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The Impacts of Fuel Ethanol on the Corn and Soybean Industries: An Econometric Approach

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The issue of corn, or crop related fuel ethanol has been around for some time. One of the first articles appeared in the early 40's when corn and wheat derived ethanol were to be used in aiding the war effort.

Since then, the fuel ethanol industry has gone through a number of changes with respect to reason for and amount of use as well as the quantity of crops demanded for its production. Currently fuel ethanol is at a cross-roads. The opportunity of capturing larger shares of the total petroleum market exists due to lead phase down rulings by the Environmental Protection Agency. Offsetting this potential for market expansion is the decline in oil prices and the sharp drop in the price of fuel ethanol.

Yet, in spite of these ups and downs several major commodity organizations continue to push for the use of ethanol blended fuels as a way of raising the demand and hopefully the price of their products. These groups include the National Sweetener Producers Group and the National Corn Growers. Other industries, such as the American Soybean Association are ambivalent, if not opposed to increased utilization of corn for ethanol purposes. One of the reason is that it is unknown what large increases in fuel ethanol demand will do soymeal prices. One of the byproducts of ethanol production is protein meal which can directly compete with soybean meal. Thus cross effects from the corn industry may adversely impact the soybean sector.

Other researchers have attempted to tackle this problem. Meekhof, Tyner and Holland (1980) investigated the potential impacts via the use of a stochastic simulation model and determined that soybean prices over the long term increased, due to declines in the area planted to soybeans, after an initial price decline.

This paper attempts to address and update the issues described in the Meekhof, Tyner and Holland paper utilizing an econometric model of the corn and soybean sectors. The corn model is described in some detail and compared to earlier econometric models. The soybean model is described conceptually. Projections which increase ethanol demand to the 1,000 million bushel level by 1990 are made, including impacts on exports, area planted and government costs. The paper will not describe a mechanism to achieve 1000 million bushels of ethanol demand, but will include the size of foregone highway tax revenues under current law.

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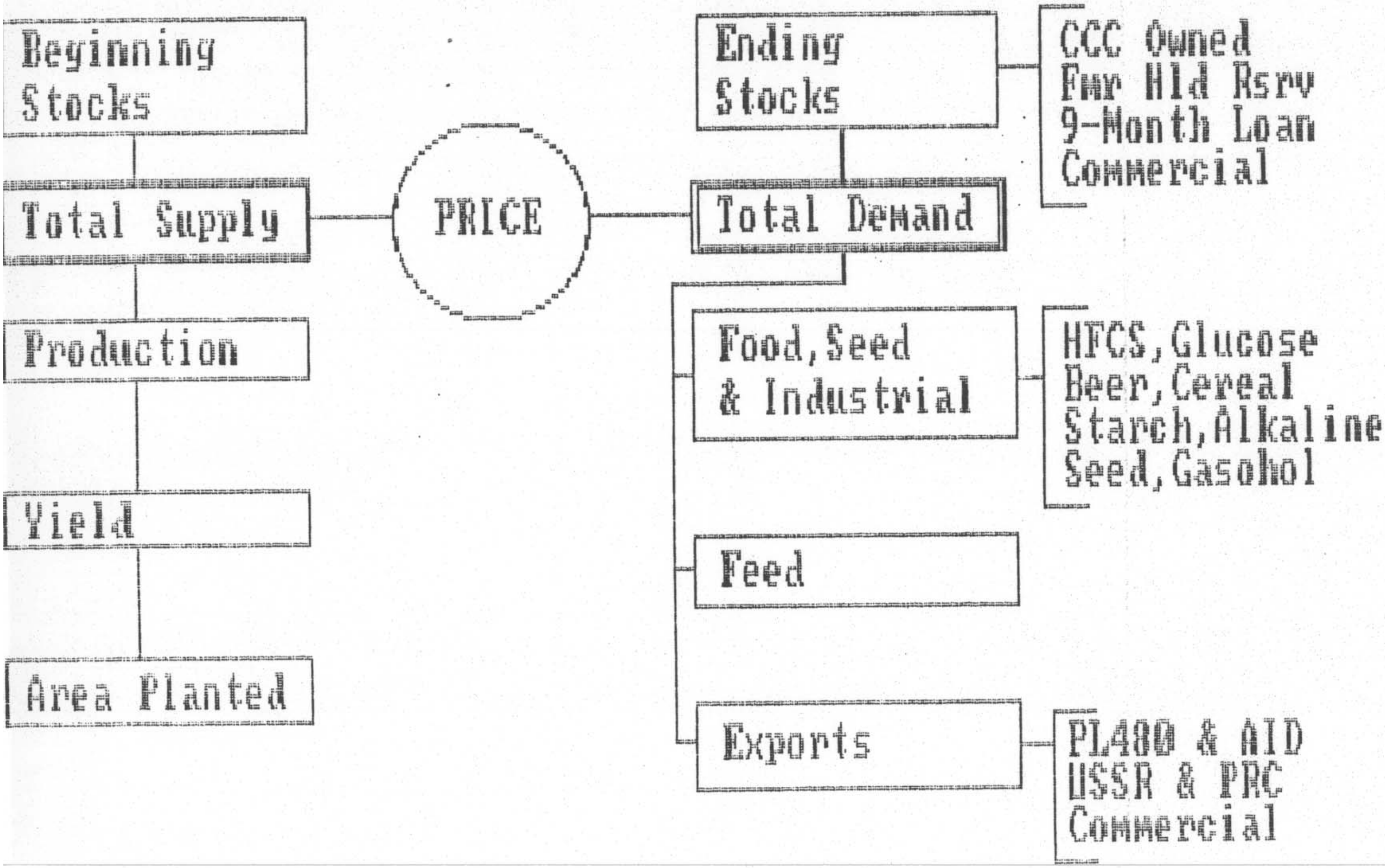
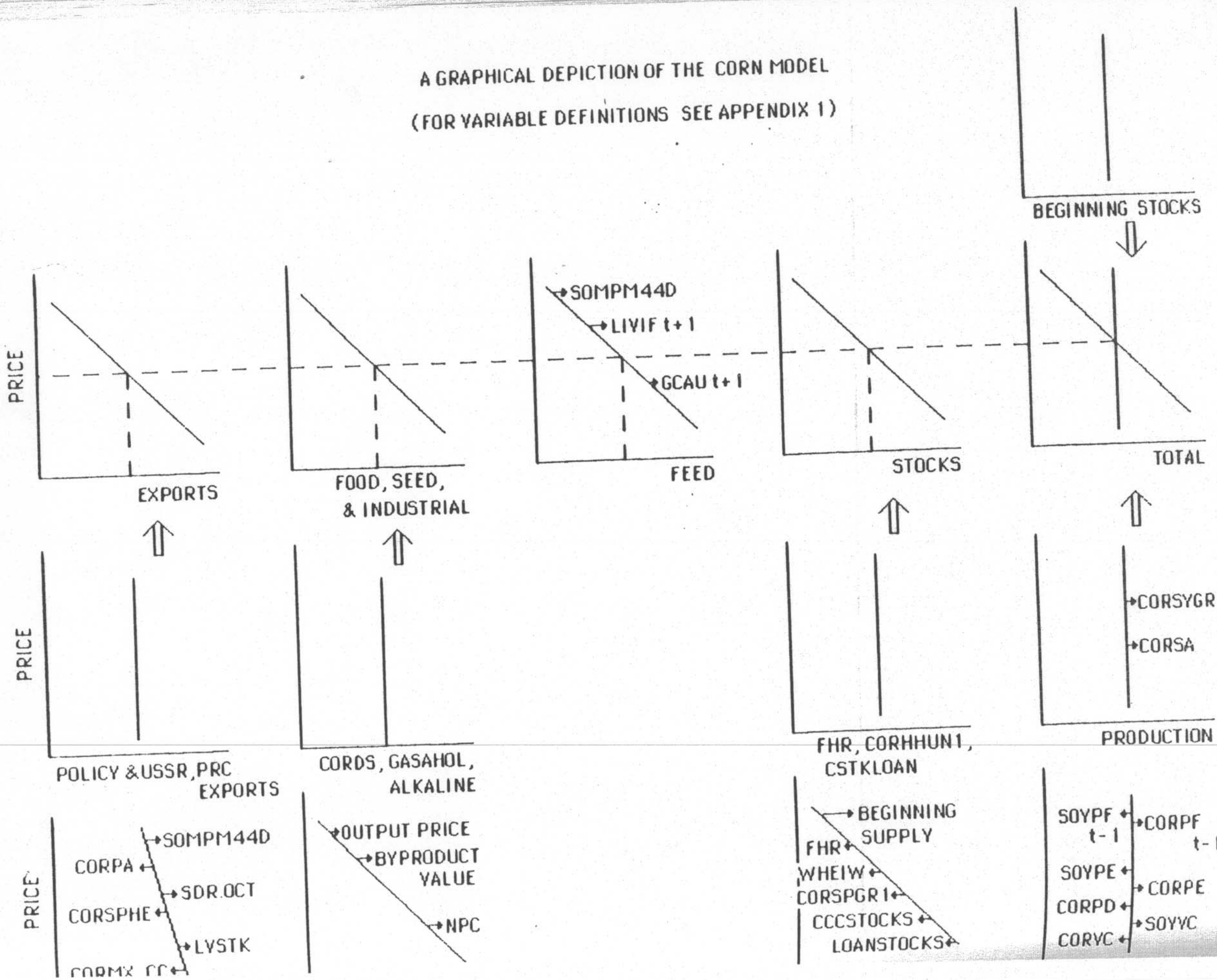


Figure 1. Corn Model Product Flows

A GRAPHICAL DEPICTION OF THE CORN MODEL

(FOR VARIABLE DEFINITIONS SEE APPENDIX 1)



The Econometric Model

The corn model utilized to analyze the scenario consists of two supply related equations, eight demand related equations, three price linkage equations and four identities. Product flows and a graphical representation are given in Figures 1 and 2 respectively.

Supply Relationships

The primary component of the corn model's supply side is the planted acreage equation. Planted acreage is estimated as a function of the effective support prices for corn and soybeans, a ratio of the effective corn diversion rate and lagged market price for corn, a risk variable, lagged corn acreage and a shift variable for the period 1966-1972 to account for the increased acreage response during that time. The development of the effective support and diversion prices are detailed in Green, Womack and Young (1984).

Production is generated via a behavioral equation which combines area planted and corn yields. Also included is an intercept shifter from 1978 forward to account for lower levels of abandonment or harvest for silage.

Demand Relationships

Separate demand relationships are estimated for feed, commercial exports, stocks not under loan and five food, seed and industrial use categories. Remaining as exogenous on the demand side are policy exports, such as PL-480/AID and shipments to the Soviet Union and China. Also exogenous are alkaline demand and other food. Under stock activity, CCC owned, Farmer Held Reserve and stocks under loan are treated as exogenous.

Feed

Feed use, a derived demand equation, is estimate as a function of the feed consumed per animal unit. It is estimated as being functionally related to the farm price of corn deflated by a livestock price index, the soybean meal price deflated by the livestock price index and intercept shifters. An intercept shifter is utilized for 1972 forward, and for 1963, 1973 and 1982. It should be pointed out that this category is officially used to balance supplies with demand by USDA. Thus any actual errors associated with production or other demand components are accounted for in the official feed use statistic. This may be a cause of the relatively large number of outliers associated with this demand category.

Food, Seed and Industrial

Perhaps the most substantial difference between this model and those utilized in the past is in the food and industrial use component. Most make use of only one equation for Food, Seed and Industrial (FSI) use. However, the output of the FSI sector consists of a variety of products, each facing different output prices and demand conditions. In addition, while total usage of corn for FSI purposes has increased substantially over the past two decades, the increased utilization has not affected all of this sectors' components equally. Therefore, in order to clarify the structure and mechanics of this sector, it has been partitioned into five product categories; starch, high fructose corn syrup (HFCS), glucose, beer and beverage and cereal.

Corn is processed by either wet or dry milling procedures. The majority of growth in FSI demand over the past two decades has been for products resulting from the wet milling process. This process separates the corn kernel into germ, hull, gluten and starch. For this reason, the processing industry becomes sensitive not only to the price of corn and to the output price of the final product, but also to the value of the byproducts. This generates an additional linkage between the corn and soybean sectors. Four of the five equations which make up FSI demand are estimated utilizing the net price of corn to the processor. The value of corn gluten feed and meal are subtracted from the farm price of corn allowing for the net cost of corn to the producer to enter the equation. Cereal demand, where most of the kernel is utilized is estimated using the price of corn without the value of the byproducts.

Specifications for each equation vary. Beer and other beverage use, estimated on a percapita basis, includes the net cost of corn, the Consumer Price Index (CPI) for alcoholic beverages and the price of rice. Starch use is estimated with the net cost of corn and the consumer price index for nondurables. HFCS also makes use of the net cost of corn as well as the retail price index for non-alcoholic beverages and the retail price index for sweeteners. Cereal demand, as previously mentioned, makes use of the farm price of corn deflated by the CPI of nondurables, the retail price index for baked goods and the farm price of wheat. All equations are also consistent with a derived demand specification, giving a negative response to an increase in the net cost of corn while giving a positive response to the proxy variable for their respective output prices.

Commercial Exports

The commercial export equation is specified as U.S. commercial exports. Price enters the export equation via a combination of the European threshold price and the U.S. farm price. This combination is entered in ratio form with the price of soymeal as the denominator. The level of livestock production in Europe and Japan are used as a proxy for their feed requirements. Production or available supplies in Europe are also included in a term with exports from our major competing countries, Argentina, Thailand and South Africa. U.S. PL480/AID shipments and foreign shipments to the Soviet Union and PRC are entered as separate terms. The Special Drawing Rate is included as a separate term as an indicator of economic performance by other countries, relative to the U.S. Intercept shifters are utilized for the post 1972 period and for the 1980 grain embargo.

Commercial Stocks - Not Under Loan

The dependent variable in the commercial stock equation are stocks held at the end of the year, net of the quantity still under the CCC 9-month loan or in the Farmer Held Reserve(FHR). Commercial stocks are estimated to be functionally related to the price of corn deflated by the wholesale price index, beginning supplies, expectations of production for the upcoming year and government stock variables. CCC owned stocks, combined with FHR stocks enter the equation with a slope shifter. Commercial stocks are impacted more by government stock activity when government controlled stocks are increasing as opposed to periods of decreasing government stocks. Intercept shifters enter the equation for 1975, 1976, 1967 and 1970.

Identities

The identity required to close the system equates total supply with total demand where beginning stocks enter as supply and ending stocks enter as a demand category. Other identities exist within the system such as total exports being equal to commercial exports, PL480/AID shipments and exports to the Soviet Union and PRC. Total stocks are made up of commercial stocks, stocks held under 9-month loan, CCC owned stocks and FHR. For ease in computation the various food demand components are combined to give total food demand.

Price Linkage Equations

As was mentioned in the section on FSI use the model estimates several of the processing categories utilizing the net cost of corn. In order to generate the net price of corn to the processor some method must be developed to estimate the price of corn gluten feed and meal. Rather than develop complete structural models for the corn gluten and Distiller's Dried Grains (DDGS) industries, three semi-reduced form price equations are estimated to give the three byproduct prices. The specifications for gluten feed and meal prices are identical. Each is estimated as a function of the price of corn, the price of meal, level of processing demand for corn and the number of high protein animal units. DDGS prices are estimated as a function of corn and meal prices and level of high protein animal units.

Model Estimation and Validation

The model as described above was estimated utilizing OLS. Coefficients and statistical properties of each equation are given in Appendix 1. When possible, equations were estimated using data from 1961 through 1984. For some equations, particularly those associated with FSI use, data were limited to 1971-1984. Single equation performance statistics indicate satisfactory results in all cases. The lowest percentages of variance explained was consistently in the FSI categories, which were estimated in a percaptia form. Thus the size of error when translated to total corn consumption was relatively low.

When operated in a simultaneous mode the model also performs well. Performance statistics based on a dynamic, simultaneous solution from 1971 through 1984 are given in Appendix 1. Theil statistics indicate little bias in most terms of the model. Exceptions to this rule are noted for starch and beer demands.

Impact Multipliers

In order to determine the impacts of various levels of fuel ethanol demand for corn, the model was solved in a variety of modes. The simplest approach naively increases demand for ethanol by 100 million bushels without lower stocks, or allowing a feedback process to occur between the soybean complex and corn.

However, in the production of ethanol various byproducts are produced, which as already mentioned compete with soybean meal. Currently a large portion of corn gluten feed and meal are exported with roughly 25 percent remaining for domestic consumption. The model was also solved in a form where the soybean sector, including beans, meal and oil were allowed to interact with the corn sector. The appropriate level of byproducts were produced. Domestic demand for soymeal is estimated as being dependent on the price of meal, the price of corn and the quantity of non-soymeal high protein feeds consumed, among other terms. Twenty-five percent of the byproducts generated were retained domestically and exogenously added to the consumption of other high protein feeds. The remaining 75 percent of corn by-products produced were exogenously added to soybean meal exports from Brazil in the meal export equation.

Finally, the model was solved for multipliers allowing for interaction of the corn and soybean models, and by allowing for a reduction in government stock activity by a similar amount. As the model is specified with stocks under loan as exogenous, these were lowered by 100 million bushels. The assumption in this case was that producers would market the 100 million bushels rather than hold them under loan or default them to CCC. The results of these three solutions are displayed in table 1.

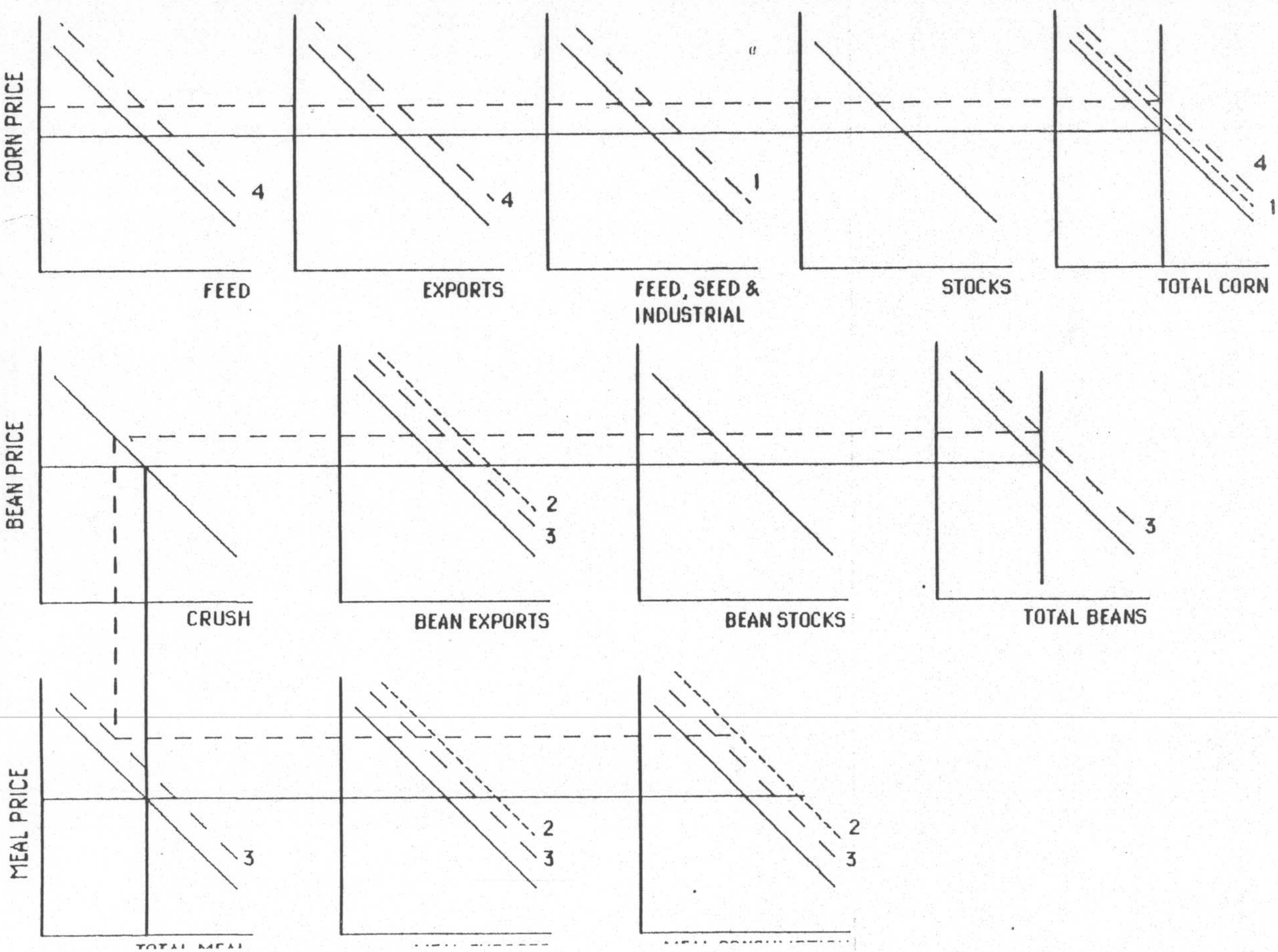
Table 1.
Impact Multipliers for
a 100 Mil. Bu. Increase in Ethanol Demand
Alternative Scenarios

Impact On	Corn Model Only No Stock Change	Corn & Soybean No Stock Change	Corn & Soybean With Stock Chng
Corn Price	$0.14	$0.27	$0.03
Soybean Price	-----	$0.64	-$0.03
Soymeal Price	-----	$27.00	-$1.80

The increase in the size of the multiplier for corn when linked to the soybean complex may at first appear counter intuitive but examination of Figure 3 indicates the cause. The increase in ethanol use for corn (1) stimulates a higher price for corn, while at the same time producing an increase in the supply of byproduct feed. The increase in the price of corn shifts the export demand for soybeans to the right, as well as the export and domestic utilization of soybean meal (2). The rightward shift in the domestic and export categories of soybean meal demand increases the overall demand for soybean meal, implying greater demand for soybean crush. This combination of factors, is offset by a simultaneous increase in byproduct high protein feeds. This generation of other feeds is not sufficent to offset the increase in price generated by higher corn prices. Thus the net effect is an increase in the price of soymeal (3). An increase in the price of meal tends to increase the feed use and export utilization of corn, thereby generating a slightly higher corn price than one would anticipate when viewing corn in isolation (4).

When the increase in demand for ethanol purposes are offset by declines in stock activity, corn price increases slightly, while soybean meal and oil prices decline marginally. Thus under current excess supply conditions the
benefits from increase ethanol use would be primarily a lowering of government stock defaults. However, in periods where loan activity was

A GRAPHICAL DEPICTION OF THE SOYBEAN COMPLEX AND CORN MODELS



limited, due to the loan rate being lower than market prices, then price strength could be generated via increased ethanol activity.

Model Simulation

Two model solutions were generated utilizing the corn model described and other models operated by the Center for National Food and Agricultural Policy. These include linkages between not only the corn and soybean sector but other crops such as wheat, cotton, rice and other feed grains as well as the livestock sector.

Baseline Projections

The baseline projection utilized estimates of fuel ethanol demand were generated by discussions with various individuals currently operating in or analysts for the ethanol industry. These forecasts place fuel ethanol consumption under current conditions at 351 mil. bu. by the 89/90 crop year.

Under the baseline, policy variables were consistent with the 1985 Food Security Act. These included declining loan rates, fixed targets for the first two years with a 2% decline in the 88/89 crop year followed by a 3% drop in 89/90. Participation rates were high and when coupled with declining market prices and fixed target prices, deficiency outlays were large. Stock activity under the baseline was considerable in the 86/87 crop year with large loan defaults of the 85/86 crop. In subsequent years, stock activity diminished with the majority of CCC acquisitions coming from defaults of FHR grain. CCC sales, or disposition of stocks were via the form of PIK deficiency payments or in the form of PIK payments for the Long Term Conservation Reserve. This projection is documented in Womack et. al. (1986) and will not be described in detail here.

Enhanced Ethanol Demand Scenario

Under the enhanced ethanol (EE) scenario, demand for corn for ethanol purposes was increased 195 mil. bu./year from the 85/86 crop year through the 89/90 crop. This resulted in a total of 1,000 mil. bu. of ethanol consumption by the end of the projection period. Demand for corn for ethanol by the 89/90 crop year was 649 mil. bu. over levels observed in the baseline.

As anticipated from the impact multipliers, relatively little price effect was noted under EE for the 86/87 crop year. Stock activity declined with loan placements and defaults of 85/86 crop corn reduced. In subsequent years however prices began to increase over baseline levels. Stock activity became limited, and due to CCC release rules, it was not possible to place government owned stocks back on the market.

Soybean prices also reacted to the increase in corn price. After exhibiting no change in the 86/87 crop year, prices were up marginally in 87/88 at $4.98/bu as opposed to the baseline level of $4.85/bu. This led to a reduction in the corn/soybean price ratio for the 87/88 crop year and a subsequent reduction in the area planted to soybeans in 88/89 and again in 89/90. Under the baseline soybean area reached 66.0 mil. acres in 89/90 while under the EE soybean area totaled only 63.5 mil. acres in 89/90. Corn area also reacted to the reduction in the corn/soybean price ratio. After holding at baseline levels in 86/87 and 87/88 participation rates, and a shift of some soybean area into corn raised area planted to 75.4 mil. acres in 88/89. Participation under the baseline reached 82% in 88/89 and held at those levels in 89/90. Under EE these rates declined to 75% in 88/89 and to 65% in 89/90. The further reduction in participation rates and in the corn /soybean price ratio increased corn area planted to 78.2 mil. acres in 89/90.

A comparison of several other pertinent features of the analysis are summarized in table 2.

Table 2.
Comparison of Model Solutions Under
Baseline and Enhanced Ethanol Scenarios

Crop Year	86/87	87/88	88/89	89/90
Ethanol Demand (mil. bu.)				
Base	257	290	319	351
EE /1	415	610	805	1000
Area Planted (mil. acres)				
Corn				
Base	75.5	74.5	73.5	72.3
EE	75.5	74.5	75.4	78.2
Soybeans				
Base	63.0	63.0	65.0	66.0
EE	63.0	62.8	63.0	63.5
Farm Price ($/bu)				
Corn				
Base	$1.98	$1.87	$1.82	$1.89
EE	$2.04	$2.14	$2.23	$2.43
Soybeans				
Base	$4.96	$4.85	$4.84	$5.04
EE	$4.96	$4.98	$5.18	$5.46
Value of Production (mil. $'s)				
Corn				
Base	$14992	$14102	$13657	$14453
EE	$15447	$16138	$17068	$19753
Soybeans				
Base	$9627	$9530	$9941	$10649
EE	$9627	$9756	$10308	$11089
Direct Government Payments (mil. $'s)				
Base	$4993	$5268	$5281	$4520
EE	$4676	$3793	$3369	$2395
Net Returns over Variable Costs for Corn & Soybeans (mil. $)				
Base	$14253	$13210	$12468	$12364
EE	$14391	$14011	$14195	$15218
Increase in Foregone Federal Highway Tax (@$0.06/gal blend) (mil. $)	$237	$480	$729	$973

/1 Enhanced Ethanol Scenario

One of the interesting features of the analysis is a comparison of net returns to the corn and soybean sectors under both scenarios. Under the baseline scenario prices decline for both corn and soybeans in the early years, followed by a slight increase in soybean prices in the out years. Government outlays in the form of deficiency payments contribute significantly to net returns in the baseline. Under the EE scenario government outlays for deficiency payments decline, while net returns for corn and soybeans increase. In the 89/90 crop year government payments are $2125 million lower under the EE scenario while net returns to corn and soybean producers are $2854 higher.

Offsetting the increase in net returns to corn producers and the decline in government outlays under the EE scenario is the increase in federal highway taxes foregone. Current legislation allows for a $0.06/gal tax reduction for the sale of ethanol blended fuels. While this is not a direct outlay at the federal level, it does represent a decline in revenues over values that would have been observed without the increase in sales. Engineering constraints currently limit the quantity of ethanol produced per bushel of corn to 2.4-2.5 gal/bu. Thus 1,000 mil. bu. of corn for ethanol would translate to 25 billion gallons of gasoline/ethanol blend. This converts to $1500 million in foregone tax revenues. Comparison between the baseline revenue reductions and the EE reductions are included in table 2.

Summary

An econometric model of the corn industry has been presented and utilized to examine the fuel ethanol industry. Sharply increased rates of consumption were compared to more modest, currently anticipated rates of increase. The model suggested that prices for both corn and soybeans would increase under an enhanced ethanol scenario. This was contingent on government stocks of a sufficient magnitude to offset the increase in ethanol demand **not** being placed back on the market. When government controlled stocks were returned to the market in a level similar to that demanded for ethanol purposes then corn prices were observed to increase only marginally, with concurrent declines in soybean and soymeal prices.

A baseline projection was made utilizing the model and the provisions of the 1985 Food Security Act. This analysis suggested lower prices for corn and soybeans and sharp increases in government outlays in the form of deficiency payments. A more pronounced growth rate for ethanol demand was imposed, with ethanol requiring 1000 mil. bu. in the 89/90 crop year. Under this scenario corn and soybean prices were observed to increase in the outyears with corn prices increasing relatively more than soybean prices. This led to a reduction in soybean area and an increase in corn area when compared to the baseline projection.

Government outlays were higher under the baseline than under the enhanced ethanol demand scenario by as much as $2125 million in the 89/90 crop year. Net returns to corn and soybean producers were higher under the enhanced ethanol scenario by as much as $2854 million in 89/90.

Utilization of the model described here indicates that significant positive returns can be observed with increased ethanol demand. However, no attempt was made to indicate what mechanism would be required to generate this type of increase utilization. It is likely that a demand enhancement of this order would require either substantial outlays, or a marked increase in tax incentives.

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APPENDIX I

Behavioral Equations

```
() - Indicates t statistic    §¶ - Indicates elasticity
     DUM?? - Indicates dummy variable for year ??
SHIFT?? - Indicates Shift variable begining in year ??
==========================================================================
Corn Acreage Planted for All Purposes  -  CORSA
     48.152 + 325.25*COR  - 40.405*SOY  - 66.531*CORPD1/CORPF[-1]  - 2.667*RNUM/RMAC
              (1.266)      (-.773)       (-6.125)                    (-1.592)
                 §0.08¶       §-0.05¶            §-0.08¶

       + 0.398*CORSA[-1]  + 4.359*D6672
        (5.034)
            §0.396¶

     COR = (CORPE1+0.88505*((CORD+1)*LOG(CORD+1)-CORD))/CORVC
     CORD = CORPF[-1] - CORPE1 (If CORPF[-1]¶CORPE1, 0 otherwise)
     SOY = (SOYPE+0.59775*((SOYD+1)*LOG(SOYD+1)-SOYD))/SOYVC
     SOYD = SOYPF[-1] - SOYPE1 (If SOYPF[-1]¶SOYPE1, 0 otherwise)
     RMAC = (CORPF[-2]+CORPF[-3]+CORPF[-4])/3
     RNUM = (CORPF[-1]-RMAC)**2

        R-Square 0.9712     D.W. 2.456     1st Order Autocorr. -0.33


Corn Production for Grain - CORSPGR
     - 54.406  + 0.8632*CORSA*CORSYGR  + 239.61*SHIFT78
                (63.319)
                    §0.99¶ §0.99¶

        R-Square 0.9984     D.W. 2.079     1st Order Autocorr. -0.15
```

```
Corn Feed and Residual Demand - CORDF
     GCAU[+1]*(38.917  - 5.641*CORPF/LIVIF[+1]  + 0.0612*SOMPM44D/LIVIF[+1]  - 3.951*DUM63
                        (-2.259)                  (2.996)
                               §-.17¶  §.09¶               §0.08¶

          + 5.700*SHIFT78  + 9.933*DUM73  + 5.160*DUM82)

          R-Square 0.8208      D.W. 1.642      1st Order Autocorr.  0.10


Corn High Fructose Corn Syrup Demand - HFCS
     NPC*( -0.3104  - 0.0423*NETCORN  + 0.00186*BEVIR  + 0.00127*CPISWT  + 0.0684*DUM73
                     (-0.718)           (2.341)          (2.455)
                            §-.14¶              §.85¶             §1.13¶

     NETCORN = CORPF - 15/56*.03*CRNGLFD - 2/56*.03*CRNGLML


          R-Square 0.9727      D.W. 0.825      1st Order Autocorr.  0.47


Corn Glucose Demand  -  GLUCOSE
     NPC*(0.5553  - 0.0002*NETCORN/PCNDF[+1] + 0.0017*CPIBA/PCNDF[+1] -0.1672*DUM71 -0.0785*DUM72)
                     (-0.0127)                  (0.6102)
                           §-0.005¶ §-0.21¶            §0.22¶

          R-Square 0.8876      D.W. 2.115      1st Order Autocorr. -0.06


Corn Cereal Demand  -  CEREAL
     NPC*(0.093  - 0.05643*CORPF/PCNDF[+1]  + 0.0006*CPIBA/PCNDF[+1] - 0.0247*WHEPF/PCNDF[+1]
                  (-2.9976)                   (2.7000)                 (2.1304)
                         §-0.53¶§-0.27¶              §0.49¶                    §0.31¶

          + 0.0171*DUM80  + 0.0190*DUM83)

          R-Square 0.7837      D.W. 1.584      1st Order Autocorr.  0.20
```

```
Corn Beer and Other Beverage Demand  -  BEER
     NPC*(0.3082  - 0.01997*NETCORN  + 0.00017*CPIALCBV  + 0.0059*RICPF  + 0.0115*DUM75
                    (-2.2557)            (1.8627)             (3.7179)
                               §-0.13¶              §0.13¶              §0.25¶

          +0.0164*DUM79  - 0.0235*DUM84)

          R-Square 0.8313     D.W. 1.519     1st Order Autocorr.  0.19

Corn Starch Demand - STARCH
     NPC*(0.4845  - 0.0131*NETCORN  + 0.0537*PCNDF[+1]  - 0.0535*DUM71  - 0.0444*DUM80)
                   (-0.8389) §-0.03¶  (4.5362) §0.19¶

          R-Square 0.8041     D.W. 1.696     1st Order Autocorr.  0.15

Corn Commercial Export Demand  - CORMXCC
      745.180  - 556.8818*(.2*CORPA + .8*39.368*CORPF/SDR_OCT)/(SOMPM44DE/SDR_OCT)
                   (-1.713)
                               §-0.09¶            §-0.23¶ §0.14¶      §0.32¶

          + 747.534*LVSTK  - 0.0273*CORRICE1  + 0.1096*CORME_US    + 226.278*SDR_OCT
            (2.328)          (-2.423)              (7.158)             (0.399)
                   §0.93¶            §-0.57¶             §0.14¶                 §0.14¶

          - 3.32.797*SHIFT72  - 332.314*DUM78  + 411.391*DUM80  + 487.67*DUM83

     LVSTK = 0.5*((HOGSDEC+HOGSDJN)/6812 + (CHISPEC+CHISPJN)/2488)
     CORRICE1 = CORSP_HE + CORNESEC + RICDF_J + CORMX_CC

          R-Square 0.9851     D.W. 2.349     1st Order Autocorr. -0.24
```

```
Corn Commercial Stocks Demand (not under loan)  -  CSTKFREE
     755.062  - 33346.6*CORPF/WHEIW  - 0.1228*(CORHHUN1 + CORHPRRE)  - 0.0395*CORSPGR1
                 (-5.1651)                (-1.0120)                       (-4.5971)
                       §-0.83¶ §0.83¶              §0.11¶                          §-0.02¶

        + 0.0868*(CSTKFREE[-1] + CORHPRRE[-1] + CORHHUN1[-1] + CSTKLOAN[-1] + CORSPGR)
          (5.3378)
                                              §1.28¶

        - 0.1751*IUMGOV*(CORHHUN1 + CORHPRRE)  - 0.60327*CSTKLOAN  + 161.561*DUM7576
         (-1.5497)                              (-6.2479)
                                                         §-0.28¶

        + 102.7579*DUM67  - 88.864*DUM70

     IUMGOV = 1 if (CORHHUN1+CORHPRRE) ¶ (CORHHUN1[-1]+CORHPRRE[-1])  0 otherwise

        R-Square 0.9784     D.W. 2.150     1st Order Autocorr. -0.07
```

Identities

```
=============================================================================================-
=
     CORSPGR + CSTKFREE[-1] + CSTKLOAN[-1] + CORHPRRE[-1] + CORHHUN1[-1] + CORMI  =
        CORDF + CORMXC + CORMG + CORMXSUPRC + HFCS + GLUCOSE + BEER + STARCH + ALKALINE
        + CORDS + CEREAL + GASOHOL + CSTKFREE + CSTKLOAN + CORHPRRE + CORHHUN1

     CORHT = CSTKFREE + CSTKLOAN + CORHPRRE + CORHHUN1

     FSI = HFCS + GLUCOSE + BEER + STARCH + ALKALINE + CEREAL + CORDS + GASOHOL

     CORMX = CORMXC + CORMG + CORMXSUPRC
```

Price Linkages

```
==========================================================================================================
=
Corn Gluten Feed Price - CRNGLFD
     -107.197  + 16.742*CORPF  + 0.3895*SOMPM44DE  - 0.01101*(CORDH + GASOHOL)  + 0.7786*HPAU
                 (5.0134)        (7.4367)            (-0.7506)                    (3.5662)

          - 43.8167*DUM72  - 21.066*DUM80

Corn Gluten Meal Price - CRNGLML
     -36.3446  + 32.8875*CORPF  + 0.7972*SOMPM44DE  - 0.0324*(CORDH + GASOHOL)  + 0.5495*HPAU
                 (4.128)          (9.652)             (-0.771)                    (0.865)

          -29.3107*DUM80

Distillers Dried Grains Price - DDGS
     -87.2767  + 27.4533*CORPF  + 0.3236*SOMPM44DE  + 0.6412*HPAU
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Corn Model Variable Definition and Units

ALKALINE	Corn for alkaline processing	mil. bu.
BEER	Corn utilized for beer and other alcoholic bev.	mil. bu.
BEVIR	Retail price index, non-alcoholic beverages	index
CEREAL	Corn utilized for cereal	mil. bu.
CHISPEC	Chicken production - EC10	Thou MT
CHISPJN	Chicken production - Japan	Thou MT
CORDF	Corn feed and residual demand	mil. bu.
CORDS	Corn used for seed purposes	mil. bu.
CORHHUN1	Corn stocks CCC owned	mil. bu.
CORHPRRE	Corn Farmer Held Reserve	mil. bu.
CORME_US	USSR Corn Imports from non-U.S. sources	Thou MT
CORMG	Corn PL480/AID Exports	mil. bu.
CORMXC	Corn, commercial exports	mil. bu.
CORMXSUP	Corn U.S. exports to USSR & PRC	mil. bu.
CORMX_CC	Corn exports by Argentina, Thailand and S. Africa	Thou MT
CORNESEC	Corn ending stocks EC10	Thou MT
CORPA	Corn, European threshold price	ECU/MT
CORPD1	Corn effective diversion payment	$/bu
CORPE	Corn effective support price	$/bu
CORPF	Corn farm price, national season average	$/bu
CORSA	Corn area planted for all purposes	mil. acres
CORSPGR	Corn production for grain	mil. bu.
CORSPGR1	Corn production in year t+1	mil. bu.
CORSP_HE	Corn Production + Beginning Stocks EC10	Thou MT
CORSYGR	Corn yield for grain per harvested acre	bu/acre
CORVC	Corn variable cost of production	$/acre
CPIALCBV	Retail price index, alcoholic beverages	index
CPIBA	Retail price index, baked goods	index
CPISWT	Retail price index, sugars and sweets	index
CRNGLFD	Corn gluten feed price	$/ton
CRNGLFD	Price corn gluten feed	$/ton
CRNGLML	Corn gluten meal price (60% protein)	$/ton
CRNGLML	Price corn gluten meal - 60% protein	$/ton
CSTKFREE	Corn commerical stocks (not under loan)	mil. bu.
CSTKLOAN	Corn stocks under 9-month loan	mil. bu.
DDGS	Distillers dried grains price	$/ton
GASOHOL	Corn used for fuel ethanol purposes	mil. bu.
GCAU	Grain consuming animal unit	index
GLUCOSE	Corn utilized for glucose & dextrose	mil. bu.
HFCS	Corn used for high fructose corn syrup	mil. bu.
HOGSDEC	Pork production - EC10	Thou MT
HOGSDJN	Pork production - Japan	Thou MT
HPAU	High protein animal unit	index
LIVIF	Livestock price index	index
PCNDF	Retail price index, non-durables less food	index
RICDF_J	Rice fed to livestock in Japan	Thou MT
RICPF	Rice, farm price season average	$/cwt
SDR_OCT	U.S. Special Drawing Rights, October basis	$/SDR
SOMPM44D	Soybean meal price, 44% Decatur	$/ton
SOYPE	Soybean effective support price	$/bu
SOYPF	Soybean farm price, national season average	$/bu
SOYVC	Soybean variable cost of production	$/acre
STARCH	Corn utilized for starch	mil. bu.
WHEIW	Wholesale price index	Index
WHEPF	Wheat, farm price season average	$/bu

Model Validation Statistics

Variable	% Root Mean Square Error	% Mean Error	Bais	Systematic	Random
CORDF	3.1%	0.5%	0.026	0.000	0.974
CORMXC	5.4%	-1.7%	0.083	0.004	0.913
CSTKFREE	14.7%	-5.3%	0.107	0.029	0.864
HFCS	18.1%	-0.2%	0.000	0.283	0.717
GLUCOSE	2.4%	0.1%	0.001	0.028	0.971
STARCH	4.2%	2.7%	0.367	0.056	0.577
BEER	9.3%	7.5%	0.561	0.000	0.439
CEREAL	7.6%	-1.9%	0.046	0.030	0.924
CORSA	2.1%	0.3%	0.020	0.006	0.974
CORSPGR	2.4%	-0.1%	0.002	0.053	0.945
CRNGLFD	8.9%	1.3%	0.017	0.067	0.916
CRNGLML	7.1%	1.4%	0.034	0.175	0.791
CORPF	9.5%	1.0%	0.008	0.103	0.889