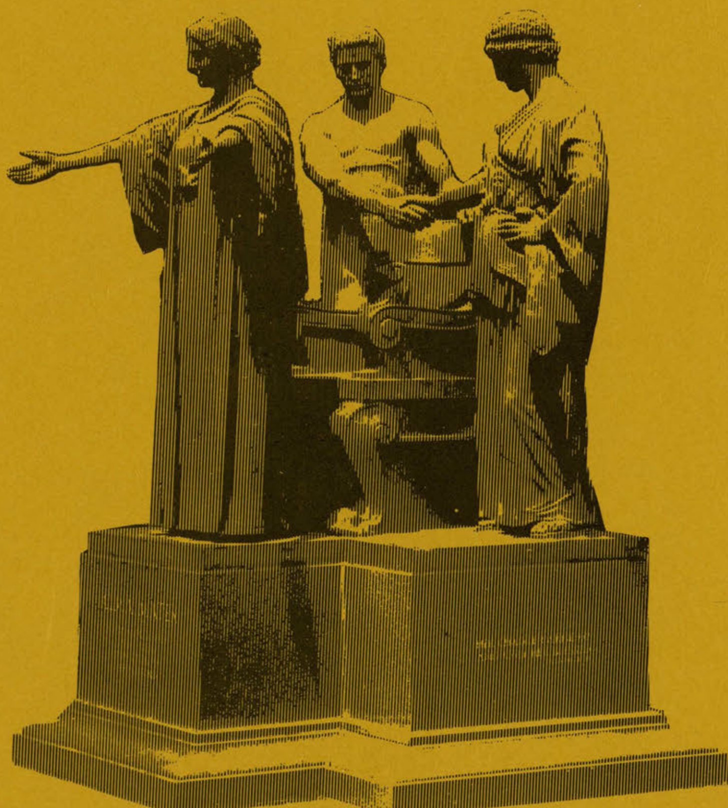
PESTMODEL: An Econometric Pesticide Policy Evaluation Model

by

J. Park

July 1980 No. 80 E-123



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I. INTRODUCTION

Pesticides are very important in the production of grain crops. Pesticides help farmers increase production of agricultural crops by controlling insects, weeds, and crop diseases. As a result, more food is available to consumers with lower prices than with a system not using pesticides. However, some pesticides may have potentially adverse effects on human health and the environment. Therefore, it is essential to make sure that the most economical pesticides consistent with environmental risks are used so that net social benefits are maximized.

Under the Rebuttable Presumption Against Registration (RPAR) process, the Office of Pesticide Programs, U. S. Environmental Protection Agency (EPA), identifies the pesticides whose potential environmental risks may outweigh the benefits to farmers and consumers. The evaluation of the loss of benefits from the discontinuation of the use of these pesticides is an essential part of the information needed for risk-benefit decisions.

The primary intended use of the model described in this report is to evaluate the benefits of alternative pesticide policies as they affect the production of grain crops at the national and regional levels. A simultaneous equation system was developed and estimated in order to generate equilibrium quantities and prices of soybeans, corn, wheat, grain sorghum, oats, and barley. The application of simulation techniques with this model permits evaluation of the economic impacts of various pesticide policies.

In their prototype model, Taylor and Lacewell[1] used a modified version

[1]Taylor, C. Robert, and Ronald Lacewell, An Econometrically Based Simulation Model for Analyzing the Impacts of Pesticide Policies on Feed Grains, Small Grains, and Cotton. Southwestern Resource Analysts, Technical Report 793, October 21, 1978.

of one of the USDA econometric models. In their supply structures, however, they did not, except for cotton, include the regional supply functions and production cost information. Further, in the Taylor-Lacewell model soybeans have regional acreage response functions that do not require yield and cost information. Given the responsibility for a regional analysis of grain crops and the need for explicit consideration of the influence of yield and cost-of-production variation among regions, the model described in this report was developed. The model is simultaneous in the sense that supply and demand relationships among the seven crops ---soybeans, corn, wheat, grain sorghum, oats, barley, and cotton--- were considered in an interdependent system during the estimation process. This model contains the regional acreage response functions, yield response functions, and production costs for the seven crops by region. In addition to regional analysis, the model can also estimate the impacts of alternative pesticde policies at the national level.

II. GENERAL STRUCTURE AND ESTIMATION PROCEDURES

A. General Structure of the Model

This model uses annual data with 136 equations, 89 of which are behavioral equations with the other 47 being identities. The model contains a total of 211 variables, with 136 endogenous and 75 predetermined. Of the endogenous variables, 52 are related to the national level and 84 are regional variables. As mentioned earlier, this model was developed to estimate regional production, acreage, yield, and national production, acreage and prices for the seven crops.

The general structure of the model is outlined in Figure 1. The flow chart has been simplified to clarify the general structure. Rectangles

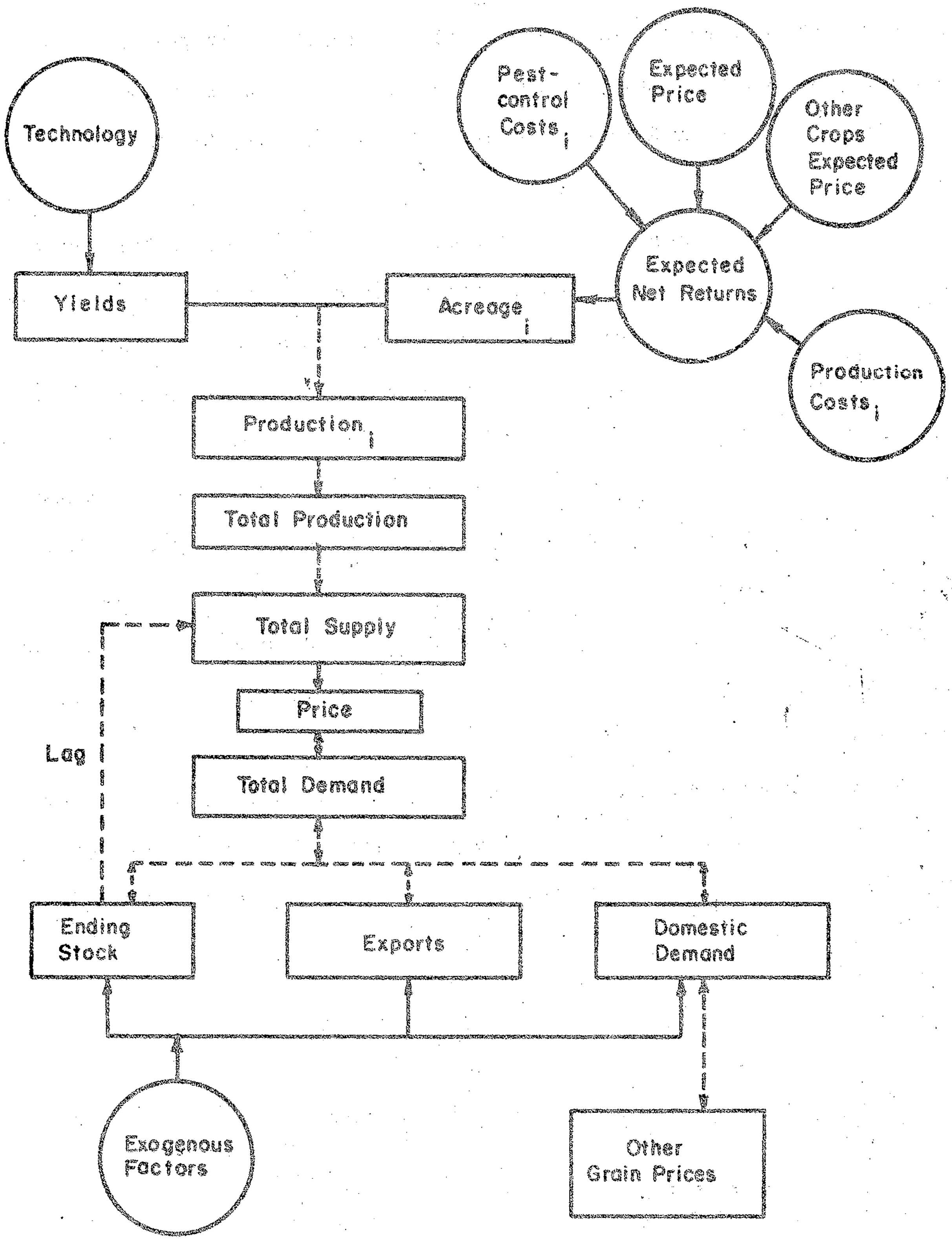

Figure 1. Schematic Flow Chart for Grains: Their Demand and Supply

represent the endogenous variables and circles represent exogenous variables. Solid lines indicate behavioral relationships and dashed lines show identities. Subscript letter i refers to the specific region for each crop.

The acreage for a given crop in each region is related to the expected net returns for that crop. The expected net return is a function of expected prices of this crop and competing crops and their respective production costs including pest-control costs. This concept was suggested by Taylor and Lacewell.[1] The expected net returns for a crop is important to producers in making production decisions. Several different assumptions can be made regarding the formation of price expectation. Among others, Bailey[2] has discussed this topic. In this model, a simple (equal weights) moving average of prices over the past three years[3] is used in most acreage response functions, and a distributed lag moving average expectation[4] is used in the remaining ones.

Total national production consists of the sum of the regional production of each crop. The total national supply consists of total national production together with the beginning-of-period stock. Then, the interaction of

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1 Taylor, C. Robert, and D. Lacewell, op. cit.

2 Bailey, Martin J., National Income and the Price Level: A Study in Macro-Economic Theory, McGraw-Hill Co., 1971, ch. 11.

3 Prices over the past three years are lagged endogenous variables which are predetermined. They are used in acreage resonse functions, not for the current price levels. Therefore they would not create any autocorrelation problem.

4 A higher weight is given on the most recent period. For example,

$P^*_t = aP_{t-1} + bP_{t-2} + cP_{t-3}$, where P^*_t = expected price at t, $a + b + c = 1.0$ and $a \geq b \geq c$.

total national supply and demand generates an estimated equilibrium price at the national level. Basically, the supply side for a given crop can be expressed algebraically as follows:

1. $NR^{*}_{it} = P^{*}_{t} * Y_{it} - C_{it}$

2. $Y_{it} = f(LT, A_{it})$

3. $A_{it} = f(NR^{*}_{it}, NR^{C}_{it}, A_{it-1})$

4. $Q^{P}_{it} = A_{it} * Y_{it}$

5. $K_{t} = f(P_{t}, Q^{P}_{t})$

6. $Q^{s}_{t} = \sum_{i=1}^{n} Q^{P}_{it} + K_{t-1}$

where,

NR^{*}_{it} = expected net returns per acre.

i = region, i=1, 2, ... etc.

t = year.

Y_{it} = yield per acre.

C_{it} = production costs per acre.

LT = log(T).

T = year, 1950=1, 1951=2, ... etc.

A_{it} = acreage planted.

NR^{C}_{it} = expected net returns per acre of a competitive crop.

Q^{P}_{it} = quantity produced in region i.

K_{t} = end-of-period stock at national level

P_{t} = price at farm level, U.S.

Q^{P}_{t} = quantity produced, U.S.

Q^{s}_{t} = total supply, U.S.

The alternative pesticide policies to be evaluated are expected to differ in terms of cost and/or yield. If production cost changes for a crop in a certain region due to a new pesticide policy, then the expected net return will be affected and, as a result, some changes of acreage planted might occur. Yield might change because of differences in the efficacy of alternative pest control methods. These changes in acreage and yield will eventually affect the market clearing prices and, finally, social benefits.

Crop prices are closely interdependent in this model. For example, the soybean price affects other grain prices and vice versa either directly or indirectly. Also, the expected net return for one crop will affect the production decisions for other crops in a given region, as well as in other regions in later periods via their effect on expected net returns.

B. Estimation Procedures

Ordinary Least Squares (OLS) techniques yield biased and inconsistent estimates of the parameters in an equation when these parameters are estimated in a simultaneous equation system similar to the one used in this study. In order to get consistent estimators, more elaborate simultaneous estimation methods, such as Two-stage Least Squares (2SLS) techniques have been developed. Due to the relatively small number of observation (28 observations for the period of 1950-1977) in this model, the 2SLS techniques were applied by using the principal-components method. That is, it is not necessary to estimate the parameters of the whole system of equations in order to estimate a given equation. In this study, for example, corn demand for feed was estimated by 2SLS using only 18 of our 75 predetermined variables.[1] The equations of the model were estimated for the period of 1950-1977 using annual data.

III. EQUATION SPECIFICATION AND ESTIMATION RESULTS

Theoretically, price is determined by the interaction of demand and supply. In order to get the equilibrium price accurately in each year, demand and supply functions should be estimated simultaneously.

The general requirements for the simulaneous equation system of this study such as order and rank conditions were examined and were found to be satisfactory and are not presented in this report.[2] Also, the theoretical descriptions of the structural and reduced forms are not presented.

A note should be made of the problem of the deficiency in cost-of-production information for the crops. The cost data for the seven crops were estimated from USDA publications for a limited number of years and the rest of the years were interpolated by using the prices paid by farmers for all commodities used in production.

A. Demand Functions

The demand for each crop includes various components. Each crop, except oats, contains both a domestic and an export demand. The demand functions are interrelated among the c-ops as mentioned above, and they are estimated simultaneously using the 2SLS method.

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[1] For a further discussion of simultaneous equation system, see Johnston, Econometric Methods, 2nd edition, N.Y.: McGraw-Hill Book Co., 1972, ch. 5, and Jan Kmenta, Elements of Econometrics, N.Y.: Macmillan Co., 1971, ch. 13. Also, see H. H. Kolejian and W. E. Oates, Introduction to Econometrics - Principles and Applications, Harper and Row Publishers, 1974, ch. 7.

[2] The testing method for order and rank conditions are explained in detail by Jan Kmenta, Elements of Econometrics, N.Y.: Macmillan Co., 1971, ch. 13.

For each crop, ending stock is an identity by definition. That is, ending stock is equal to supply minus demand in a given year. However, in order to reflect the real market situation in the process of simulating the future, the ending stock equation will be estimated separately as a function of the quantity produced.

1. Soybeans: The United States is the world's leading producer of soybeans, with production of more than 70 percent of the world's soybean supply. In the recent decade, soybean exports form the U.S. have increased very rapidly. More than one third of the soybeans were exported in the form of soybeans.

Soybean demand is derived from the demand for soybean meal and oil, which are joint products. Therefore, the domestic demand for soybeans may be estimated by the soybean demand for crushing. The U.S. demand for crushing accounted for about 55-58 percent of total soybean demand. Soybeans used directly for feed amount to less than two percent of total demand, and hence they are excluded from this model.

The hypothesized demand functions for soybeans are:[1]

SBD = f(PSB, PC, NAU, PCPCE)

SBX = f(PSB, SBPR)

SBDEM = SBD + SBX

SBK = f(PSB, SBPR, WSP)

where,

SBD = soybean demand for crushing, 1,000 bushels.

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[1] Listing of the definition of variables of the PESTMODEL is given in Appendix Table A-1.

SBX = soybean demand for exports, 1,000 bushels.

PSB = price of soybeans, \$/bushel.

PC = price of corn.

NAU = number of animal units on U.S. farms, 1,000 units.

PCPCE = per capita personal consumption expenditures in the U.S., \$/bushel.

SBPR = soybeans produced, 1,000 bushels.

SBK = soybean ending stocks on farms, 1,000 bushels.

WSP = world soybean production, million bushels.

Corn price (PC) was deleted from the equation SBD because the sign of its coefficient was inconsistent with theory. For the same reason, PSB was deleted from the hypothesized equations SBX and SBK. All of the remaining estimated coefficients carry signs consistent with theory. The estimated results, with the levels of statistical significance (t-values) in the parentheses, are given in Appendix Table A-2.

2. Corn: Livestock feed is the major portion of corn demand. Therefore, livestock information is important and, in this model, it is assumed to be exogenous. Corn exports have been increasing rapidly in the recent decade, and have accounted for around 20-30 percent of total corn demand. Around eight percent of corn was used for food and seed in recent years. The corn demand functions were hypothesized as follows:

CNFO = f(PC, PW, PCPCE)

CNFE = f(PC, PSB, NAU)

CNX = f(PC, CNPR)

CNDEM = CNFO + CNFE + CNX

CNK = f(PC, CNPR)

where,

CNFO = corn demand for food, 1,000 bushels.

CNFE = corn demand for feed, 1,000 bushels.

CNX = corn exports, 1,000 bushels.

CNPR = corn produced, 1,000 bushels.

CNK = corn ending stock, 1,000 bushels.

CNDEM = total demand for corn.

PW = wheat price, $/bushel.

The price of wheat (PW) was deleted from the equation CNFO because it carried a sign incosistent with theory. For the same reason, the price of corn (PC) was left out of the export equation CNX. The estimated results are given in Appendix Table A-3.

3. Wheat: Wheat demand also can be defined as uses for food, feed, and exports. The demand for food has been about 70-90 percent of the total domestic demand. More than half of wheat supply has been exported until recent years, the major portion of which was under government programs. The quantity exported under government programs has been decreasing and the export for dollars has expanded rapidly. The demand functions were hypothesized as follows:

WFO = f(PW, PC, PCPCE)

WFE = f(PW, PC, NAU)

WX = f(PW, WPR)

WDEM = WFO + WFE + WX

WK = f(WPR)

where,

WFO = wheat demand for food, 1,000 bushels.

PW = wheat price, $/bushel.

WFE = wheat demand for feed, 1,000 bushels.

WX = wheat demand for exports, 1,000 bushels.

WK = ending stock of wheat, 1,000 bushels.

The price of wheat was initially included in the export equation but it was subsequently left out because it carried a sign inconsistent with theory. The rest of the coefficients carry signs consistent with theory and the estimated results appear in Appendix Table A-4.

4. Grain Sorghum: Grain sorghum is one of the major agricultural crops in the U.S. Less than one percent is used for food and seed, and most of the grain sorghum is consumed by livestock in the U.S. Consequently, livestock information is important in estimating the demand equations. About 20-30 percent of sorghum has been exported since the early 1970's. Demand for food will be excluded in this model since it is minimal. The hypothesized demand functions are:

GSFE = f(PGS, PC, NAU, TCPFI)

GSX = f(PGS, GSPR)

GSDEM = GSFE + GSX

GSK = f(GSPR)

where,

GSFE = grain sorghum demand for feed, 1,000 bushels.

GSX = export demand, 1,000 bushels.

GSK = ending stock, 1,000 bushels.

PGS = price of grain sorghum, $/bushel.

GSPR = grain sorghum produced, 1,000 bushels.

TLPFI = total number of livestock and poultry on farms, index (1967=100).

Number of animal units (NAU) and corn price (PC) were deleted from the equation GSFE due to the inconsistency of their signs with theory. The price of grain sorghum was also excluded from the export equation for the same reason. The estimated results of the sorghum model are given in Appendix Table A-5.

5. Barley: More than half of the barley crop has been used for feed in the U.S. in the period of 1962-1970 and less than 20 percent has been exported in the same period. Therefore, livestock information is important for explaining production and consumption of this crop. Of course, other feed grain prices such as corn price might also affect the demand for barley. In the 1972-1976 period, barley demanded for exports accounted for less than 20 percent of total demand whereas the demand for food accounted for 30-40 percent of the total demand for barley. The barley demand functions were hypothesized as follows:

BFE = f(PB, PC, MPI)

BFO = f(PB, PW, PCPCE)

BX = f(PB, BPR)

BDEM = BFE + BFO + BX

BK = f(PB, BPR)

where,

BFE = barley demand for livestock feed, 1,000 bushels.

BFO = barley demand for food, 1,000 bushels.

PB = price of barley, $/bushel.

BX = barley demand for exports, 1,000 bushels.

MPI = meat animal production index (1967=100).

BK = barley ending stock, 1,000 bushels.

BPR = barley produced, 1,000 bushels.

Both corn price (PC) and wheat price (PW) carried signs inconsistent with the theory, and hence were deleted from the demand equations for feed (BFE) and food (BFO). The results of the estimated coefficients are shown in Appendix Table A-6.

6. Oats: Oat grain occupies a relatively small acreage in the U.S., similar to that of barley and rye. Both the demand and the size of this crop have been decreasing since the early 1960's. Only 10-15 percent of the U.S. oat crop is used for food. Exports have accounted for about 2-3 percent of the total demand in recent decades. Consequently, an export equation for oats was not estimated for this model. The rest of the crop is demanded for animal feeds. The hypothesized equations are as follows:

$$OFE = f(PO, PC, PW, MPI, T)$$

$$OFO = f(PO, PW, PCPCE, T)$$

$$ODEM = OFE + OFO$$

$$OK = f(OPR)$$

where,

OFE = oat demand for livestock feed, 1,000 bushels.

OFO = oat demand for food, 1,000 bushels.

OK = oat ending stock, 1,000 bushels.

PO = price of oats, $/bushel.

OPR = oats produced, 1,000 bushels.

The price of corn (PC) carried a sign incosistent with theory and hence it was deleted from the demand equation for feed (OFE). The wheat price (PW) substantially affects the demand for oats. The estimated results are given in Appendix Table A-7.

7. Cotton: Cotton is not a feed grain but it is included in this model because it competes with grain crops in the Southeastern and Delta states. Its principal competitor is soybeans. Cotton accounted for about 85 percent of the total textile market in the 1930's. But cotton's share of the total textile market has dropped sharply in recent decades mainly because of advances in chemical technology and textile engineering. However, it is still one of the major sources of textile fibers in the U.S. About half of the total cotton supply has been consumed domestically and 15-30 percent has been exported since the early 1960's. In estimating the demand equation for cotton, chemical fiber prices as well as the price of cotton are important. The hypothesized demand functions for cotton were as follows:

CTD = f(PCT, PCCC, PCRN)

CTX = f(CTPR, WCIM)

CTDEM = CTD + CTX

CTK = f(CTPR, CTX)

where,

CTD = domestic demand for cotton, 1,000 bales.

CTX = export demand for cotton, 1,000 bales.

PCT = price of cotton, cents/lb.

PCCC = per capita consumption of cotton, lbs./person.

PCRN = per capita consumption of rayon and noncellulose fibers, lbs./person.

CTK = cotton ending stock, 1,000 bales.

CTPR = cotton produced, 1,000 bales.

WCIM = world cotton imports by major importing nations, million bales.

CTDEM = total cotton demand, 1,000 bales.

All of the coefficients carried the correct signs and the estimated results are given in Appendix Table A-8.

B. Supply Response Functions

Supply response functions consist of regional acreage response functions, yield functions, and production functions. The number of regions per crop varies from three to five depending upon the USDA's classification for the regional production cost information.[1] As mentioned earlier, each regional acreage response function contains production costs appropriate for that region. Yield is assumed to be a function of time trend, LT (=log T), in every region.

Most of the regional acreage response functions include proxy variables for the expected net returns for the crop considered and its principal competitor. Also, most of the acreage response functions include lagged acres planted in that crop. The theoretical framework for this acreage response function was explained algebraically earlier in this report.

The impact of a pesticide policy can be evaluated through the acreage response and yield functions. A change in production cost would affect the acreage planted which will in turn affect the supply side. Changes in

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[1] For further inquiry, see Appendix A-9 for the data sources of production costs.

yield will have the same effect. Then, at the national level, the prices of crops will change and eventually the quantity demanded.

1. Soybeans: Total U.S. soybean acreas planted are divided into four regions as follows:

1. Lake and Corn-belt Region (SBALC) ---Iowa, Illinois, Indiana, Michigan, Minnesota, Missouri, Ohio, Wisconsin.

2. Northern Plains Region (SBANP) ---Kansas, Nebraska, South Dakota.

3. Southeastern Region (SBASE) ---Alabama, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia.

4. Delta Region (SBADL) ---Louisiana, Mississippi, Arkansas.

The major competing crop for soybeans is corn in all but the Delta Region where the competing crop is cotton. Therefore, the expected prices of corn and cotton are included in soybean acreage response functions. As mentioned earlier, yield is a function of technology.

The hypothesized supply equations are as follows:

$$SBALC = f(PSB1/PC1, SBCLC/CNCLC, SBALC_{-1})$$

$$SBANP = f(PSB1/PC1, SBCNP/CNCNP, SBANP_{-1})$$

$$SBASE = f(PSB1/PC1, SBCSE/CNCSE, SBASE_{-1})$$

$$SBADL = f(PSB1/PCT1, SBCDL/T, SBADL_{-1})$$

$$SBYLC = f(LT)$$

$$SBYNP = f(LT)$$

$$SBYSE = f(LT)$$

$$SBYDL = f(LT)$$

$$SBPLC = SBALC * SBYLC$$

$$SBPNP = SBANP * SBYNP$$

$$SBPSE = SBASE * SBYSE$$

$SBPDL = SBADL * SBYDL$

$SBPR = SBPLC + SBPNP + SBPSE + SBPDL$

$SBS = SBPR + SBK_{-1}$

where,

SBALC, SBANP, SBASE, SBADL = soybean acreages planted in Lake and Corn-belt, Northern Plains, Southeastern, and Delta region, respectively, 1,000 acres.

SBYLC, SBYNP, SBYSE, SBYDL = soybean yield in Lake and Corn-belt, Northern Plains, Southeastern, and Delta region, respectively, bushels/acre.

$PSB1 = (PSB_{-1} + PSB_{-2} + PSB_{-3})/3$. This is used as an expected price for soybeans, $/bushel.

$PCT1 = (PCT_{-1} + PCT_{-2} + PCT_{-3})/3$. Expected price for cotton, cents/lb.

$LT = \log(T)$. This is used as a proxy for technology.

SBCLC, SBCNP, SBCSE, SBCDL = production costs of soybeans in Lake and Corn-belt, Northern Plains, Southeastern, and Delta region, respectively, $/acre.

CNCLC, CNCNP, CNCSE = production costs of corn in Lake and Corn-belt, Northern Plains, and Southeastern, respectively, $/acre.

SBS = total soybean supply, 1,000 bushels.

The estimated results are given in Appendix Table A-2 with t-values in the parentheses. As explained earlier, equilibrium price is generated by setting SBS equal to SBDEM. The price equations for soybeans (PSB), corn (PC), wheat (PW), grain sorghum (PGS), barley, (PB), oats (PO), and cotton (PCT) are given in Appendix Tables A-2 to A-8, respectively.

2. Corn: U.S. corn acreages are divided into five regions based on the same classification criteria mentioned in the soybean section:

1. Northeastern Region (CNANE) --New York, Pennsylvania.

2. Lake and Corn-belt Region (CNALC) --Iowa, Illinois, Indiana, Missouri, Minnesota, Michigan, Ohio, Wisconsin.

3. Northern Plains Region (CNANP) --Colorado, Kansas, Nebraska, South Dakota.

4. Southeastern Region (CNASE) --Alabama, Georgia, Kentucky, North Carolina, South Carolina, Tennessee.

5. Southwestern Region (CNASW) --California.

The major crop competing with corn is soybeans, except for the Southwestern region where wheat is the principal competing crop. The expected net returns of competing crops are important in estimating the acreage response functions.

The corn acreage response functions were hypothesized as follows:

$$CNANE = f(PC1/CNCNE, CNANE_{-1}, LT)$$

$$CNALC = f(PC2/CNCLC, CNALC_{-1}, LT)$$

$$CNANP = f(PC1, CNCNP/PAC, CNANP_{-1})$$

$$CNASE = f(PC1/CNCSE, CNASE_{-1})$$

$$SNASW = f(PC1/PW1, CNCSW/T, CNASW_{-1})$$

$$CNYNE = f(LT)$$

$$CNYLC = f(LT)$$

$$CNYNP = f(LT)$$

$$CNYSE = f(LT)$$

$$CNYSW = f(LT)$$

$$CNPNE = CNANE * CNYNE$$

$$CNPLC = CNALC * CNYLC$$

$$CNPNP = CNANP * CNYNP$$

$$CNPSE = CNASE * CNYSE$$

$$CNPSW = CNASW * CNYSW$$

$$CNPR = CNPNE + CNPLC + CNPNP + CNPSE + CNPSW$$

$$CNS = CNPR + CNK_{-1}$$

where,

CNANE, CNALC, CNANP, CNASE, CNASW = corn acreage planted in Northeastern, Lake and Corn-belt, Northern Plains, Southeastern, and Southwestern region, respectively, 1,000 acres.

CNYNE, CNYLC, CNYNP, CNYSE, CNYSW = corn yield in Northeastern, Lake and Corn-belt, Northern Plains, Southeastern, and Southwestern region, respectively, 1,000 acres.

CNS = total corn supply, 1,000 bushels.

CNCNE, CNCSW = corn production costs in Northeastern, and Southwestern region, \$/acre.

PC2 = $(.5*PC_{-1} + .3*PC_{-2} + .2*PC_{-3})/3$. This variable is another variable used as an expected price, \$/bushel.

PAC = prices paid by farmers for all commodities used in production, index (1967=100).

PW1 = $(PW_{-1} + PW_{-2} + PW_{-3})/3$. Expected price of wheat, \$/bushel.

Initially, the expected price of soybeans and its production cost information were included in the equations where corn and soybeans compete with each other. However, the soybean variables carried signs inconsistent with theory, and therefore, they were deleted. Only the expected price of wheat was included in the equation of CNASW. The estimated results are shown in Appendix Table A-3.

3. Wheat: Total U.S. wheat acreage consists of four regions:

1. Central Plains Region (WACP) --Minnesota, North Dakota, South Dakota, Colorado, Wisconsin, Kansas, Nebraska.
2. Southern Plains Region (WASP) --New Mexico, Oklahoma, Texas.
3. Northern Plains Region (WANP) --Montana, Idaho, Utah, Wyoming.
4. Southwestern Region (WASW)[1] -- California, Nevada, Oregon, Washington, Arizona.

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[1] The states of Washington and Arizona are not in the Southwestern area but they are included in Southwestern Region following the classification of USDA publication, Costs of Producing Food Grains, Feed Grains, Oilseeds and Cotton. 1974-1976. USDA, ERS, AER-338.

Among the four regions, the Central Plains region produces more than half of the U.S. wheat production. The planted acres have been stable over the last two decades in all regions except the Central Plains, where the acres have fluctuated, but in recent years, have increased.

The hypothesized supply functions are as follows:

$$WACP = f(PW1,\ WCCP/T,\ WACP_{-1})$$

$$WASP = f(PW1/WCSP,\ WASP_{-1})$$

$$WANP = f(PW1/WCNP,\ WANP_{-1})$$

$$WASW = f(PW1,\ WCSW/T,\ WASW_{-1})$$

$$WYCP = f(LT)$$

$$WYSP = f(LT)$$

$$WYNP = f(LT)$$

$$WYSW = f(LT)$$

$$WPCP = WACP * WYCP$$

$$WPSP = WASP * WYSP$$

$$WPNP = WANP * WYNP$$

$$WPSW = WASW * WYSW$$

$$WPR = WPCP + WPSP + WPNP + WPSW$$

$$WS = WPR + WK_{-1}$$

where,

WACP, WASP, WANP, WASW = wheat acres planted in Central, Southern, Northern Plains, and Southwestern region, respectively, 1,000 acres.

WYCP, WYSP, WYNP, WYSW = wheat yield in Central, Southern, Northern Plains, and Southwestern region, respectively, bushels/acre.

WS = total supply of wheat, 1,000 bushels.

WCCP, WCSP, WCNP, WCSW = wheat production costs in Central, Southern, Northern Plains, and Southwestern region, \$/acre.

The results of estimation are given in Appendix Table A-4. All of the coefficients carry signs consistent with theory.

4. Grain Sorghum: U.S. grain sorghum acreas planted are divided into three regions as follows:

1. Northern Plains Region (GSANP) —Colorado, Kansas, Missouri, Nebraska, South Dakota.
2. Southern Plains Region (GSASP) —Arkansas, Oklahoma, New Mexico, Texas.
3. Southwestern Region (GSASW) —Arizona, California.

The time pattern of sorghum acres has been stable, similar to that of wheat. Sorghum acres since the early 1960's have maintained a stable level in each region. Yield has increased during the same period.

The hypothesized supply functions are:

$$GSANP = f(PGS1/PB1, GSCNP/T, GSANP_{-1})$$

$$GSASP = f(PGS1/GSCSP, GSASP_{-1})$$

$$GSASW = f(PGS1/PC1, GSCSW, GSASW_{-1})$$

$$GSYNP = f(LT)$$

$$GSYSP = f(LT)$$

$$GSYSW = f(LT)$$

$$GSPNP = GSANP * GSYNP$$

$$GSPSP = GSASP * GSYSP$$

$$GSPSW = GSASW * GSYSW$$

$$GSPR = GSPNP + GSPSP + GSPSW$$

$$GSS = GSPR + GSK_{-1}$$

where,

GSANP, GSASP, GSASW = grain sorghum acres planted in Northern, Southern Plains, and Southwestern region, respectively, 1,000 acres.

GSYNP, GSYSP, GSYSW = grain sorghum yield in Northern, Southern Plains, and Southwestern region, respectively, bushels/acre.

GSPR = GSPNP + GSPSP + GSPSW

GSS = GSPR + GSK_{-1}. Grain sorghum supply, 1,000 bushels.

PGS1 = $(PGS_{-1} + PGS_{-2} + PGS_{-3})/3$. Expected price of grain sorghum, $/bushel.

PB1 = $(PB_{-1} + PB_{-2} + PB_{-3})/3$. Expected price of barley, $/bushel.

GSCNP, GSCSP, GSCSW = production costs of grain sorghum in Northern, Southern Plains, and Southwestern region, respectively, $/acre.

Expected price of barley was included in the GSANP equation and expected corn price (PC1) was included in the equation of GSASW, because of the competitive position of these two crops with grain sorghum in their respective regions. All of the coefficients carry correct signs. The estimated results are shown in Appendix Table A-5.

5. Barley: Barley is grown in five regions;

1. Northeastern Region (BANE) —Pennsylvania.
2. Northern Plains Region (BANP) —Montana, North Dakota, South Dakota, Wyoming.
3. Southern Plains Region (BASP) —Colorado, Oklahoma.
4. Southwestern Region (BASW) —Arizona, California.
5. Northwestern Region (BANW) —Idaho, Oregon, Washington.

Barley acres have been stable in all regions except the Northern Plains where acres have been fluctuating in recent years. Overall, the U.S. acreage of barley has been decreasing since late 1950's. More than half of the U.S. barley crop has been produced in the Northern Plains region.

The barley supply functions were hypothesized as follows:

$$BANE = f(PB1/PO1, BCNE, BANE_{-1})$$

$$BANP = f(PB1/BCNP, BANP_{-1})$$

$$BASP = f(PB1/PGS1, BCSP, BASP_{-1})$$

$$BASW = f(PB1/BCSW, BASW_{-1})$$

$$BANW = f(PB1/BCNW, BANW_{-1})$$

$$BYNE = f(LT)$$

$$BYNP = f(LT)$$

$$BYSP = f(LT)$$

$$BYSW = f(LT)$$

$$BYNW = f(LT)$$

$$BPNE = BANE * BYNE$$

$$BPSP = BASP * BYSP$$

$$BPNP = BANP * BYNP$$

$$BPSW = BASW * BYSW$$

$$BPNW = BANW * BYNW$$

$$BPR = BPNE + BPSP + BPNP + BPSW + BPNW$$

$$BS = BPR + BK_{-1}$$

where,

BANE, BANP, BASP, BASW, BANW = barley acres planted in Northeastern, Northern Plains, Southern Plains, Southwestern, Northwestern region, respectively, 1,000 acres.

BYNE, BYNP, BYSP, BYSW, BYNW = barley yield in BANE, BANP, BASP, BASW, BANW, respectively, bushels/acre.

PB1 = $(PB_{-1} + PB_{-2} + PB_{-3})/3$. Expected price of barley, \$/bushel.

PO1 = $(PO_{-1} + PO_{-2} + PO_{-3})/3$. Expected price of oats, \$/bushel.

BS = total supply of barley, 1,000 bushels.

BCNE, BCNP, BCSP, BCSW, BCNW = production cost of barley in Northeastern, Northern Plains, Southwestern, and Northwestern Plains, respectively, \$/acre.

Oats and grain sorghum are competing with barley in Northeastern and Southern Plains region, respectively. Therefore, the expected prices of oats (PO1) and grain sorghum (PGS1) were included in those respective regions. All of the estimated coefficients carry correct signs. The estimated results are shown in Appendix Table A-6.

6. Oats: Acres for oats are divided into three regions:

   1. Northeastern Region (OANE) --Pennsylvania, New York.
   2. Lake and Corn-belt Region (OALC) --Iowa, Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin.
   3. Northern Plains Region (OANP) --Montana, North Dakota, Nebraska, South Dakota.

The trends show that oat acres have been decreasing since 1950. Especially, acres in the Lake and Corn-belt region decreased from 22.8 million acres in 1950 to less than seven million acres in 1977. The regional acreage functions have been hypothesized as follows:

$$OANE = f(PO1/OCNE, OANE_{-1})$$

$$OANP = f(PO1/OCNP, OANP_{-1})$$

$$OALC = f(PO1/OCLC, OALC_{-1})$$

$$OYNE = f(LT)$$

$$OYNP = f(LT)$$

$$OYLC = f(LT)$$

$$OPNE = OANE * OYNE$$

$$OPNP = OANP * OYNP$$

$$OPLC = OALC * OYLC$$

$$OPR = OPNE + OPNP + OPLC$$

$$OS = OPR + OK_{-1}$$

where,

OANE, OANP, OALC = oat acres planted in Northeastern, Northern Plains, and Lake and Corn-belt region, respectively, bushels/acre.

OYNE, OYNP, OYLC = oat yield in Northeastern, Northern Plains, and Lake and Corn-belt region, respectively, bushels/acre.

$PO1 = (PO_{-1} + PO_{-2} + PO_{-3})/3$. Expected price of oats, \$/bushel.

OCNE, OCNP, OCLC = oat production cost in Northeastern, Northern Plains, and Lake and Corn-belt region, \$/acre.

Expected prices of competing crops such as corn and soybeans were included in the oat acreage response functions initially but were excluded because they carried signs inconsistent with theory. The estimated coefficients all carry correct signs. The results are given in Appendix Table A-7.

7. Cotton: Cotton is mostly grown in the South:

1. Southwestern Region (CTASW) ---Arizona, California, New Mexico.
2. Southern Plains Region (CTASP) ---Oklahoma, Texas.
3. Southeastern Region (CTASE) ---Alabama, Georgia, South Carolina.
4. Delta Region (CTADL) ---Arkansas, Louisiana, Missouri, Mississippi, Tennessee.

Cotton acreage decreased until the late 1960's, but there has been no obvious trend thereafter. Acreage in the Southeastern region has decreased continuously in recent years but that region accounts for a very small portion of the U.S. total.

In the Southeastern and Delta regions, the principal crop competing with cotton is soybeans. In those two regional acreage response functions, the expected price of soybeans is included together with cotton expected price.

The cotton equations are hypothesized as follows:

$CTASW = f(PCT1/CTCSW, CTASW_{-1})$

$CTASP = f(PCT1/CTCSP, CTASP_{-1})$

$CTASE = f(PCT1/PSB1, CTCSE, CTASE_{-1})$

$CTADL = f(PCT1, CTCDL, CTADL_{-1})$

$CTYSW = f(LT)$

$CTYSP = f(LT)$

$CTYSE = f(LT)$

$CTYDL = f(LT)$

$CTPSW = CTASW * CTYSW$

$CTPSP = CTASP * CTYSP$

$CTPSE = CTASE * CTYSE$

$CTPDL = CTADL * CTYDL$

$CTPR = CTPSW + CTPSE + CTPDL + CTPSP$

$CTS = CTPR + CTK_{-1}$

where,

CTASE, CTASP, CTASW, CTADL = cotton acres planted in Southeastern, Southern Plains, Southwestern, and Delta region, respectively, 1,000 acres.

CTYSE, CTYSP, CTYSW, CTYDL = cotton yield in Southeastern, Southern Plains, Southwestern, and Delta region, respectively, bales/acre.

$PCT1 = (PCT_{-1} + PCT_{-2} + PCT_{-3})/3$. Expected price of cotton, cents/lb.

CTCSE, CTCSP, CTCSW, CTCDL = cotton production cost in Southeastern, Southern Plains, Southeastern, and Delta region, respectively, $/acre.

CTS = cotton cupply in U.S., 1,000 bales.

Soybean expected price was deleted from the equation CTADL because it carried a sign inconsistent with theory. The estimated results are shown in Appendix Table A-8.

So far, 129 equations were either estimated or expressed as identities. In order to analyze the impact of pesticide policy alternatives, the equilibrium prices of each of the seven crops should be generated for each year. Theoretically, price is determined by the interaction of demand and supply in a given time period. Therefore, total demand is set equal to total supply for each crop to generate the national-level price for each crop. This requires seven more equations making a total of 136 equations in the PESTMODEL.

IV. PERFORMANCE OF THE MODEL

In order to analyze future impacts of various pesticide policies, a simultaneous econometric system was formulated and estmated, and the results are presented in the Appendix of this report. In this section, an "ex post" forecast of the model is discussed. This "ex post" forecast generates the price, demand, production, acreage, and yield for each crop during the period of 1956-1977. These generated values are then compared with historical data to test how well the simulation model performs. Both numerical and graphical methods are used.[1]

Before "experimenting" with the model for forecasting, the disturbance terms were set equal to zero in order to simplify the computation procedures. The forecasted values of this model, therefore, are in terms of their expected values. In addition to the graphical method, some quantitative measures are used to evaluate the "ex post" forecasting for prices of the seven crops.

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[1] For a further discussion on verification of model, see Robert S. Pindyck and Daniel L. Rubinfeld, Econometric Models and Economic Forecasts, McGraw-Hill Book Co., New York, 1976, ch. 9.

1. RMS (Root-Mean-Square) Simulation Error

$$= \left[\frac{1}{T}\sum_{t=1}^{T}(P_t^f - P_t^a)^2\right]^2$$

2. RMS Percent Error

$$= \left\{\frac{1}{T}\sum_{t=1}^{T}\left[(P_t^f - P_t^a)/P_t^a\right]^2\right\}^{\frac{1}{2}}$$

3. Mean Error

$$= \frac{1}{T}\sum_{t=1}^{T}(P_t^f - P_t^a)$$

4. Mean Percent Error

$$= \frac{1}{T}\sum_{t=1}^{T}\left[(P_t^f - P_t^a)/P_t^a\right]$$

The difference between the actual and the estimated values of an endogenous variable is the error of simulation. The smaller the error, the better is the performance of the model. Mean Percent Error and RMS Percent Error are two of the most commonly used measures for testing the performance of forecasting models.

The econometric model has been simulated dynamically over the sample period of 1956–1977. The simulation results for the price levels are described in terms of Mean Percent Error and RMS Percent Error. They will also be shown graphically in this report (Figures 2–16).

The simulation results indicate that the prices of corn and oats are higher than their actual price levels in most years except for the last several years. As a result, the Mean Percent Error and RMS Percent Error become larger than other crops as shown in Table 1 even though the predictions follow the actual levels closely. Therefore, those numbers should be

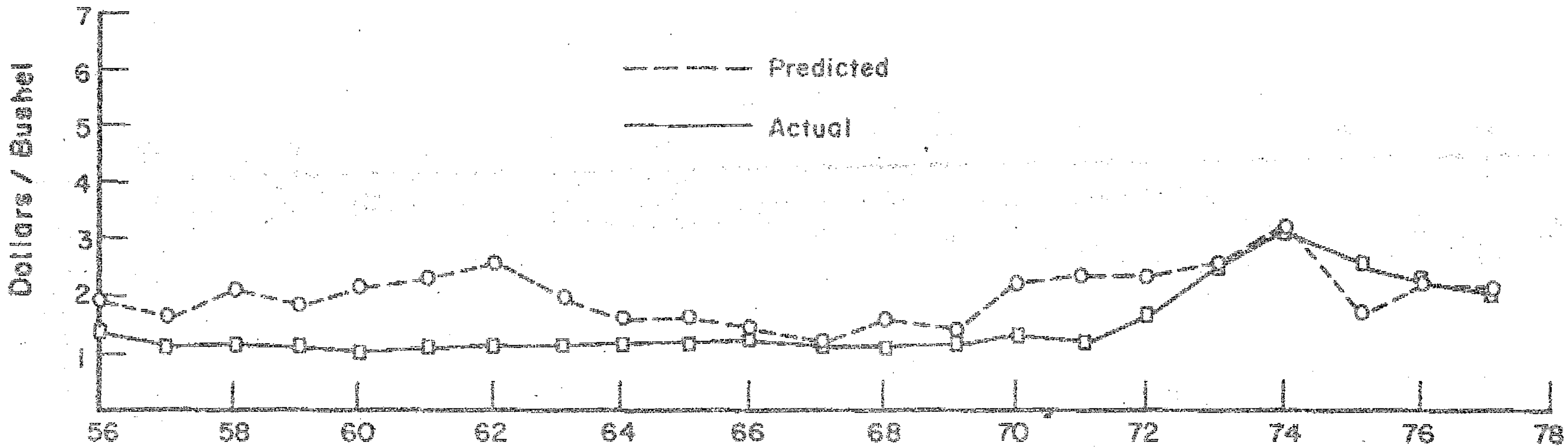

Figure 2. Price of Corn

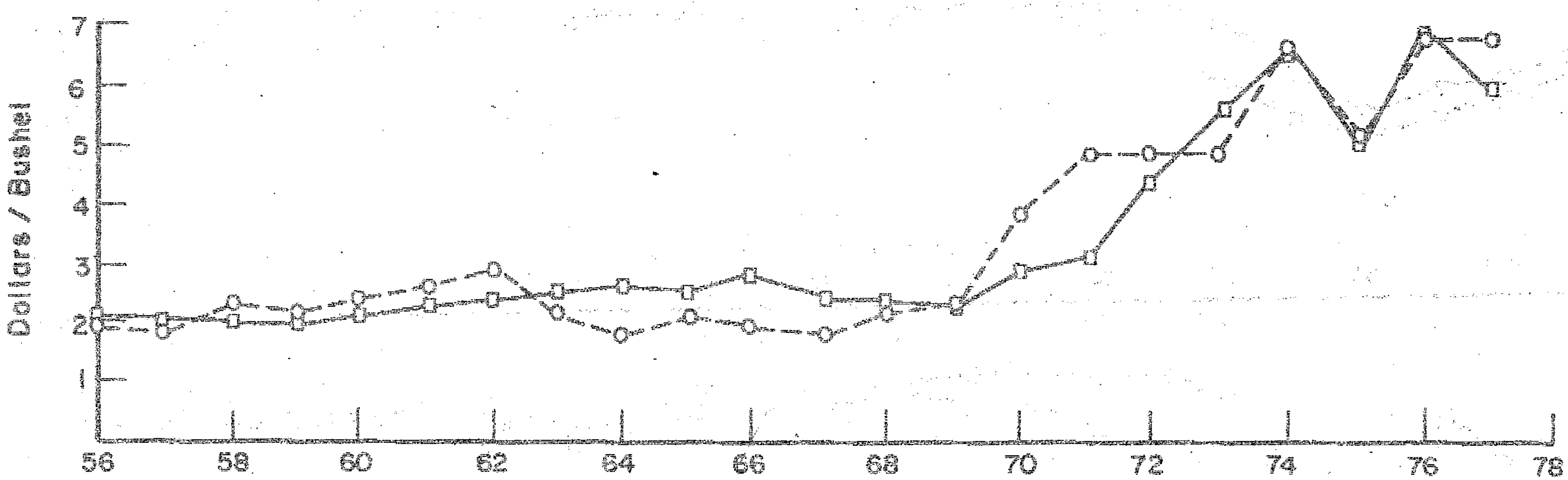

Figure 3. Price of Soybeans

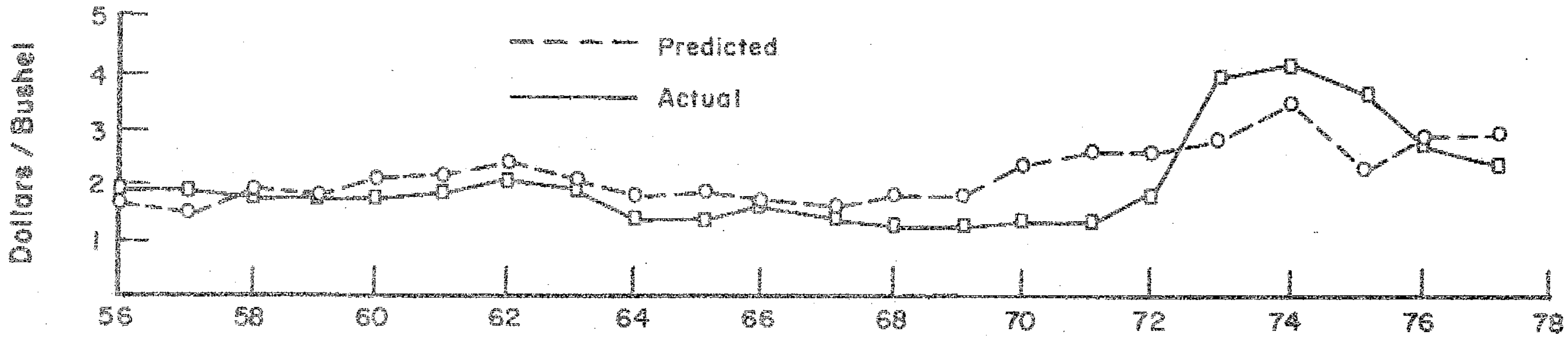

Figure 4. Price of Wheat

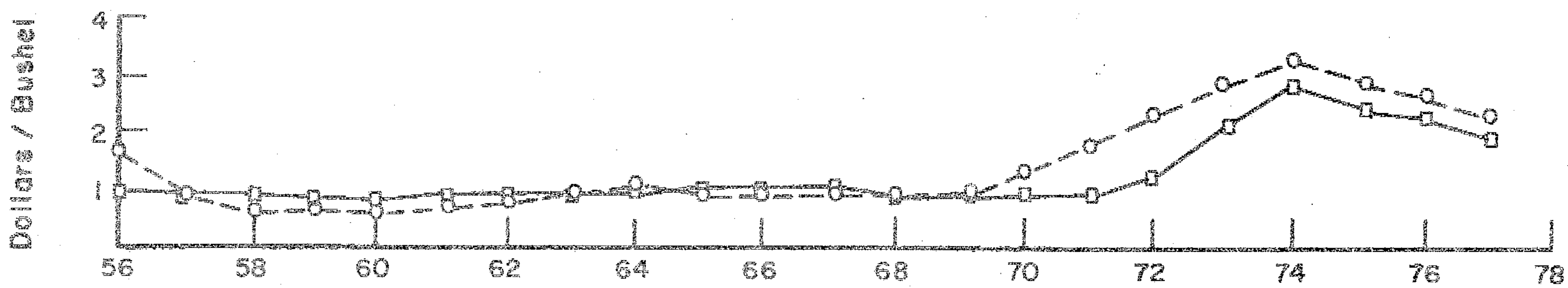

Figure 5. Price of Barley

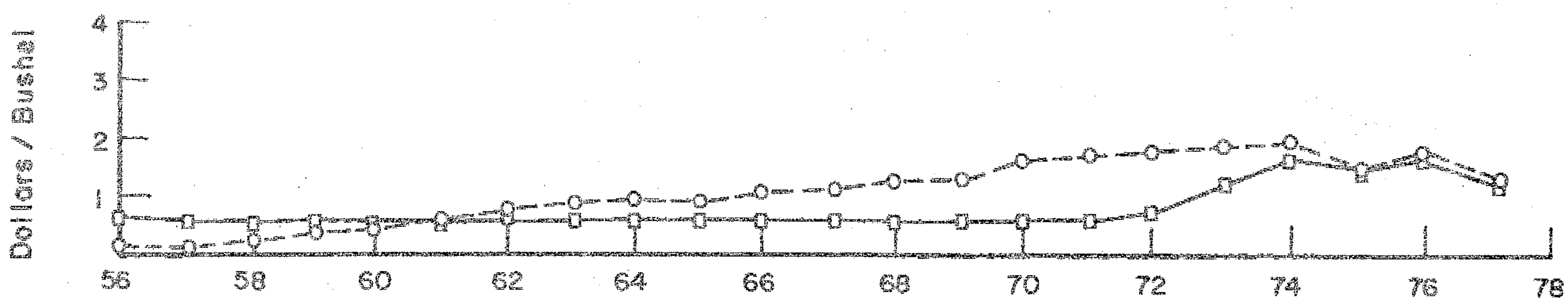

Figure 6. Price of Oats

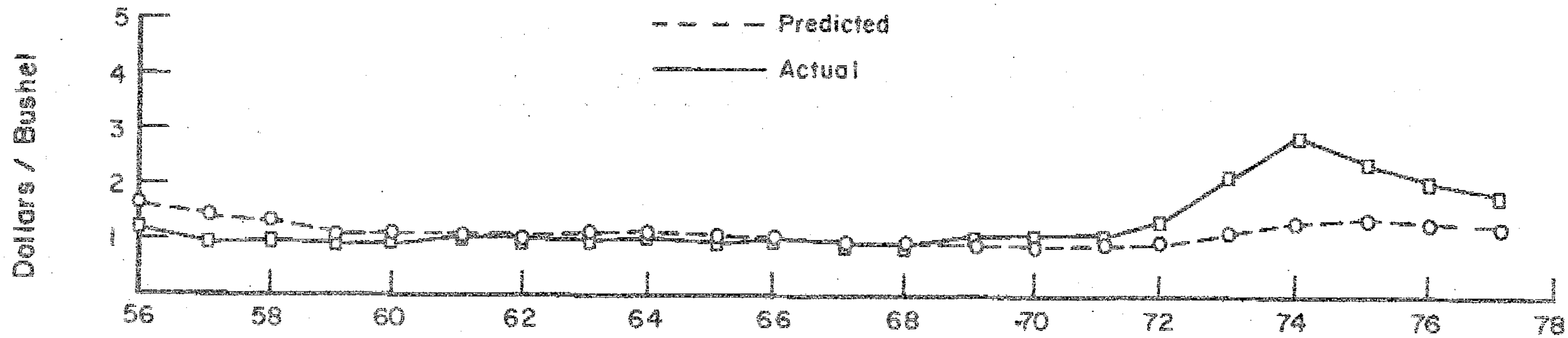

Figure 7. Price of Grain Sorghum

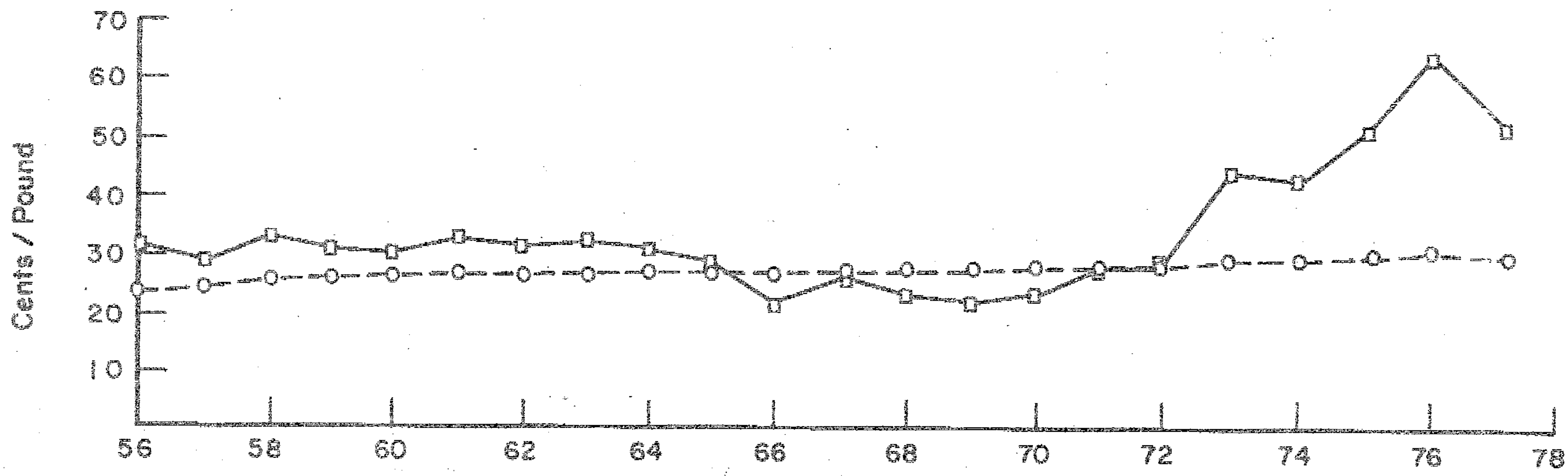

Figure 8. Price of Cotton

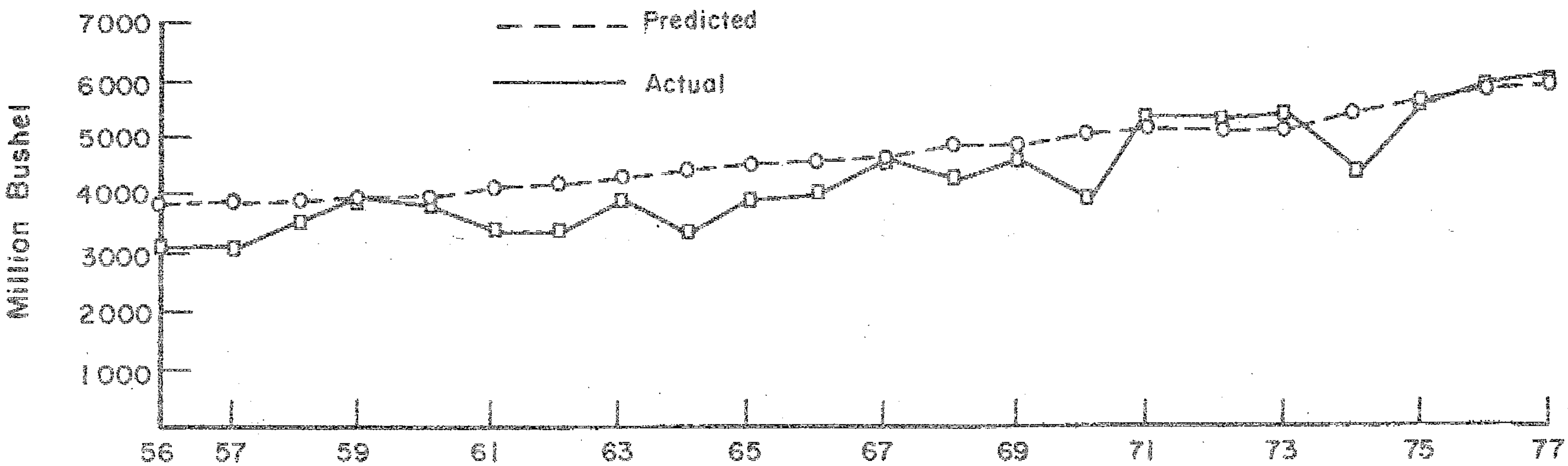

Figure 9. Corn Production

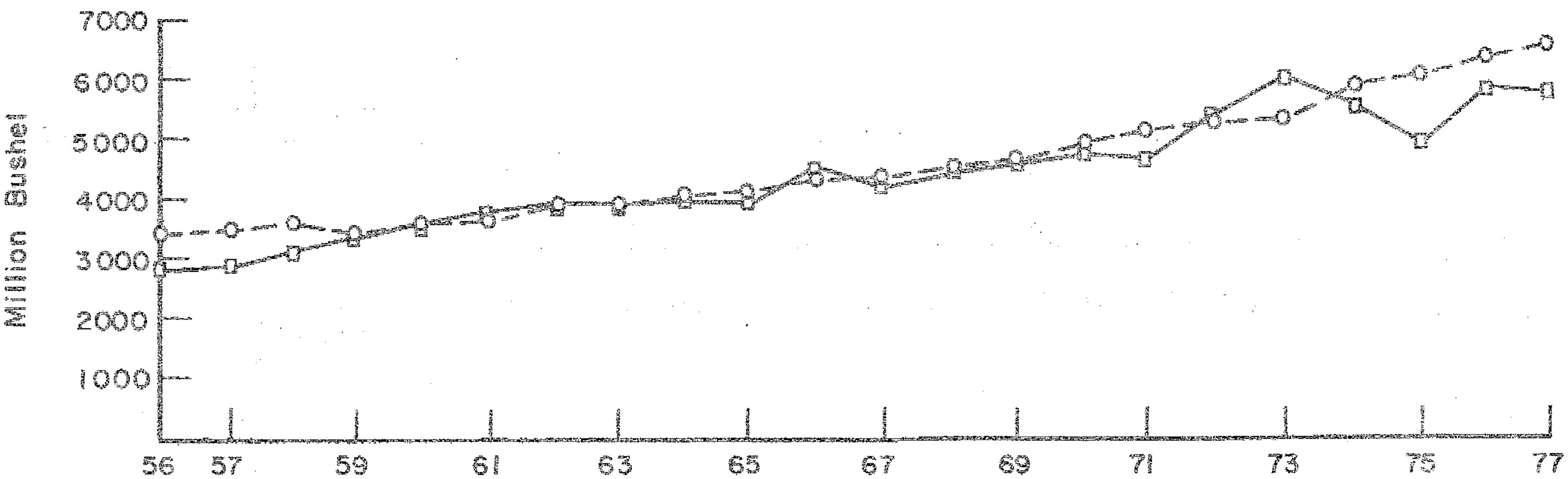

Figure 10. Corn Demand

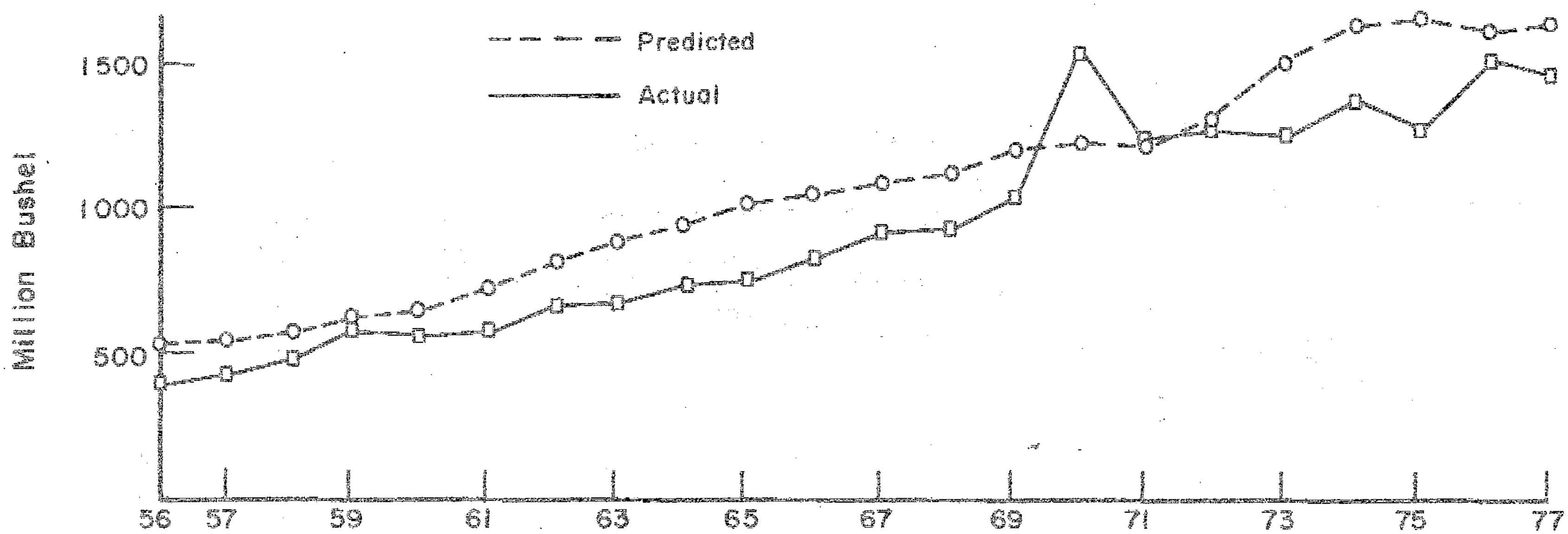

Figure 11. Total Soybean Demand -- Domestic & Export

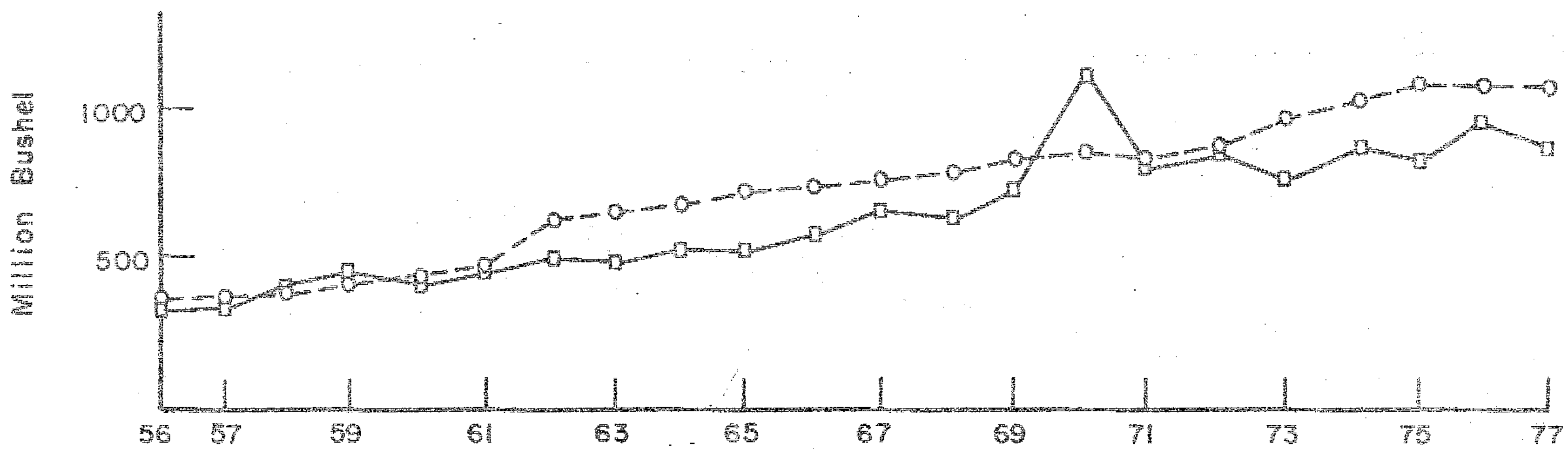

Figure 12. Soybean Domestic Demand

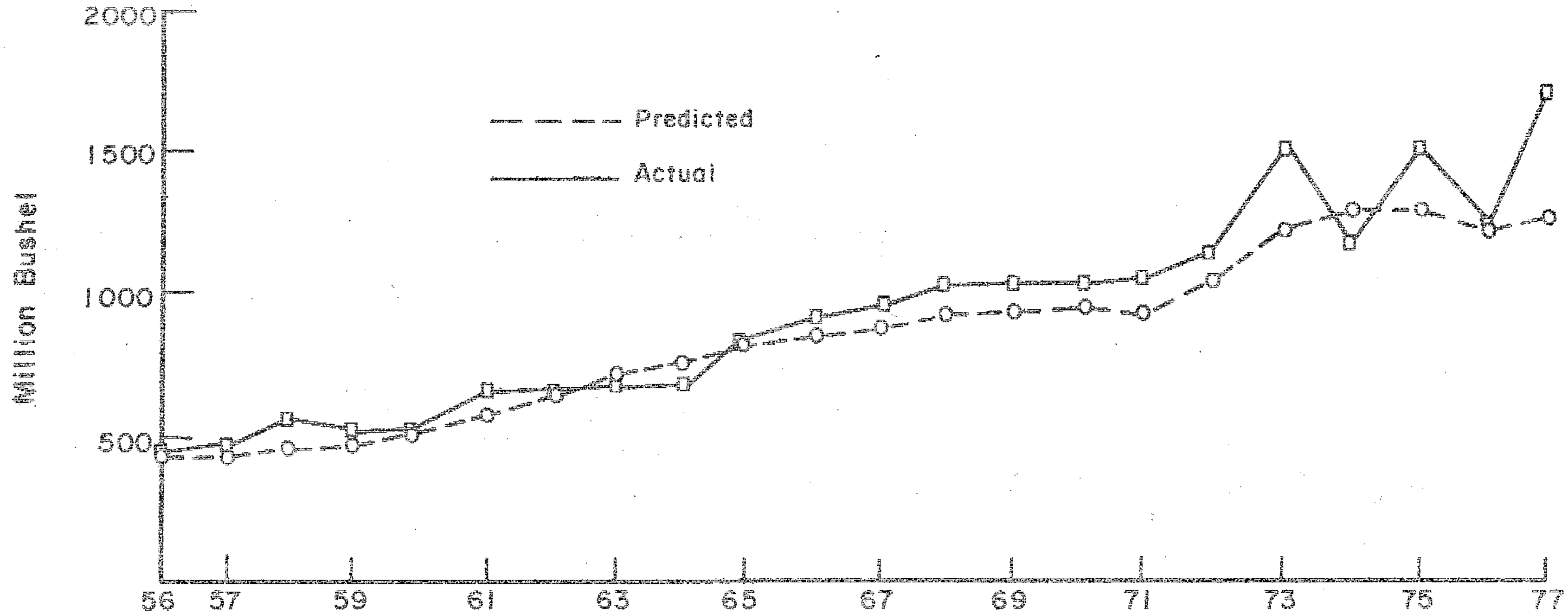

Figure 13. Soybean Production

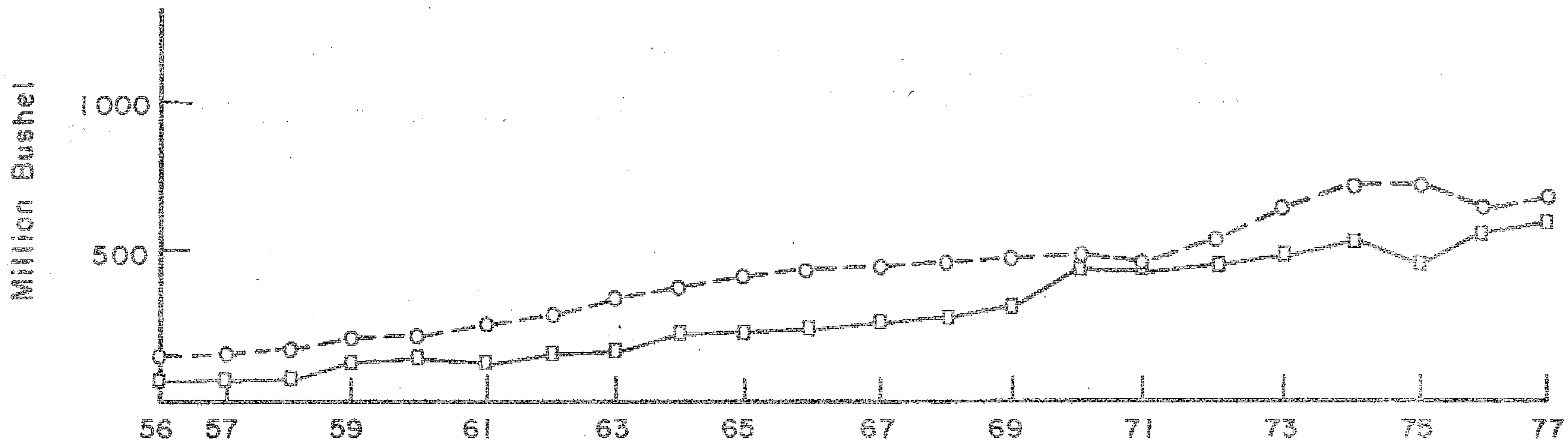

Figure 14. Soybean Export

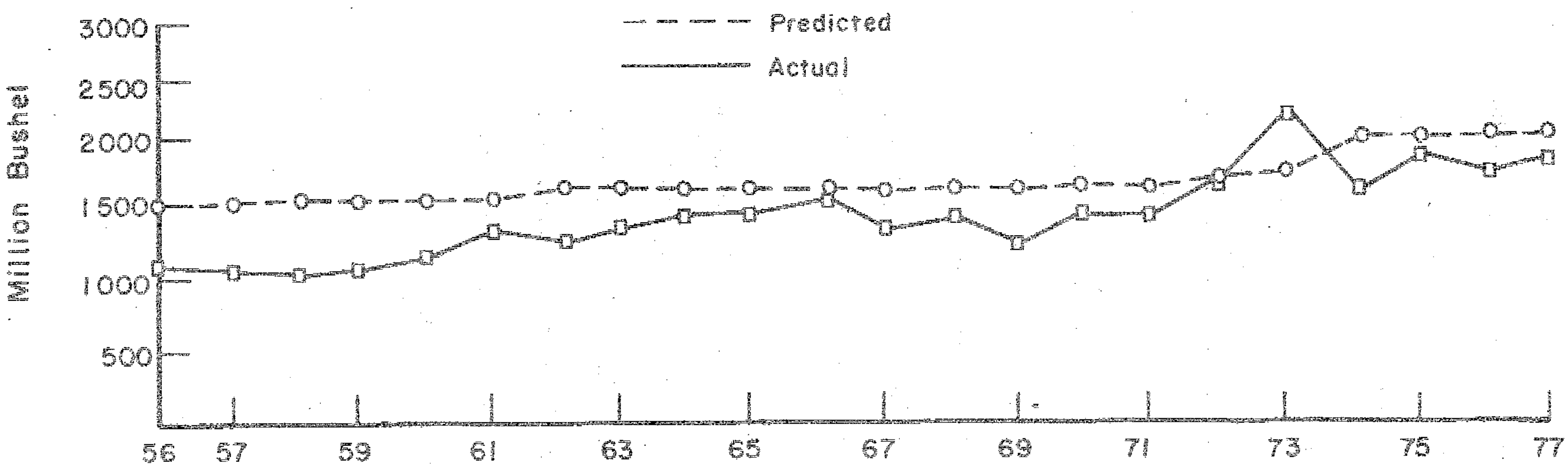

Figure 15. Wheat Demand

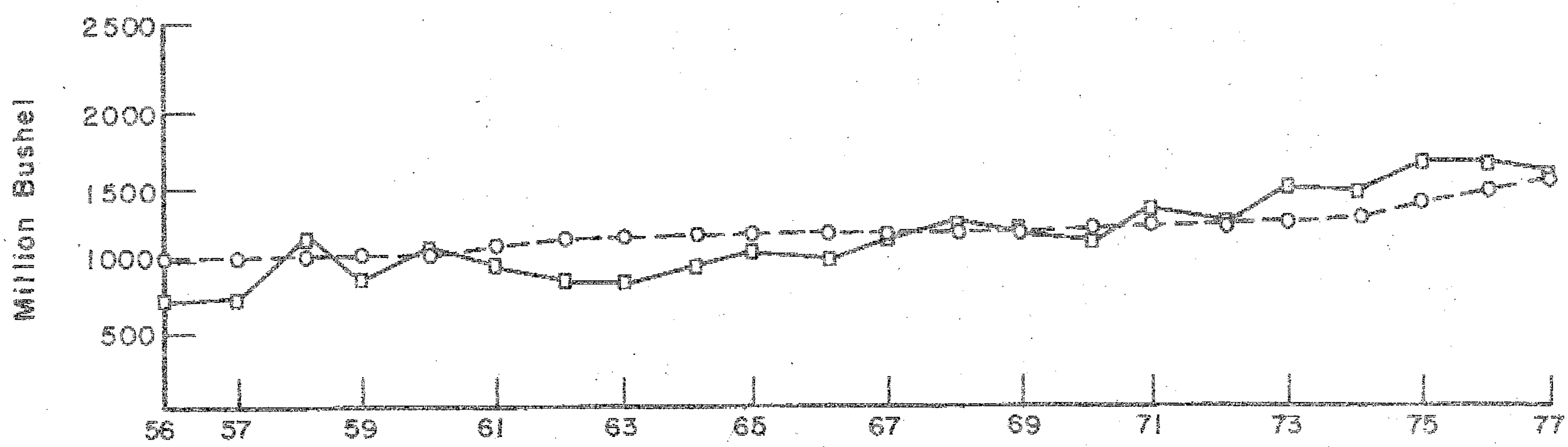

Figure 16. Wheat Production

considered together with the graphs. Other price levels such as soybeans, barley, and grain sorghum seem to be far better according to the numerical statistics. The numerical results are given in Table 1.

Table 1. Mean and RMS Percent Error (1956-1977)

	PSB	PC	PW	PB	PO	PGS	PCT
Mean Percent Error	.008	.499	.182	.036	.395	.024	-.116
RMS Percent Error	.216	.663	.359	.36	.819	.293	.248

The Mean Percent Error of Cotton Price (PCT) is a negative number because the actual price levels were higher than the predicted levels since 1973. The expected price of soybeans was included in the cotton acreage response functions in the Southern regions, but it does not seem to affect appreciably the cotton acreage in this model.

Figures 2-8 compare the paths of the simulated prices and the actual prices of the seven crops in the 1956-1977 period. These graphs indicate that the model reasonably tracks the actual values. Therefore, it appears that this model could be used with a relatively high degree of confidence to perform the "ex ante" forecasts needed to evaluate the economic impacts of various pesticide policies on the indicated crops at the national and regional levels.

V. SIMULATION EXPERIMENTS

As shown in the previous section of this report, it appears that the PESTMODEL is able to generate credible forecasts of certain key variables for each of the included crops. Therefore, the model will be used to perform experiments that would provide further insights into the operation of the model. The application interest is the assessment of the effects of various alternative pesticide policies. The impacts of a given pesticide policy are assessed in this model by specifying changes in production costs and/or yields. To experiment with this model, the initial input of actual price levels of the past three years (1975-1977) were used in formulating the expected prices for the year 1978. To start the model operating, average values of the past three years (1975-1977) were used for lagged acres and stocks. Projections of the exogenous variables were made in order to permit the model to generate values of the endogenous variables up to 1990. Many alternative projections could be made for the exogenous variables which influence, for example, demand, supply, and technology and thus there could be many combinations of projections for the exogenous variables.

In order to simplify the evaluation of various pesticide policies, a certain combination of projections of exogenous variables have been selected and will be referred to as the "baseline" model. The simulation experiments compare the values of endogenous variables generated by the "baseline" model with those obtained by new pesticide policies.

The following projections of the exogenous variables were employed to define the "baseline" model as shown in Table 2.

1. Production costs, $C_{ij,t} = 1.01 * C_{ij,t-1}$

where, C_{ij} = production cost for crop i in region j. Based on 1973-1977 average level.

2. $PCPCE_t = 1.01 * PCPCE_{t-1}$ (Per capita personal consumption expenditure, \$/person).

3. $CPIFI_t = 1.01 * CPIFI_{t-1}$ (Consumer price index for food items, 1967=100).

4. $PAC_t = 1.01 * PAC_{t-1}$ (Prices paid by farmers for all commodities used in production, index, 1967=100).

5. $WSP_t = 1.0025 * WSP_{t-1}$ (World soybean production, million bushels).

6. $T_t = T_{t-1} + 1$ (Time variable, 1950=1).

7. LT = log T (A proxy variable for technology).

8. LPI = 105 (Livestock production index, 1967=100, based on 1970-1977 level).

9. $MPI_t = MPI_{t-1} + .5$ (Meat animal production index, 1967=100, based on 1970-1977 level).

10. $NAU_t = NAU_{t-1} + 10$ (Number of animal units, 1,000 units, based on 1970-1977 level).

11. $TLPFI_t = TLPFI_{t-1} + .5$ (Total livestock and poultry on farms, index, 1967=100, based on 1970-1977 level).

12. PCCC = 15.3 (Per capita consumption of cotton, lbs./person, based on 1973-1977 level).

13. PCRN = 37.8 (Per capita consumption of rayon and noncellulose, lbs./person, based on 1973-1977 level).

14. WCIM = 10407 (World cotton imports, by major importing nations, 1,000 bushels, based on 1973-1977 level).

The specific values of these "baseline" model projections from 1978 to 1990 are shown in Table 2. These projections reflect the past trends for the exogenous variables of the PESTMODEL. Using these projected values, the "ex ante" forecasts of the endogenous variables were made for the period of 1978-1990. The "ex ante" values of selected endogenous variables generated by the "baseline" models are shown by the solid lines in Figures 17-25, and their numerical values are shown in Table 3.

Under the "baseline" assumptions, the projections from this model indicate that the prices of the seven crops would increase continuously

Table 2. EXOGENOUS VARIABLES: PROJECTIONS (1978–1990)*/

	BCNE	BCNP	BCNW	BCSP
1978	48.38	30.54	41.22	44.82
1979	48.87	30.84	41.63	45.26
1980	49.36	31.15	42.05	45.72
1981	49.85	31.46	42.47	46.17
1982	50.35	31.78	42.89	46.63
1983	50.86	32.10	43.32	47.10
1984	51.36	32.42	43.75	47.57
1985	51.88	32.74	44.19	48.05
1986	52.40	33.07	44.63	48.53
1987	52.92	33.40	45.08	49.01
1988	53.45	33.73	45.53	49.50
1989	53.98	34.07	45.98	50.00
1990	54.52	34.41	46.44	50.50

	BCSW	CNCLC	CNCNE	CNCNP
1978	66.20	87.78	92.43	78.31
1979	66.86	88.66	93.35	79.09
1980	67.53	89.54	94.28	79.88
1981	68.20	90.45	95.22	80.68
1982	68.89	91.35	96.17	81.49
1983	69.58	92.26	97.13	82.30
1984	70.27	93.18	98.10	83.12
1985	70.97	94.11	99.08	83.95
1986	71.68	95.05	100.07	84.79
1987	72.40	96.00	101.07	85.64
1988	73.12	96.96	102.08	86.50
1989	73.86	97.93	103.10	87.37
1990	74.59	98.91	104.13	88.24

	CNCSE	CNCSW	CTCDL	CTCSE
1978	98.44	157.59	152.07	175.44
1979	99.42	159.16	153.59	177.19
1980	100.41	160.75	155.13	178.96
1981	101.41	162.35	156.68	180.75
1982	102.42	163.97	158.24	182.56
1983	103.44	165.60	159.83	184.38
1984	104.47	167.25	101.43	186.23
1985	105.51	168.92	103.04	188.09
1986	106.56	170.60	164.67	189.97
1987	107.62	172.30	166.32	191.87
1988	108.69	174.02	167.98	193.79
1989	109.77	175.76	169.66	195.73
1990	110.86	177.51	171.36	197.68

*/ The projections are based on the average of 1973–1977.
See Appendix Table A-1 for definitions of variables.

Table 2 con't.

	CTCSP	CTCSW	GSCNP	GSCSP
1978	102.21	328.94	43.53	55.86
1979	103.23	330.58	43.97	56.42
1980	104.26	332.23	44.41	56.98
1981	105.30	333.89	44.86	57.55
1982	106.36	335.55	45.30	58.13
1983	107.42	337.22	45.76	58.71
1984	108.49	338.90	46.21	59.30
1985	109.58	340.59	46.68	59.89
1986	110.68	342.29	47.14	60.49
1987	111.78	344.00	47.62	61.09
1988	112.90	345.72	48.09	61.70
1989	114.03	347.44	48.57	62.32
1990	115.17	349.17	49.06	62.94

	GSCSW	LT	LPI	MPI
1978	137.27	3.37	105.13	107.0
1979	138.64	3.40	105.13	107.5
1980	140.03	3.43	105.13	108.0
1981	141.43	3.47	105.13	108.5
1982	142.84	3.50	105.13	109.0
1983	144.27	3.53	105.13	109.5
1984	145.71	3.56	105.13	110.0
1985	147.17	3.58	105.13	110.5
1986	148.64	3.61	105.13	111.0
1987	150.13	3.64	105.13	111.5
1988	151.63	3.66	105.13	112.0
1989	153.15	3.69	105.13	112.5
1990	154.68	3.71	105.13	113.0

	NAU	OCLC	OCNE	OCNP
1978	78260	26.75	48.27	22.17
1979	78270	27.02	48.75	22.39
1980	78280	27.29	49.24	22.61
1981	78290	27.56	49.73	22.84
1982	78300	27.84	50.23	23.06
1983	78310	28.11	50.73	23.29
1984	78320	28.39	51.24	23.52
1985	78330	28.67	51.75	23.75
1986	78340	28.96	52.27	23.99
1987	78350	29.25	52.79	24.23
1988	78360	29.54	53.32	24.47
1989	78370	29.83	53.85	24.72
1990	78380	30.13	54.39	24.96

Table 2 con't.

	PAC	PCCC	PCPCE	PCRN
1978	202	15.3	5,678	37.8
1979	204	15.3	5,735	37.8
1980	206	15.3	5,792	37.8
1981	208	15.3	5,849	37.8
1982	210	15.3	5,907	37.8
1983	212	15.3	5,966	37.8
1984	214	15.3	6,025	37.8
1985	217	15.3	6,085	37.8
1986	219	15.3	6,146	37.8
1987	221	15.3	6,207	37.8
1988	223	15.3	6,269	37.8
1989	225	15.3	6,332	37.8
1990	228	15.3	6,395	37.8

	SBCDL	SBCLC	SBCNP	SBCSE
1978	49.99	41.64	34.41	60.24
1979	50.49	42.06	34.75	60.84
1980	50.99	42.48	35.10	61.44
1981	51.50	42.91	35.45	62.05
1982	52.02	43.34	35.80	62.67
1983	52.54	43.77	36.16	63.30
1984	53.07	44.21	36.52	63.93
1985	53.60	44.65	36.89	64.57
1986	54.14	45.10	37.26	65.22
1987	54.68	45.55	37.63	65.87
1988	55.23	46.01	38.01	66.53
1989	55.78	46.47	38.39	67.20
1990	56.34	46.93	38.77	67.87

	T	TLPFI	WCIM	WCCP
1978	29	109.0	10407	31.02
1979	30	109.5	10407	31.33
1980	31	110.0	10407	31.64
1981	32	110.5	10407	31.96
1982	33	111.0	10407	32.28
1983	34	111.5	10407	32.60
1984	35	112.0	10407	32.93
1985	36	112.5	10407	33.26
1986	37	113.0	10407	33.59
1987	38	113.5	10407	33.93
1988	39	114.0	10407	34.27
1989	40	114.5	10407	34.61
1990	41	115.0	10407	34.96

Table 2 con't.

	WCNP	WCSP	WCSW	WSP
1978	28.26	36.78	90.84	2473813
1979	28.54	37.14	91.74	2479998
1980	28.83	37.51	92.66	2486198
1981	29.12	37.89	93.59	2492413
1982	29.41	38.27	94.53	2498644
1983	29.70	38.65	95.47	2504891
1984	30.00	39.04	96.43	2511153
1985	30.30	39.43	97.39	2517431
1986	30.60	39.82	98.36	2523725
1987	30.91	40.22	99.35	2530034
1988	31.22	40.62	100.34	2536359
1989	31.53	41.03	101.34	2542700
1990	31.84	41.44	102.44	2549057

Table 3. Projected Endogenous Variables by Baseline Model: 1978-1990*/

	PSB	PC	PW	PGS	PB	PO	PCT
	$/bushel						¢/lb.
1978	6.75	2.90	3.07	1.88	2.08	2.01	57.80
1979	5.85	2.89	4.28	1.67	1.46	3.03	74.02
1980	6.23	3.07	4.45	1.73	1.52	2.89	71.62
1981	7.09	3.69	5.23	1.79	1.64	2.92	67.70
1982	7.75	4.41	6.10	1.84	1.76	2.95	64.91
1983	8.41	4.67	6.25	1.90	1.85	2.72	66.00
1984	9.00	4.81	6.21	1.96	1.91	2.45	67.84
1985	9.45	4.87	6.09	2.02	1.97	2.20	68.90
1986	9.64	4.81	5.84	2.08	2.01	1.97	69.32
1987	9.67	4.70	5.59	2.14	2.06	1.78	69.58
1988	9.63	4.61	5.42	2.19	2.11	1.67	69.82
1989	9.56	4.51	5.29	2.25	2.15	1.59	70.35
1990	9.51	4.48	5.28	2.31	2.20	1.56	70.72

	SBPR	CNPR	WPR	GSPR	BPR	OPR	CTPR
	1,000 bushels						1,000 bales
1978	1,808,428	5,526,083	1,635,567	728,315	311,611	574,753	6,346
1979	1,895,701	5,490,688	1,642,854	726,652	319,739	553,640	6,484
1980	1,775,629	5,593,458	1,683,736	732,592	316,924	562,710	6,665
1981	1,723,844	5,742,850	1,737,454	739,516	310,469	595,417	6,958
1982	1,622,815	5,886,298	1,820,445	747,542	301,814	635,697	7,168
1983	1,516,440	6,103,026	1,918,780	749,660	297,740	664,858	7,089
1984	1,424,782	6,386,544	2,027,274	751,194	296,771	683,769	6,951
1985	1,368,095	6,646,607	2,120,351	752,165	296,988	672,619	6,871
1986	1,370,341	6,848,325	2,189,709	756,521	298,366	679,316	6,839
1987	1,408,652	6,992,207	2,231,514	761,999	299,950	658,247	6,820
1988	1,464,083	7,067,644	2,245,092	766,502	301,108	628,625	6,802
1989	1,527,020	7,119,979	2,247,173	773,299	302,814	596,096	6,762
1990	1,585,536	7,131,319	2,235,647	778,704	304,100	562,500	6,734

	SBDEM	CNDEM	WDEM	GSDEM	BDEM	ODEM	CTDEM
	1,000 bushels						1,000 bales
1978	1,777,487	6,346,982	1,866,933	685,674	378,957	864,702	14,353
1979	1,889,971	5,998,159	1,675,246	740,163	421,810	761,794	13,475
1980	1,824,832	6,093,908	1,716,107	743,430	420,829	767,970	13,608
1981	1,755,944	6,158,350	1,769,799	747,239	415,785	790,244	13,824
1982	1,680,463	6,082,585	1,852,748	751,653	410,159	817,675	13,978
1983	1,602,597	6,287,393	1,951,034	752,818	407,511	837,533	13,918
1984	1,535,503	6,555,317	2,059,473	753,662	406,881	850,412	13,816
1985	1,494,009	6,801,077	2,152,502	754,196	407,023	853,736	13,758
1986	1,495,653	6,991,701	2,221,827	756,592	407,918	847,379	13,735
1987	1,523,696	7,127,669	2,263,612	759,604	408,948	833,031	13,720
1988	1,564,272	7,198,957	2,277,183	762,081	409,700	812,859	13,707
1989	1,610,342	7,248,414	2,279,285	765,820	410,809	790,706	13,678
1990	1,653,175	7,259,130	2,267,769	768,792	411,645	767,828	13,658

*/ Other variables are not presented but available from the investigator.

during the next decade, but not at a uniform rate. What is important in the evaluation of pesticide policy is not the absolute level of the variables but the differences between the values of these variables and those generated under alternative situations that describe the pesticide policy to be evaluated. Accordingly the next step was to investigate how the endogenous variables are affected by the various alternative pesticide policies. For evaluation by this model, the alternative policies are described in terms of changes in yields and/or production cost. Thus we have three cases: a change in yield only, a change in cost only, and simultaneous changes in yield and cost.

A. Change in Yield

If a pesticide for soybeans is banned, a change in yield might be expected. This may affect the total production of soybeans and lead to new equilibrium prices and quantities of soybeans and other crops. In order to illustrate the use of the PESTMODEL, soybean yields in Southeastern and Delta regions were assumed to decrease by three bushels per acre for the period of 1978-1990. These models are denoted "A" in the Figures 17-25 and Tables 4-5.

The results show that if a pesticide ban results in a three-bushel soybean yield reduction in these two regions, then the total soybean production would decrease substantially in the early 1980's and the soybean price would rise in the same years as shown in the Tables 3-6 and Figures 17-25. As soybean production decreases, other grain production such as corn and wheat increases in the early 1980's as expected. Regional changes in acres of soybeans, corn and cotton due to the yield change in SBASE (Southeastern region) and SBADLC (Delta region) are given in Table 6.

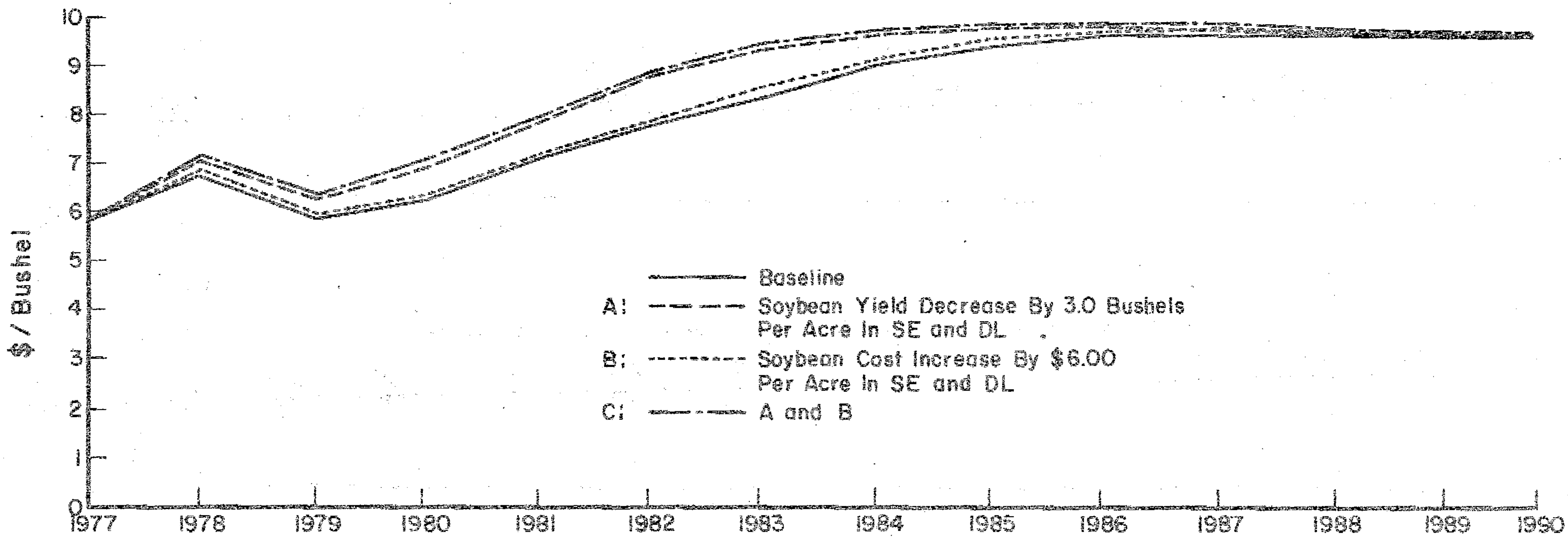

Figure 17. Soybean Price Projections: 1978-1990

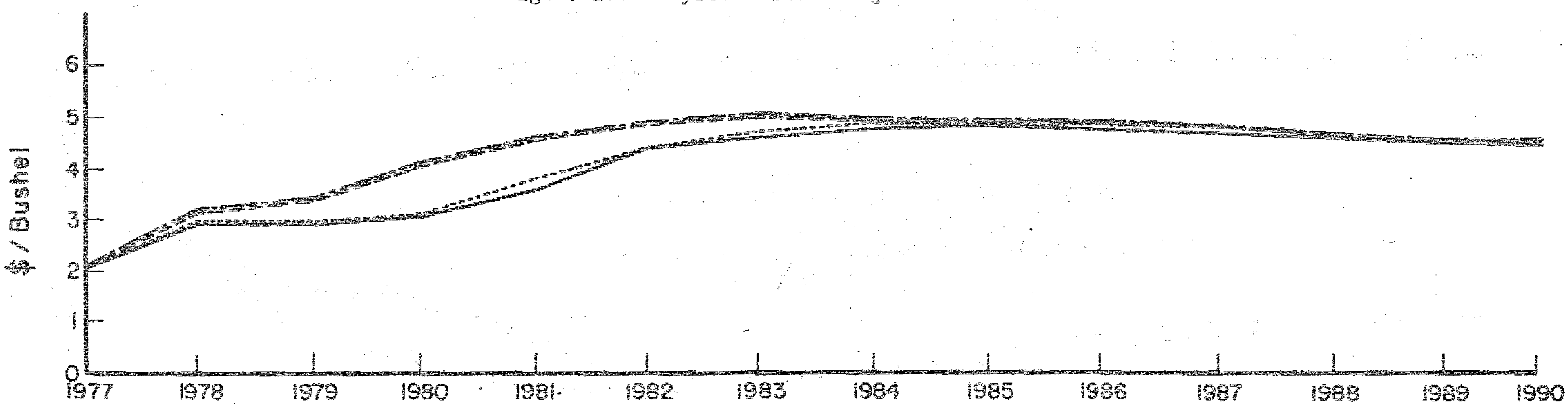

Figure 18. Corn Price Projections: 1978-1990

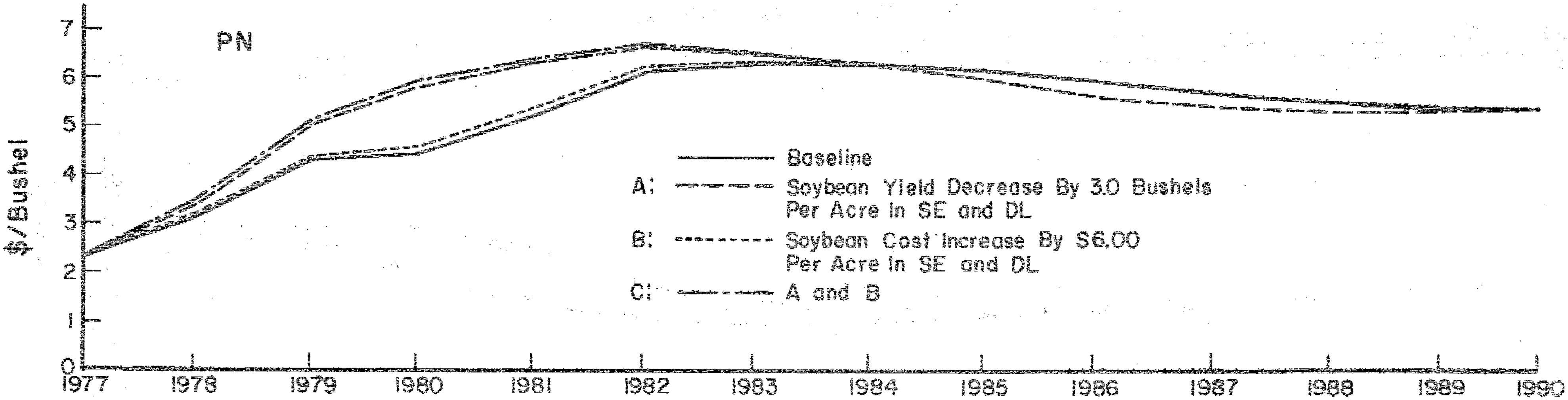

Figure 19. Wheat Price Projections: 1978-1990

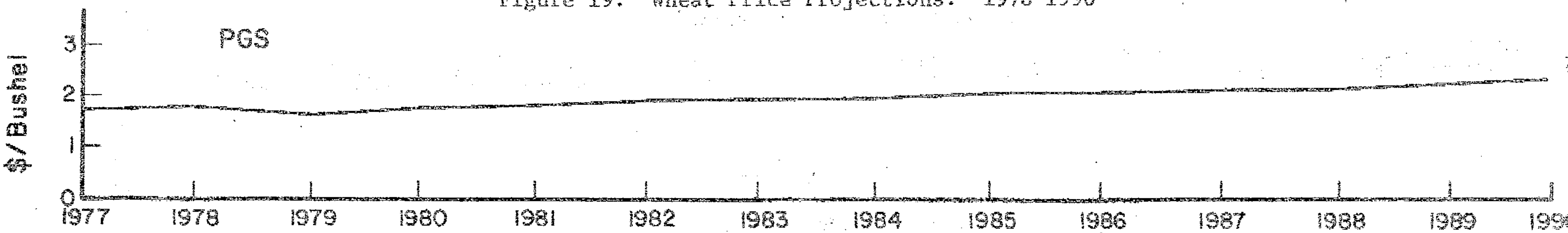

Figure 20. Grain Sorghum Price Projections: 1978-1990

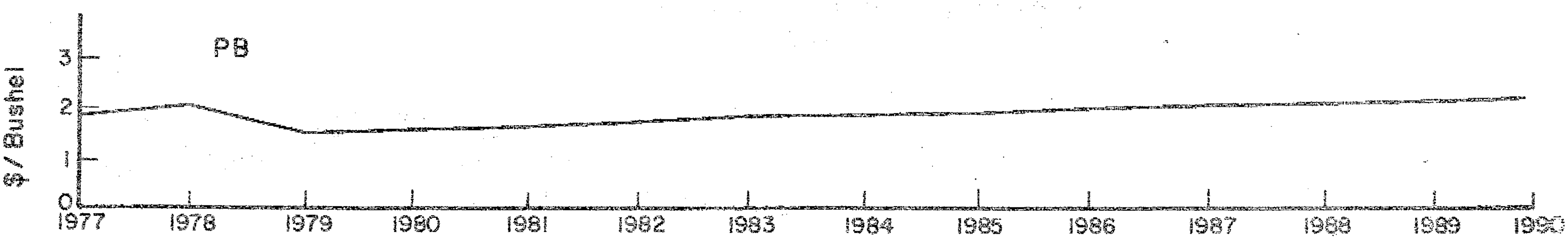

Figure 21. Barley Price Projections: 1978-1990

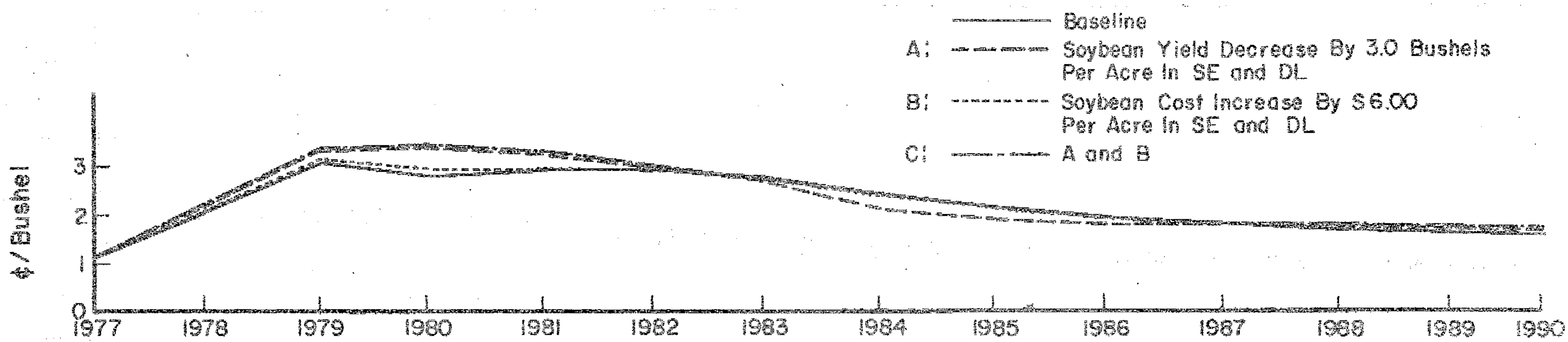

Figure 22. Oat Price Projections: 1978-1990

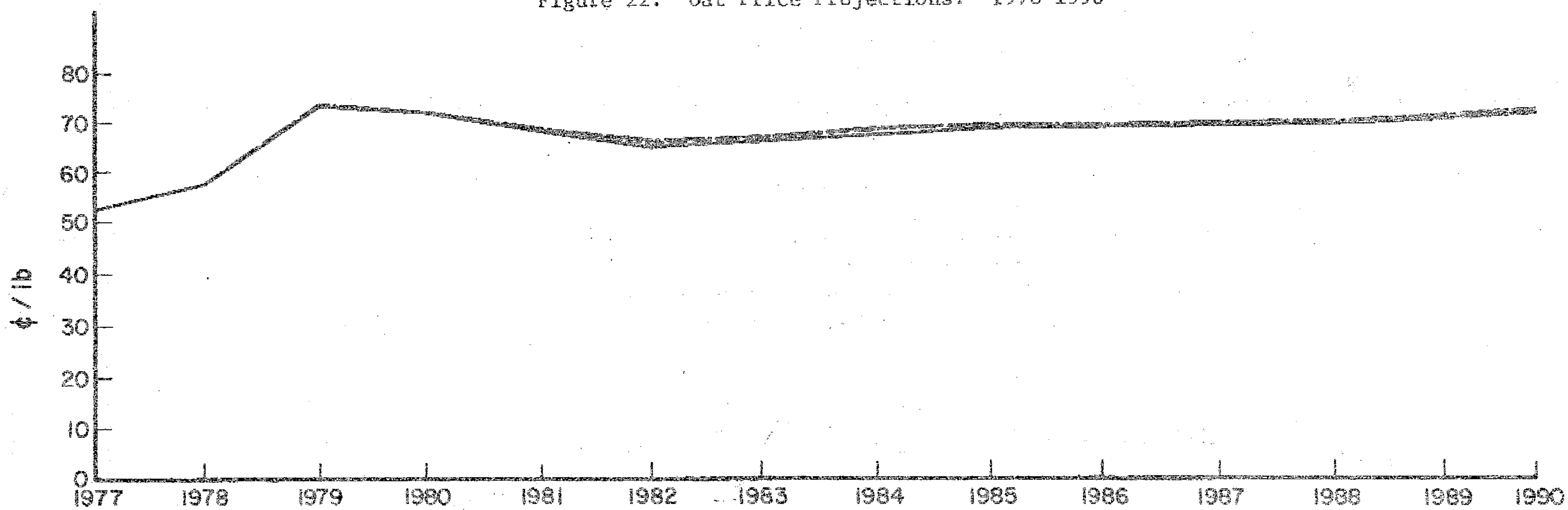

Figure 23. Cotton Price Projections: 1978-1990

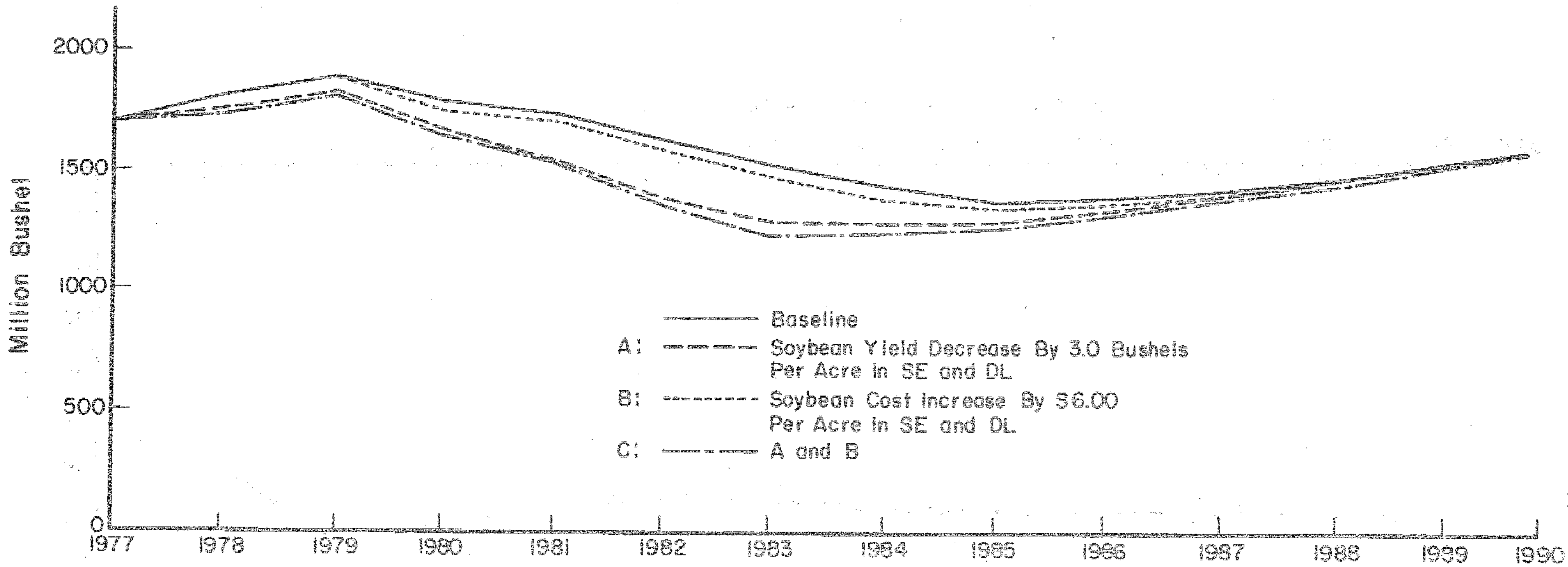

Figure 24. Soybean Production: 1978-1990

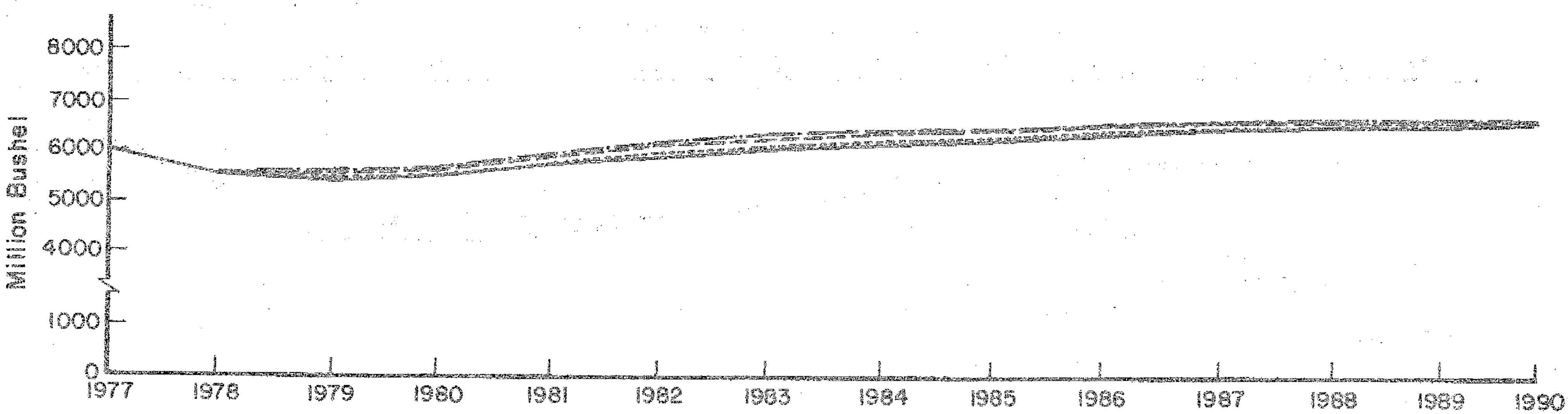

Figure 25. Corn Production: 1978-1990

Table 4. Price Projections: 1978-1990*/

	Soybeans			Corn			Wheat			Grain Sorghum		
	A	B	C	A	B	C	A	B	C	A	B	C
1978	7.01	6.76	7.02	3.09	2.91	3.10	3.35	3.08	3.36	1.88	1.88	1.88
1979	6.31	5.87	6.33	3.40	2.92	3.42	5.01	4.32	5.04	1.67	1.67	1.67
1980	6.98	6.28	7.02	4.06	3.13	4.11	5.84	4.54	5.90	1.73	1.73	1.73
1981	7.94	7.18	7.98	4.52	3.81	4.55	6.29	5.40	6.32	1.79	1.79	1.79
1982	8.80	7.86	8.85	4.88	4.47	4.91	6.52	6.17	6.54	1.84	1.84	1.84
1983	9.38	8.53	9.44	5.01	4.73	5.03	6.42	6.31	6.44	1.90	1.90	1.90
1984	9.67	9.11	9.72	4.96	4.85	4.98	6.12	6.24	6.14	1.96	1.96	1.96
1985	9.78	9.52	9.82	4.86	4.90	4.88	5.84	6.09	5.85	2.02	2.02	2.02
1986	9.76	9.69	9.80	4.72	4.83	4.74	5.57	5.84	5.58	2.08	2.08	2.08
1987	9.67	9.71	9.72	4.60	4.71	4.62	5.38	5.58	5.40	2.14	2.14	2.14
1988	9.60	9.67	9.64	4.54	4.62	4.56	5.33	5.43	5.35	2.19	2.19	2.19
1989	9.54	9.60	9.59	4.50	4.53	4.52	5.30	5.31	5.32	2.25	2.25	2.25
1990	9.55	9.55	9.60	4.51	4.50	4.54	5.36	5.30	5.39	2.31	2.31	2.31

	Barley			Oats			Cotton (¢/lb.)		
	A	B	C	A	B	C	A	B	C
1978	2.08	2.08	2.08	2.13	2.02	2.14	57.80	57.80	57.80
1979	1.46	1.46	1.46	3.33	3.04	3.34	74.05	74.02	74.05
1980	1.53	1.52	1.53	3.45	2.93	3.47	71.72	71.62	71.72
1981	1.64	1.64	1.64	3.26	2.98	3.27	67.92	67.72	67.93
1982	1.76	1.76	1.76	2.94	2.96	2.95	65.24	64.94	65.25
1983	1.85	1.85	1.85	2.57	2.72	2.57	66.35	66.04	66.37
1984	1.91	1.91	1.91	2.16	2.44	2.15	68.16	67.88	68.18
1985	1.97	1.97	1.97	1.88	2.19	1.88	69.16	68.93	69.17
1986	2.01	2.01	2.01	1.75	1.95	1.75	69.52	69.35	69.53
1987	2.06	2.06	2.06	1.73	1.77	1.73	69.70	69.60	69.72
1988	2.11	2.11	2.11	1.70	1.67	1.71	69.89	69.84	69.90
1989	2.15	2.15	2.15	1.66	1.60	1.67	70.39	70.37	70.40
1990	2.20	2.20	2.20	1.65	1.57	1.66	70.73	70.73	70.74

*/ $/bushel except for cotton.

Table 5. Production: 1978-1990*/

	Soybeans A	Soybeans B	Soybeans C	Corn A	Corn B	Corn C
1978	1,748,246	1,806,206	1,746,339	5,526,083	5,526,083	5,526,083
1979	1,821,935	1,891,047	1,817,960	5,502,875	5,491,138	5,503,261
1980	1,667,427	1,767,463	1,660,876	5,648,115	5,596,012	5,649,969
1981	1,536,410	1,708,661	1,525,955	5,899,354	5,751,271	5,905,568
1982	1,383,273	1,597,149	1,371,139	6,159,853	5,906,462	6,170,679
1983	1,293,881	1,488,083	1,281,503	6,452,085	6,133,823	6,466,877
1984	1,271,795	1,399,460	1,260,784	6,710,197	6,423,825	6,723,924
1985	1,292,699	1,350,538	1,282,516	6,891,925	6,678,311	6,904,907
1986	1,343,284	1,357,732	1,333,448	7,019,265	6,875,146	7,031,213
1987	1,407,774	1,399,047	1,397,803	7,088,765	7,012,784	7,099,758
1988	1,472,241	1,455,777	1,461,859	7,104,355	7,082,139	7,114,793
1989	1,531,355	1,518,686	1,520,327	7,121,842	7,130,405	7,132,284
1990	1,577,085	1,576,161	1,505,352	7,121,451	7,139,939	7,132,323

	Wheat A	Wheat B	Wheat C	Grain Sorghum A	Grain Sorghum B	Grain Sorghum C
1978	1,635,567	1,635,567	1,635,567	728,315	728,315	728,315
1979	1,648,630	1,643,067	1,648,813	726,319	726,639	726,308
1980	1,708,814	1,684,917	1,709,667	731,406	732,533	731,368
1981	1,805,102	1,741,175	1,807,835	736,971	739,362	736,885
1982	1,933,491	1,829,114	1,937,984	743,837	747,234	743,716
1983	2,055,731	1,931,368	2,061,468	745,511	749,259	745,370
1984	2,154,286	2,041,753	2,159,869	747,281	750,762	747,142
1985	2,215,933	2,133,146	2,221,077	748,788	751,763	748,653
1986	2,250,199	2,200,036	2,254,771	753,755	756,161	753,625
1987	2,258,928	2,238,891	2,263,022	759,886	761,690	759,759
1988	2,247,756	2,249,839	2,251,588	765,009	766,247	764,883
1989	2,236,525	2,250,227	2,240,362	772,306	773,088	772,176
1990	2,222,117	2,238,045	2,236,156	778,054	778,522	777,915

*/ 1,000 bushels except for cotton.

Table 5 (con't.).

	Barley			Oats		
	A	B	C	A	B	C
1978	311,611	311,611	311,611	574,753	574,753	574,753
1979	319,519	319,730	319,512	555,826	553,721	555,895
1980	316,938	316,925	316,938	572,206	563,156	572,528
1981	310,514	310,470	310,516	620,822	596,813	621,847
1982	301,877	301,816	301,879	677,680	638,914	679,354
1983	297,796	297,742	297,797	714,260	669,466	716,337
1984	296,793	296,771	296,794	726,491	688,871	728,389
1985	296,989	296,988	296,989	714,929	692,803	716,399
1986	298,356	298,365	298,356	687,273	682,178	688,230
1987	299,937	299,948	299,937	650,562	659,755	651,095
1988	301,097	301,106	301,096	608,241	629,121	613,116
1989	302,806	302,813	302,805	579,576	596,091	580,147
1990	304,095	304,099	304,095	550,427	562,498	551,276

	Cotton (1,000 bales)		
	A	B	C
1978	6,346	6,346	6,346
1979	6,482	6,482	6,482
1980	6,657	6,657	6,657
1981	6,941	6,957	6,941
1982	7,144	7,166	7,143
1983	7,063	7,087	7,062
1984	6,927	6,948	6,926
1985	6,852	6,869	6,851
1986	6,824	6,837	6,823
1987	6,810	6,818	6,809
1988	6,796	6,800	6,795
1989	6,759	6,761	6,758
1990	6,733	6,733	6,732

Table 6. Simulation Results: Soybeans, Corn, and Cotton Acres in 1990

	Baseline	A	B	C
	1,000 acres			
Soybeans:				
LC	30,003	31,018	30,108	31,030
NP	2,344	2,447	2,356	2,447
SE	6,965	7,020	6,633	6,687
DL	11,890	12,253	11,625	11,967
U.S.	51,202	52,138	50,722	52,131
Corn:				
NE	4,273	4,404	4,294	4,417
LC	48,593	48,414	48,629	48,473
NP	17,382	17,377	17,415	17,415
SE	9,468	9,498	9,493	9,524
SW	419	434	421	435
U.S.	80,135	80,127	80,252	80,264
Cotton:				
SW	1,803	1,805	1,803	1,805
SP	6,736	6,740	6,736	6,740
SE	547	520	540	515
DL	4,323	4,329	4,324	4,330
U.S.	13,409	13,394	13,403	13,390

The final effects become minimal toward the end of the period. The prices of barley and sorghum are not changed compared with the "baseline" projections. Cotton acreage in the Delta region increased slightly but decreased unexpectedly in the Southeastern region.

B. Change in Cost of Production

If a pesticide is banned, and farmers switch to other substitutes, yield may not change but the cost of controlling the pest might increase. To illustrate this case, soybean production costs were assumed to increase by six dollars per acre in the Southeastern and Delta regions, and the consequences of this increase are labeled "B" in Figures 17-25 and Tables 4-6.

The results show that, when compared to the "baseline" model, cost changes in those two regions make only a slight change in the selected variables. However, the direction of their movements are consistent with the model "A". In this illustration, which assumes no yield change with the new control method, the unavailability of a specific pesticide would not affect substantially either the national price of the quantities produced. Table 6 shows both national and regional changes in acres of soybeans, corn, and cotton in 1990.

C. Changes in both Yield and Cost of Production

If a pesticide is no longer available and a substitute control method required, changes in both yields and costs might occur. That is, yield might decrease and production costs increase. In order to study this possiblity, soybean yeild was decreased by three bushels and production costs were increased by six dollars per acre in Southeastern and Delta regions. The results for this case are labeled "C" in Figures 17-25 and Tables 3-6.

The Figures and Tables show that model "C" follows the same general pattern as the other models but has more significant effects upon prices and quantities produced than when only yields or costs are altered by the change in pesticide policy. This is, of course, the expected result. As with models "A" and "B", the study shows that by the end of the ten-year period, the impact of model "C" has nearly vanished. Changes in both national and regional acres of soybeans, corn, and cotton at the end of the period are shown in Table 6.

VI. SUMMARY AND CONCLUSION

The primary objectives of this study were to formulate a simultaneous equation system to generate the equilibrium quantities and prices for the seven crops ---soybeans, corn, wheat, barley, oats, and cotton; and to use simulation techniques to illustrate the use of the model in evaluating the economic impact of various pesticide policies.

The equation system consists of 136 equations including those at both national and regional levels. The supply equations were estimated by Ordinary Least Squares method whereas the demand equations were estimated by Two-stage Least Squares method. All of the estimated coefficients in the final version of the model carried theoretically consistent signs. In order to reflect the regional changes in the national production and prices of the seven crops, the model ---PESTMODEL--- has regional acreage response, yield, and production functions.

Simulation techniques were used to obtain both "ex post" and "ex ante" forecasts of the endogenous variables. "Ex post" results, in both their graphic and numerical form, were reasonable and acceptable. In order to make the "ex ante" forecasts, the exogenous variables were projected first for the period of 1978-1990 under the assumption that their future values would follow past trends. A "baseline" model was formulated from these projections and the results indicated that prices and production would stabilize in the late 1980's.

In order to illustrate the usefulness and ability of the PESTMODEL to evaluate the various pesticide policies, three experiments were performed. These experiments assumed a shift in pest control practices on soybeans in the Southeastern and Delta regions. The three experiments involved changes in 1) soybean yield only, 2) soybean production costs only, and 3) soybean yield and production costs. The results are, in general, consistent with economic logic. Thus, it is concluded that PESTMODEL is able to generate credible results for the evaluation of the economic impact of alternative pesticide policies.

APPENDIX

Table A-1. LIST OF THE DEFINITIONS OF VARIABLES.

BACRE	Barley acres planted, 1,000 acres, U.S.
BANE	Barley acres planted, 1,000 acres, Northeastern region
BANP	Barley acres planted, 1,000 acres, Northern Plains region
BANW	Barley acres planted, 1,000 acres, Northwestern region
BASP	Barley acres planted, 1,000 acres, Southern Plains region
BASW	Barley acres planted, 1,000 acres, Southwestern region
BCNE	Barley production costs in Northeastern region, $/acre
BCNP	Barley production costs in Northern Plains region, $/acre
BCNW	Barley production costs in Northwestern region, $/acre
BCSP	Barley production costs in Southern Plains region, $/acre
BCSW	Barley production costs in Southwestern region, $/acre
BDEM	Total barley demand, 1,000 bushels
BX	Barley demand for exports, 1,000 bushels
BFE	Barley demand for livestock feed, 1,000 bushels, U.S.
BFO	Barley demand for food, 1,000 bushels, U.S.
BPR	Total barley production, 1,000 bushels
BPRNE	Barley production in Northeastern region, 1,000 bushels
BPRNP	Barley production in Northern Plains region, 1,000 bushels
BPRNW	Barley production in Northwestern region, 1,000 bushels
BPRSP	Barley production in Southern Plains region, 1,000 bushels
BPRSW	Barley production in Southwestern Plains region, 1,000 bushels
BK	Barley ending stock, 1,000 bushels, U.S.
BS ≡	$BPR + BK_{-1}$
BYNE	Barley yields in Northeastern region, bushels/acre
BYNP	Barley yields in Northern Plains region, bushels/acre
BYNW	Barley yields in Northwestern region, bushels/acre
BYSP	Barley yields in Southern Plains region, bushels/acre
BYSW	Barley yields in Southwestern region, bushels/acre
CNACRE	Corn acreage planted in U.S., 1,000 acres
CNALC	Corn acreage planted in Lake and Corn-Belt region, 1,000 acres
CNANE	Corn acreage planted in Northeastern region, 1,000 acres
CNANP	Corn acreage planted in Northern Plains region, 1,000 acres
CNASE	Corn acreage planted in Southeastern region, 1,000 acres
CNASW	Corn acreage planted in Southwestern region, 1,000 acres
CNCLC	Corn production costs in Lake and Corn-Belt region, $/acre
CNCNE	Corn production costs in Northeastern region, $/acre
CNCNP	Corn production costs in Northern Plains region, $/acre
CNCSE	Corn production costs in Southeastern region, $/acre
CNCSW	Corn production costs in Southwestern region, $/acre
CNDEM	Total corn demand, U.S., 1,000 bushels
CX	Corn demand for exports, 1,000 bushels
CNFE	Corn demand for livestock feed, 1,000 bushels
CNFO	Corn demand for food, 1,000 bushels
CNPR	Total corn production, U.S., 1,000 bushels
CNPLC	Corn production in Lake and Corn-Belt region, 1,000 bushels
CNPNE	Corn production in Northeastern region, 1,000 bushels

Table A-1 con't.

CNPNP	Corn production in Northern Plains region, 1,000 bushels
CNPSE	Corn production in Southeastern region, 1,000 bushels
CNPSW	Corn production in Southwestern region, 1,000 bushels
CNK	Corn ending stock, U.S., 1,000 bushels
CNS =	$CNPR + CNK_{-1}$
CNYLC	Corn yields in Lake and Corn-Belt region, bushels/acre
CNYNE	Corn yields in Northeastern region, bushels/acre
CNYNP	Corn yields in Northern Plains region, bushels/acre
CNYSE	Corn yields in Southeastern region, bushels/acre
CNYSW	Corn yields in Southwestern region, bushels/acre
CPIFI	Consumer price index for food items, 1967=100
CTACRE	Cotton acreage planted, U.S., 1,000 acres
CTADL	Cotton acreage planted in Delta region, 1,000 acres
CTASE	Cotton acreage planted in Southeastern region, 1,000 acres
CTASP	Cotton acreage planted in Southern Plains, 1,000 acres
CTASW	Cotton acreage planted in Southwestern region, 1,000 acres
CTCDL	Cotton production costs in Delta region, $/acre
CTCSE	Cotton production costs in Southeastern region, $/acre
CTCSP	Cotton production costs in Southern Plains region, $/acre
CTCSW	Cotton production costs in Southwestern region, $/acre
CTDEM =	CTD + CTX
CTD	Cotton domestic disappearance, 1,000 bales (500 lbs)
CTX	Cotton exports, 1,000 bales (500 lbs)
CTPR	CTPRDL + CTPSE + CTPSP + CTPSW
CTPDL	Cotton production in Delta region, 1,000 bales
CTPSE	Cotton production in Southeastern region, 1,000 bales
CTPSP	Cotton production in Southern Plains region, 1,000 bales
CTPSW	Cotton production in Southwestern region, 1,000 bales
CTK	Cotton ending stock, 1,000 bales
CTS =	$CTPR + CTK_{-1}$
CTYDL	Cotton yields in Delta region, bales/acre
CTYSE	Cotton yields in Southeastern region, bales/acre
CTYSP	Cotton yields in Southern Plains region, bales/acre
CTYSW	Cotton yields in Southwestern region, bales/acre
GSACRE	Grain sorghum acreage planted, U.S., 1,000 acres
GSANP	Grain sorghum acreage Northern Plains region, 1,000 acres
GSASP	Grain sorghum acreage planted in Southern Plains region, 1,000 acres
GSACP	Grain sorghum acreage planted in Central Plains region, 1,000 acres
GSASW	Grain sorghum acreage planted in Southwestern region, 1,000 acres
GSCNP	Grain sorghum production costs in Northern Plains, $/acre
GSCSP	Grain sorghum production costs in Southern Plains, $/acre
GSCSW	Grain sorghum production costs in Southwestern region, $/acre
GSDEM	Grain sorghum total demand, 1,000 bushels
GSX	Grain sorghum demand for exports, 1,000 bushels
GSFE	Grain sorghum for livestock feed, 1,000 bushels
GSPR	Grain sorghum production, U.S., 1,000 bushels
GSPNP	Grain sorghum production, Northern Plains, 1,000 bushels
GSPSP	Grain sorghum production, Southern Plains, 1,000 bushels
GSPSW	Grain sorghum production, Southwestern Plains, 1,000 bushels
GSK	Grain sorghum ending stock, 1,000 bushels

Table A-1 con't.

GSS	=	GSPR + GSK_{-1}
GSYNP		Grain sorghum yields, Northern Plains, bushels/acre
GSYSP		Grain sorghum yields, Southern Plains, bushels/acre
GSYSW		Grain sorghum yields, Southwestern region, bushels/acre
LT		Log (T)
LPI		Livestock price index (1967=100)
MPI		Meat animal production index (1967=100)
NAU		Number of animal units, U.S.
OACRE		Oat acreage planted, U.S., 1,000 acres
OALC		Oat acreage planted in Lake and Corn-Belt region, 1,000 acres
OANE		Oat acreage planted in Northeastern region, 1,000 acres
OANP		Oat acreage planted, Northern Plains, 1,000 acres
OCLC		Oat production costs, Lake and Corn-Belt region, \$/acre
OCNE		Oat production costs, Northeastern region, \$/acre
OCNP		Oat production costs, Northern Plains, \$/acre
ODEM		Total demand for oats, U.S., 1,000 bushels
OFE		Oat demand for feed, U.S., 1,000 bushels
OFO		Oat demand for food, U.S., 1,000 bushels
OPR		Oat production, U.S., 1,000 bushels
OPLC		Oat production, Lake and Corn-Belt region, 1,000 bushels
OPNE		Oat production, Northeastern region, 1,000 bushels
OPNP		Oat production, Northern Plains region, 1,000 bushels
OK		Oats ending stock, 1,000 bushels
OS	=	OPR + OK_{-1}
OYLC		Oat yields, Lake and Corn-Belt region, bushels/acre
OYNE		Oat yields, Northeastern region, bushels/acre
OYNP		Oat yields, Northern Plains region, bushels/acre
PAC		Prices paid by farmers for all commodities used in production, index (1967=100)
PB		Price of barley, \$/bushel
PC		Price of corn, \$/bushel
PCCC		Per capita consumption of cotton, lbs/person
PCPCE		Per capita personal consumption expenditures, \$/person
PCRN		Per capita consumption of rayon and noncellulose, lbs/person
PCT		Price of cotton, ¢/lb
PGS		Price of grain sorghum, \$/bushel
PO		Price of oats, \$/bushel
PSB		Price of soybeans, \$/bushel
PW		Price of wheat, \$/bushel
SBACRE		Soybean acreage planted, U.S., 1,000 bushels
SBADL		Soybean acreage planted, Delta Region, 1,000 bushels
SBALC		Soybean acreage planted, Lake and Corn-Belt region, 1,000 bushels
SBANP		Soybean acreage planted, Northern Plains region, 1,000 bushels
SBASE		Soybean acreage planted, Southeastern region, 1,000 bushels
SBCDL		Soybean production costs, Delta region, \$/acre
SBCLC		Soybean production costs, Lake and Corn-Belt region, \$/acre
SBCNP		Soybean production costs, Northern Plains, \$/acre
SBCSE		Soybean production costs, Southeastern region, \$/acre
SBDEM		Soybean total demand, U.S., 1,000 bushels

Table A-1 con't.

SBD		Soybean domestic demand, 1,000 bushels
SBX		Soybean export demand, 1,000 bushels
SBPR		Soybean production, U.S., 1,000 acres
SBPDL		Soybean production, Delta region, 1,000 acres
SBPLC		Soybean production, Lake and Corn-Belt region, 1,000 acres
SBPNP		Soybean production, Northern Plains region, 1,000 acres
SBPSE		Soybean production, Southeastern region, 1,000 acres
SBK		Soybean ending stock, 1,000 bushels
SBS	=	$SBPR + SBK_{-1}$
SBYDL		Soybean yields, Delta region, bushels/acre
SBYLC		Soybean yields, Lake and Corn-Belt region, bushels/acre
SBYNP		Soybean yields, Northern Plains region, bushels/acre
SBYSE		Soybean yields, Southeastern region, bushels/acre
T		Time
TLPFI		Total livestock and poultry on farms, index (1967=100)
WACRE		Wheat acreage planted, U.S., 1,000 acres
WACP		Wheat acreage, Central Plains, 1,000 acres
WANP		Wheat acreages, Northern Plains, 1,000 acres
WASP		Wheat acreages, Southern Plains, 1,000 acres
WASW		Wheat acreages, Southwestern region, 1,000 acres
WCIM		World cotton imports, by major importing nations, 1,000 bales
WCCP		Wheat production cost, Central Plains, $/acre
WCNP		Wheat production cost, Northern Plains, $/acre
WCSP		Wheat production cost, Southern Plains, $/acre
WCSW		Wheat production costs, Southwestern region, $/acre
WDEM		Wheat total demand, U.S., 1,000 bushels
WX		Wheat demand for exports
WFE		Wheat demand for feed, 1,000 bushels
WFO		Wheat demand for food, 1,000 bushels
WPR		Wheat production, U.S., 1,000 bushels
WPCP		Wheat production, Central Plains, 1,000 bushels
WPNP		Wheat production, Northern Plains, 1,000 bushels
WPSP		Wheat production, Southern Plains, 1,000 bushels
WPSW		Wheat production, Southwestern region, 1,000 bushels
WSP		World soybean production, million bushels
WK		Wheat ending stock, 1,000 bushels
WS	=	$WPR + WK_{-1}$
WYCP		Wheat yields, Central Plains, bushels/acre
WYNP		Wheat yields, Northern Plains, bushels/acre
WYSP		Wheat yields, Southern Plains, bushels/acre
WYSW		Wheat yields, Southwestern region, bushels/acre

Table A-2. PESTMODEL: Soybean Equations.

1. SBALC = −9185.878 + 11435.5*PSBL/PC1 −5008.42*SBCLC/CNCLC
(−2.259) (4.486) (−1.82)
+.5714*$SBCLC_{-1}$
(5.099)

2. SBANP = −2380.12 + 199707*PSB1/PC1 −1042.1*SBCNP/CNCNP
(−5.835) (7.905) (−1.403)
+.3415*$SBANP_{-1}$
(3.35)

3. SBASE = −2199.97 + 1821.27*PSB1/PC1 −933.17*SBSCS/CNCSE
(−1.774) (2.615) (−.9065)
+.879693*$SBCSE_{-1}$
(10.81)

4. SBADL = 408.78 + 7912.01*PSB1/PCT1 −232.833*SBCDL/T
(.8961) (.8952) (−1.127)
+.926158*$SBADL_{-1}$
(10.6)

5. SBYLC = 24.984 + 3.01*LT
(11.07) (6.466)

6. SBYNP = 16.012 + 3.978*LT
(3.325) (4.726)

7. SBYSE = 4.003 + 5.0019*LT
(3.472) (11.19)

8. SBYDL = 8.01 + 3.9987*LT
(4.87) (6.5)

9. SBPLC = SBALC*SBYLC

10. SBPNP = SBANP*SBYNP

Table A-2 con't.

12. SBPDL = SBADL*SBYDL

13. SBPR = SBPLC + SBPNP + SBPSE + SBPDL

14. SBX = -100954 + 43243*SBPRD
(-4.834) (18.26)

15. SBK = -28261.1 + .354051*SBPRD + .03*WSP
(-2.207) (10.41) (1.221)

16. SBS = SBPR + SBK_{-1} .

17. PSB = (SBS-SBX + 1954660 -28.93*NAU -219.96*PCPCE)/(-68432)

18. SBD = -1954660 -68432*PST + 28.93*NAU + 219.96*PCPCE
(-2.667) (-2.503) (2.931) (5.84)

19. SBDEM = SBD + SBX

Table A-3. PESTMODEL: Corn Equations.

1. $$CNANE = \underset{(3.196)}{-795.983} + \underset{(2.321)}{8688.33} * PC1/CNCNE + \underset{(10.47)}{.908959} * CNANE_{-1} + \underset{(2.836)}{251.221} * LT$$

2. $$CNALC = \underset{(.5146)}{1793.63} + \underset{(2.245)}{181588} * PC2/CNCLC + \underset{(1.72)}{.347488} * CNALC_{-1} + \underset{(2.684)}{5754.47} * LT$$

3. $$CNANP = \underset{(1.538)}{4243.76} + \underset{(1.197)}{706.011} * PC1 \underset{(-.5379)}{-1907.6} * CNCNP/PAC + \underset{(3.143)}{.61} * CNANP_{-1}$$

4. $$CNASE = \underset{(2.463)}{1314.45} + \underset{(2.063)}{45016.4} * PC1/CNCSE + \underset{(6.117)}{.66} * CNASE_{-1}$$

5. $$CNASW = \underset{(-.8452)}{-61.2427} + \underset{(2.087)}{174.331} * PC1/PW1 \underset{(-.1399)}{-1.04} * CNCSW/T + \underset{(9.335)}{.825834} * CNCSW_{-1}$$

6. $$CNYNE = \underset{(4.855)}{30.76} + \underset{(3.021)}{6.2515} * LT$$

7. $$CNYLC = \underset{(6.312)}{35.8} + \underset{(9.541)}{18.92} * LT$$

8. $$CNYNP = \underset{(1.116)}{16.7} + \underset{(6.724)}{15.86} * LT$$

9. $$CNYSE = \underset{(1.645)}{4.09} + \underset{(6.993)}{10.5} * LT$$

10. $$CNYSW = \underset{(2.33)}{15.94} + \underset{(5.567)}{14.79} * LT$$

11. $$CNPNE = CNANE * CNYNE$$

Table A-3 con't.

12. CNPLC = CNALC*CNYLC

13. CNPNP = CNANP*CNYNP

14. CNPSE = CNASE*CNYSE

15. CNPSW = CNASW*CNYSW

16. CNPR = CNPNE + CNPLC + CNPNP + CNPSE + CNPSW

17. CNS = CNPR + CNK_{-1}

18. CNX = -621520 + .398684*CNPRD
(-5.788) (9.356)

19. PC = (-6125680 + 67.1233*PCPCE + e8e507*PSB + 109.98*NAU + CNX -CNS)/535927

20. CNK = 1414150 + .22465*CNPRD -572607*PC
(7.055) (11.47) (4.252)

21. CNFO = 178412 -17858.7*PC + 67.1233*PCPCE
(21.23) (-3.536) (20.89)

22. CNFE = -5504160 -518069*PC + 383507*PSB
(-5.403) (2.834) (3.951)

+109.98*NAU
(7.079)

23. CNDEM = CNFO + CNFE + CNX

Table A-4. PESTMODEL: Wheat Equations.

1. $$WACP = \underset{(2.168)}{7088.98} + \underset{(.929)}{1204.21}{*}PW1 \underset{(-.2713)}{-273.967}{*}WCCP/T + \underset{(3.101)}{.6551}{*}WACP_{-1}$$

2. $$WASP = \underset{(1.564)}{2079.8} + \underset{(.3712)}{16410.6}{*}PW1/WCSP = \underset{(4.02)}{.7012}{*}WASP_{-1}$$

3. $$WANP = \underset{(2.441)}{2001.99} + \underset{(1.214)}{9211.85}{*}PW1/WCNP + \underset{(3.068)}{.62}{*}WANP_{-1}$$

4. $$WASW = \underset{(1.972)}{882.944} + \underset{(.7982)}{148.905}{*}PW1 \underset{(-.8876)}{-46.6318}{*}WCSW/T + \underset{(3.896)}{.73}{*}WASW_{-1}$$

5. $$WYCP = \underset{(2.635)}{5.53} + \underset{(8.909)}{7.3}{*}LT$$

6. $$WYSP = \underset{(.1309)}{.3098} + \underset{(8.058)}{7.44342}{*}LT$$

7. $$WYNP = \underset{(7.889)}{12.7126} + \underset{(8.332)}{5.23938}{*}LT$$

8. $$WYSW = \underset{(6.654)}{11.0498} + \underset{(7.641)}{7.64}{*}LT$$

9. $$WPCP = WACP{*}WYCP$$

10. $$WPSP = WASP{*}WYSP$$

11. $$WPNP = WANP{*}WYNP$$

12. $$WPSW = WASW{*}WYSW$$

13. $$WPR = WPCP + WPSP + WPNP + WPSW$$

14. $$WX = \underset{(-1.147)}{269341} + \underset{(6.173)}{.614031}{*}WPRD$$

Table A-4 con't.

15. WK = 28595.4 + .0020742*WPRD
(5.716) (.1935)

16. WS = WPR + WK_{-1}

17. PW = (192908 + 236259*PC + 21.8215*PCPCE + 7.407*NAU + WX -WS)/161583

18. WFO = 465607 -25894*PW + 43968*PC + 21.8215*PCPCE
(53.19) (-1.253) (1.928) (4.553)

19. WFE = -272799 -135689*PW + 192291*PC + 7.407*NAU
(-1.052) (-1.253) (2.308) (1.351)

20. WDEM = WFO + WFE + WX

Table A-5. PESTMODEL: Grain Sorghum Equations.

1. $$GSANP = 6316.52 + 971.1{*}PGS1/PB1 - 831.344{*}GSCNP/T + .13{*}GSANP_{-1}$$
(.6997) (.5502) (-1.651) (.5248)

2. $$GSASP = 3154.01 + 8130.27{*}PGS1/GSCSP + .446{*}GSASP_{-1}$$
(2.277) (.2439) (2.366)

3. $$GSASW = -11.74 + 228.682{*}PGS1/PC1 - .352{*}GSCSW + .8829{*}GSASW_{-1}$$
(-.0466) (.3465) (-1.79) (8.768)

4. $$GSYNP = 12.044 + 14.4{*}LT$$
(.3641) (7.039)

5. $$GSYSP = 4.70638 + 11.63{*}LT$$
(1.253) (9.98)

6. $$GSYSW = 32.8967 + 11.83{*}LT$$
(14.49) (14.49)

7. $$GSPNP = GSANP{*}GSYNP$$

8. $$GSPSP = GSASP{*}GSYSP$$

9. $$GSPSW = GSASW{*}GSYSW$$

10. $$GSPR = GSPNP + GSPSP + GSSW$$

11. $$GSX = -9951 + .391{*}GSPRD$$
(-.3639) (5.748)

12. $$GSK = 425143 + .225{*}GSPRD$$
(1.208) (4.175)

Table A-5 con't.

13. GSS = GSPR + GSK_{-1}

14. PGS = (-579840 + 12670.8*TLPFI + GSX -GSS)/207736

15. GSFE = -579840 -207736*PGS + 12670.8*TLPFI
(-6.902) (-3.675) (8.196)

16. GSDEM = GSFE + GSX

Table A-6. PESTMODEL: Barley Equations.

1. BANE = -63.8323 + 149.558*PB1/PO1 -1.61529*BCNE + .5552*$BANE_{-1}$
   (-1.326) (2.69) (-3.713) (5.82)

2. BANP = 1567.67 + 4756.17*PB1/BCNP + .645879*$BANP_{-1}$
   (1.291) (.4646 (4.209)

3. BASP = 409.05 + 149.125*PB1/PGS1 -9.83*BCSP +.68912*$BASP_{-1}$
   (.5556) (.09368) (1.761) (4.559)

4. BASW = -221.83 + 11244.6*PB1/BCSW + .89864*$BASW_{-1}$
   (-1.517) (2.722) (13.18)

5. BANW = 152.23 + 9390.96*PB1/BCNW + .544*$BANW_{-1}$
   (.3369) (1.709) (4.461)

6. BYNE = 29.1 + 5.5*LT
   (7.419) (3.588)

7. BYNP = 13.9 + 6.9*LT
   (4.476) (5.042)

8. BYSP = 4.9 + 10.9*LT
   (.7335) (5.992)

9. BYSW = 20.4 + 7.9*LT
   (11.81) (11.68)

10. BYNW = 23.0 + 3.9*LT
    (8.559) (5.784)

11. BPNE = BANE*BYNE

12. BPNp = BANP*BYNP

13. BPSP = BASP*BYSP

14. BPSW = BASW*BYSW

Table A-6 con't.

15. BPNW = BANW*BYNW

16. BPR = BPNE + BPNP + BPSP + BPSW + BPNW

17. BS = BPR + BK_{-1}

18. PB = (136348.3 + 2685.12*MPI + 12.8946*PCPCE + .196162*BPRD -BS)/61218.55

19. BX = 15259.5 -4506.21*PB + .196162*BPRD
(.4715) (-.3535) (1.644)

20. BK = 43636.1 -29507.7*PB + 1.032*BPRD
(1.614) (-3.377) (10.98)

21. BFE = 25890.9 -55510.2*PB + 2685.12*MPI
(.6623) (-5.279) (5.501)

22. BFO = 95197.9 -1202.14*BP + 12.8946*PCPCE
(51.50) (-2.143) (15.0)

23. BDEM = BFE + BFO + BX

Table A-7. PESTMODEL: Oats Equation.

1. $$OANE = 1.63435 + 1524.75*PO1/OCNE + .941369*OANE_{-1}$$
(.03764) (.8685) (17.66)

2. $$OALC = -377.258 + 18263.6*PO1/OCLC + .929736*OALC_{-1}$$
(-.7797) (1.596) (24.73)

3. $$OANP = 811.263 + 9857.29*PO1/OCNP + .779783*OANP_{-1}$$
(1.989) (1.85) (7.284)

4. $$OYNE = 32.6 + 4.5*LT$$
(12.65 (4.368)

5. $$OYLC = 33.2 + 6.3*LT$$
(14.41) (4.267)

6. $$OYNP = 17.3 + 6.3*LT$$
(4.387) (3.525)

7. $$OPNE = OANE*OYNE$$

8. $$OPLC = OALC*OYLC$$

9. $$OPNP = OANP*OYNP$$

10. $$OPR = OPNE + OPLC + OPNP$$

11. $$OK = 120516 + .652*OPRD$$
(3.328) (8.448)

12. $$OS = OPR + OK_{-1}$$

13. $$PO = (1115638 + 67299.81*PW + 7109.2*MPI + 16.255*PCPCE - 33026*T - OS)/155981.7$$

14. $$OFE = 946663 - 116792*PO + 59419.1*PW$$
(2.058) (-1.031) (1.367)
$$+7109.2*MPI - 33026*T$$
(1.46) (-4.837)

15. $$OFO = 168975 - 39189.7*PO + 7880.71*PW$$
(23.42) (-1.281) (1.15)
$$+16.255*PCPCE - 1344.59*T$$
(.712) (-2.285)

16. $$ODEM = OFE + OFO$$

Table A-8. PESTMODEL: Cotton Equations.

1. $$CTASW = 326.513 + 2054.87*PCT1/CTCSW + .59123*CTASW_{-1}$$
(1.531) (.744) (2.77)

2. $$CTASP = 1910.67 + 820.15*PCT1/CTCSP + .6422*CTASP_{-1}$$
(2.443) (.03886) (6.291)

3. $$CTASE = 150.44 + 53.5114*PCT1/PSB1 - 1.90649*CTCSE$$
(.1688) (1.756) (-.4142)
$$+ .6663*CTASE_{-1}$$
(6.534)

4. $$CTADL = 894.28 + 49.99*PCT1/PSB1 - 6.5053*CTCDL$$
(.9172) (.885) (-.3256)
$$+ .2523*CTADL_{-1}$$
(3.714)

5. $$CTPSW = CTASW*CTYSW$$

6. $$CTPSP = CTASP*CTYSP$$

7. $$CTPSE = CTASE*CTYSE$$

8. $$CTPDL = CTADL*CTYDL$$

9. $$CTPR = CTPSW + CTPSP + CTPSE + CTPD:$$

10. $$CTX = 3783.05 + .01402*CTPR + .04891*WCIM$$
(.7732) (.6226) (.509)

11. $$CTK = 14488.1 - .64132*CTX$$

12. $$CTS = CTPR + CTK_{-1}$$

13. $$PCT = (12864 + 597.177*PCCC/_{PCRN} + CTX - CTS)/54.2253$$

14. $$CTD = 12864 - 54.2253*PCT + 597.177*PCCC/_{PCRN}$$
(19.03) (-4.548) (5.187)

15. $$CTDEM = CTD + CTX$$

A-9. DATA SOURCES.

1) Soybeans:

SBD - soybean demand for crushing, 1,000 bushels, DRI data bank

SBX - soybean demand for exports, 1,000 bushels, DRI data bank

SBK - ending stock, yearly, 1,000 bushels, DRI data bank

PSB - price of soybeans, $/bushel, at farm level, Agricultural Statistics

WSP - World soybean production, million bushels, commodity yearbook

Soybean acres (SBALC, ... etc.) - Acres planted, 1,000 acres, DRI and Agricultural Statistics

Soybean production (SBPLC, ... etc.) - 1,000 bushels, DRI and Agricultural Statistics

2) Corn:

CNFO - corn demand for food and alcohol, 1,000 bushels, DRI data bank

CNFE - corn demand for feed, 1,000 bushels, DRI data bank

CNX - corn demand for exports, 1,000 bushels, DRI

CNK - corn ending stock, 1,000 bushels, DRI

PC - price of conr/bushel, at farm level, $/bushel, Agricultural Statistics

PCPCE - per capita personal consumption expenditures, U.S. $, Survey of Current Business, B.E.A., USDC

NAU - number of animal units, grain consuming, U.S., 1,000 units, Agricultural Statistics

CPIFI - consumer's price index food itesm (1967=100), Agricultural Statistics

LPI - Livestock Production Index (1967=100), Agricultural Statistics

TLPFI - total livestock and poultry on farms, index (1967=100), Agricultural Statistics

Acres planted (CNANE, ... etc.) - 1,000 acres, DRI and Agricultural Statist

Production (CNPNE, ... etc.) - 1,000 bushels, DRI and Agricultural Statist

3) Wheat:

WFO - wheat demand for food, 1,000 bushels, DRI

WFE - wheat demand for feed, 1,000 bushels, DRI

WX - wheat demand for exports, 1,000 bushels, DRI

WK - wheat ending stock, 1,000 bushels, DRI

PW - wheat price at farm level, $/bushel, Agricultural Statistics

MPI - meat animals production index (1967=100), Agricultural Statistics

Acres planted (WACP, ... etc.) - 1,000 acres, DRI and Agricultural Statist

Production (WPCP, ... etc.) - 1,000 acres, DRI and Agricultural Statistics

4) Grain Sorghum:

GSFE - sorghum demand for feed, 1,000 bushels, DRI

GSX - sorghum demand for export, 1,000 bushels, DRI

GSK - sorghum, ending stock, 1,000 bushels, DRI

PGS - price of sorghum at farm level, $/bushel, Agricultural Statistics

Acres planted (GSANP, ... etc.) - 1,000 acres, DRI and Agricultural Statis

Production (GSPNP, ... etc.) - 1,000 bushels, DRI and Agricultural Statist

5) Barley:

BFE - barley demand for feed, 1,000 bushels, DRI

BFO - barley demand for food and alcohol beverage, 1,000 bushels, DRI

BX - barley demand for export, 1,000 bushels, DRI

BK - ending stock, 1,000 bushels, DRI

PB - price of barley at farm level, $/bushel, Agricultural Statistics

Acres planted (BANE, ... etc.) - 1,000 acres, DRI and Agricultural Statist

Production (BPNE, ... etc.) - 1,000 bushels, DRI and Agricultural Statisti

6) Oats:

OFE - demand for feed, 1,000 bushels, DRI

OFO - demand for food, 1,000 bushels, DRI

OK - ending stock

Acres planted (OANE, ... etc.) - 1,000 acres, DRI and Agricultural Statistics

Production (OPNE, ... etc.) - 1,000 bushels, DRI and Agricultural Statistics

7) Cotton:

CTD - cotton demand, 1,000 bales (500 lbs.), DRI and Agricultural Statistics

CTX - cotton export, 1,000 bales (500 lbs.), DRI and Agricultural Statistics

CTK - cotton ending stock, 1,000 bales, DRI and Agricultural Statistics

PCT - price of cotton at farm level, ¢/lb., Agricultural Statistics

PCCC - per capita consumption of cotton, lbs./person, Agricultural Statistics

PCCR, PCCNC - per capita consumption of rayon and non-cellulose fibers, lbs./person, Agricultural Statistics

PCRN = PCCR + PCCNC

WCIM - world cotton imports by major importing nations, 480 lbs./bale, 1,000 bales, Agricultural Statistics

Acres planted (CTASW, ... etc.) - 1,000 acres, Agricultural Statistics

Production (CTPSW, ... etc.) - 1,000 bales, Agricultural Statistics

8) Data sources for production costs:

1. 1974-75: All crops, all regions
   Costs of Producting Food Grains, Feed Grains, Oilseeds, and Cotton. 1974-1976. USDA, ERS, AER-338.

2. 1960-61
   1966-71: Farm Cost Situation. USDA. No. 39-42.
   a) Corn - East-Central Illinois Data for Corn Belt
   b) Soybeans - East-Central Illinois Data for Corn Belt
   c) Cotton - Yazoo-Mississippi Delta for Delta
   d) Wheat - South Central Kansas for Northern Plains
   e) Sorghum - South Central Kansas for Northern Plains

3. 1976-78: All crops, all regions
   Costs of Producing Selected Crops in the U.S. - 1976, 1977, and Projections for 1978. USDA, ESCS

4. 1957-58: Cotton and soybeans - Delta region
Crop Production Practices and Costs by Size of Farm. Delta Area, Mississippi 1957-78. AER No. 21, USDA, FED-ERS, Nof. 1962.

5. 1950-54: Field Crop Costs and Returns, 1948-1954. R. H. Wilcox and R. A. Hinton. University of Illinois, Agricultural Experiment Station Bulletin 609.

6. 1957: Sorghum. Oklahoma State. Oklahoma Agricultural Experiment Station Bulletin B-525, 1959 - Southern Plains.

7. 1961, 1970: Barley - Northern Plains. North Dakota State University and Agricultural Experiment Station. Bulletin 456. Costs and Returns in North Dakota.

* Using these cost data, interpolation between the years were made by using the Price Index (1967=100) Paid by Farmers for all Commodities Bought to Use In Production (PAC); this type of data is named as cost "A".

* Using the cost data of AER-338 and Congressional Report (Costs of Producing Selected Crops in the United States - 1976-1977, USDA-ESCS), extrapolation was made back to 1950 using the PAC. This is named as cost "B". In the current report, only cost "A" was utilized.

A-10. REGIONAL DIVISION OF STATES.

Soybeans:

1. Lake States and Corn-Belt: IA, IL, IN, MI, MN, MO, OH, WI
2. Northern Plains: KS, NE, SD
3. Southeastern: AL, GA, KY, NC, SC, TN, VA
4. Delta: LA, MS, AR

Corn:

1. Northeastern: NY, PA
2. Lake States and Corn-Belt: IA, IL, IN, MI, MN, MO, OH, WI
3. Northern Plains: CO, KS, NE, SD
4. Southeastern: AL, GA, KY, NC, SC, TN
5. Southwestern: CA

Wheat:

1. Central Plains: MN, ND, SD, CO, WI, KS, NE
2. Southern Plains: NM, OK, TX
3. Northern Plains: MT, ID, UT, WY
4. Southwestern: CA, NV, OR, WA, AZ

Barley:

1. Northeastern: PA
2. Northern Plains: MT, ND, SD, WY
3. Southern Plains: CO, OK
4. Southwestern: AZ, CA
5. Northwestern: ID, OR, WA

Oats:

1. Northeastern: PA, NY

2. Lake States and Corn-Belt: IA, IL, IN, MI, MN, OH, WI

3. Northern Plains: MT, ND, NE, SD

Grain Sorghum:

1. Northern Plains: CO, KS, MO, NE, SD

2. Southern Plains: AR, OK, NM, TX

3. Southwestern: AZ, CA

Cotton:

1. Southwestern: AZ, CA, NM

2. Southern Plains: OK, TX

3. Southeastern: AL, GA, SC

4. Delta: AR, LA, MO, MS, TN