AGRICULTURE AND CHANGING NATURAL GAS PRICES[1]

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[1]CARD Series Paper 83 - 10

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October 31, 1983

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ABSTRACT

For the period of analysis, 1982 through 1987, the impacts on agriculture that result from increasing natural gas prices are examined. Two types of models are used in the analysis -- econometric and linear programming. These models are linked together so that a short-run, multi- period analysis can be conducted. The econometric model represents national demand for agricultural commodities and projects next year's price while the linear programming component is an agricultural supply model.

As natural gas prices increase, concern is voiced. The impacts of natural gas prices on various sectors of the economy is a focal point in the news media and Congress. Numerous studies have been made projecting natural gas prices. These studies assume various regulatory policies and the absence of these policies. Other studies extend beyond natural gas price estimation and examine the impacts of price increases on various producing and consuming sectors of the economy. This study takes the latter approach. It determines the likely impacts on the agricultural production sector as natural gas prices change.

USE OF NATURAL GAS IN AGRICULTURE

Agricultural production is affected both directly and indirectly by changes in natural gas prices. Natural gas is used as a direct input in such farm operations as irrigation, waste disposal, space heating, crop drying, and brooding. Indirectly, it is a major input in the production of fertilizers (especially ammonia, an important ingredient in the production of nitrogenous fertilizers). Additionally, the manufacture of most agriculturally related products (i.e. machinery, pesticides), as well as the food-processing industry, are heavily dependent upon natural gas.

According to the 1978 Census of Agriculture [Bureau of Census, 1981], 78,705 farms reported spending 235.6 million on natural gas in 1978. This was approximately 4 percent of the total on-farm fuel costs reported in this census. The majority of natural gas expenditures occur in the West South Central (Arkansas, Louisiana, Oklahoma, and Texas spent $95.2 million with Texas spending $82.8 million) and the West North Central (Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas spent $41.0 million with Kansas spending $21.6 million).

The majority of natural gas used directly by the United States' agricultural production sector (96 percent) is consumed by large irrigation pumps [Bureau of Census, 1982]. Rising gas prices will no doubt be critical to local economies dependent on irrigated agriculture powered by natural gas pumps, but it will be only one of several problems faced by these economics.

Crop drying is another major use of natural gas power. Many agricultural commodities need to have some moisture removed after they are harvested in order that they may be safely stored. Corn requires approximately one-half of the fuel used to dry agricultural commodities. Other major crops that may be dried before storage include grain sorghum, peanuts, rice, soybeans, and tobacco. Drying is conducted both on-farm and off-farm with nearly 70 percent of the energy used in crop drying being done on-farm. Few farms are near natural gas pipelines and, as a result, LP gas is used for drying. Large cooperative and commercial elevators could face considerable cost increases attributable to increasing natural gas prices. Although many cooperative members will not pay for the gas directly, all members will be affected by this through decreased dividends.

The industry feeling the largest influence from a natural gas price increase could be the fertilizer industry. Fertilizer is an essential input in modern, highly intensive agriculture and nitrogen derivatives account for nearly half of the fertilizer produced. Most nitrogenous fertilizers are derived from ammonia with approximately 90 percent of this ammonia using natural gas as a basic input. Thus, price changes of natural gas would affect the cost of producing ammonia. Presently, the ammonia price is set by world markets containing significant amounts of Middle East and Soviet Union gas. An examination of the past fertilizer cost data as published by the U.S. Department of Agriculture supports this conclusion. In 1975 the cost per ton of anhydrous ammonia was $265; 1981 this same ton cost $243. Ammonium nitrate cost $186/ton in 1975 and $185/ton in 1981 [Crop Reporting Board, 1976, 1982].[1] During the same period domestic natural gas prices were rising rapidly. Currently, domestic producers who cannot compete with the world prices have been forced to shut down either permanently or, at the very least, temporarily. In addition, most ammonia plants are operating in the west Gulf coast area (an area characterized by unregulated intrastate gas use).

Commercial fertilizer used in agriculture has increased from 12,079 tons in 1940 [The Bureau of the Census, 1961] to nearly 2 million tons in 1974 [The Bureau of the Census, 1977]. Corresponding to this increase in fertilizer use, corn yields, for example, increased 71 percent [USDA, 1969, 1981]. Fertilizer was an important input in the package of inputs that created this yield increase. Impacts on the fertilizer industry caused by fertilizer shortages resulting from decreased U.S. capacity and other world phenomena could result in substantial U.S. agricutural impacts.

STUDY'S OBJECTIVES

Because of the interest generated in the projected natural gas price impacts on the U.S. agricultural sector, this study is designed so that these impacts can be analyzed. Rather than attempt to resolve the issue of whether decontrol will bring higher or lower prices, this study considers a range of prices and evaluates the effects of this range. The study examines the trade-offs in resource use, cost of production, regional shifts, and net farm income that occurs as natural gas prices increase. Furthermore, this study attempts to measure the potential response of farmers to increased natural gas prices.

THE MODEL

This study uses a recursive adaptive programming model to analyze the interregional impacts of a set of conceivable natural gas pricing situations over time. The basic structure of this model is shown in Figure 1. Within each time period (year), the model consists of three sectors: an econometric simulation model or positive component (ES_t), a procedure to revise the linear programming system with information generated by ES_t ($REVISE_t$) and a linear programming model (LP_t). More information on the theoretical basis of this model can be found in Huang, et. al. [1980].

The econometric model segment

The prices of the commodities are estimated using equations econometrically estimated in a system of equations. Equations are estimated for both prices and quantities of barley, corn, oats, sorghum, soybeans, wheat, beef, and pork. The coefficients for the equations are estimated in using "seemingly unrelated" regression techniques with annual data for the time period 1950-1980. Only the price equations are used in the model as quantities are determined by the linear programming segment.

The price equations are estimated as functions of current own quantities, current competing quantities and/or prices and lagged values. The estimated price equations are shown in Table 1 with the variables defined in Table 2. All coefficients in the equations are significant at the 5 percent level for a one-tail t-test. The mean square error and R-square statistic for each equation is shown in Table 3.

The estimated equations are simulated over the historical period to measure the accuracy of the forecasts. Several measures of the accuracy of the forecasts are also given in Table 3. The root-mean-square percent errors are all less than 20 percent. The bias proportion decompositions of the mean square error are all zero and the regression proportion decompositions are basically quite good (the closer to zero the better). Theil's U_1 statistic is also reasonable for each equation. Based on these results, it was decided that the estimated equations presented in Table 1 reasonably approximated the workings of the price quantity relationships.

These equations are then used as the predictors of price for the econometric model segment. In addition, it is assumed that the cotton and milk commodities, both government-supported commodities, maintain their 1978-1980 average price.

A schematic diagram of the linear programming model segment is presented in Figure 2. The types of resources required and outputs produced are listed vertically (rows) with the types of activities included in the model listed horizontally (colmatrix represents sets of coefficients that must be determined. The levels of resource restraints are identified with the vector of R_i's and B_i's for the contraints and bounds, respectively.

The basic units of the programming model are the 105 producing areas (PA) (Figure 3), which are derived from the U.S. Water Resource Council's 99 aggregated subareas (ASA) [U.S. Water Resources Council, 1970]. The PAs are identical to the ASAs with the exception of six ASAs which are subdivided to better reflect agricultural production. In addition, PAs 48 through 105 serve dual purposes because they define water supply regions in addition to the production areas.

These 105 PAs are aggregated into 28 market regions (MR) (Figure 4). Each market region represents an established commercial and transportation center as well as the livestock production areas. The market regions also serve as the market framework for the natural gas and nitrogen-purchasing activities.

At the different regional levels, restraints are defined as to the availability of dry and irrigated cropland. The land base, water, and nitrogen are adjusted for the requirements of the crops whose regional distribution is not spatially determined.[2] Thus, the constraints for these three inputs reflect the quantity of land available for endogenous crop production; the quantity of water required for exogenous crop production; and the quantity of nitrogen supplied by exogenous livestock less that required for exogenous crop production.

Production alternatives (activities) in the model include crop production, at three different fertilizer levels, water availability, nitrogen purchase, natural gas purchase, commodity sell, irrigation development, and livestock production. Barley, corn grain and silage, soybeans, wheat, and summer fallow are endogenously produced through dry and irrigated production practices. These crops require nitrogen, water (only on irrigated practices), capital, and land and produce a yield. The water sector includes three types of activities (surface water purchase, ground water purchase, and transfer), and defines, through bounds, the quantity of water available for both endogenous and exogenous crop and livestock needs. The nitrogen-purchasing activities, specified by MR, supply commercial nitrogen to the crop production sector. The dry/irrigation conversion activities allow a predetermined maximum quantity of land to be converted from dry to irrigated. The livestock sector consists of five basic livestock activities--feeder cattle producing, grain-fed cattle finishing, roughage-fed cattle producing, dairy producing, and pork producing. These activities produce agricultural livestock commodities and nitrogen waste while requiring feed, water, energy, and capital.

Another important aspect of the model is the levels of demands assumed. The model is a profit-maximizing one using prices estimated from the econometric simulation model in the linear programming model. This allows the model to meet the profit maximizing criteria. However, constraints on the level of demand that must be met are placed on the model. It is assumed that production of any endogenous commodity cannot exceed 110 percent of the 1978-1980 average levels of production, nor can it fall below 90 percent of this level. Thus, a 20 percent variance in commodity production is allowed.

Natural gas use is reflected in this segment. It is used by irrigation, livestock production, and fertilizer purchase activities. However, when natural gas prices increase only the costs of irrigation and livestock production are changed. As previously stated, it is assumed that the costs of fertilizer will not directly change as a result of a change in natural gas prices.

Solution of the model

The solution of the model begins in the year 1981 assuming 1978- 1980 average prices of the endogenous commodities. The production resulting from these prices is fed into the econometric model. The econometric model solves for next year's price levels, and these are fed back into the LP through a revised procedure. The LP segment is solved again for year 1982 assuming maximized profit criteria and new production levels are found. This process continues until the LP segment is solved for 1987.

ALTERNATIVES

The alternatives used in this study incorporate increasing natural gas prices. Mid-1982 acquisition costs and retail commerical prices are determined using Foster Associates [1982], estimates and a Department of Energy study [O'Neill, Steinberg, and Tobin, 1982] as the primary sources. An average acquisition cost of $2.93 is determined from this data. The transmission margin is determined by subtracting this average cost from retail commercial prices. Then projected acquisition costs of $3.10, $3.55, and $4.15 is added to the transmission margin; forming three of the alternatives -- AC $3.10, AC $3.55, and AC $4.15 (Table 4).

RESULTS

While numerous imputs are used in the production of agricultural comodities, this study focuses on land use, water use, and nitrogen use.

Land use

Total land use ranges from 304 to 327 million acres in the $3.10 alternative to 304 to 329 million acres in the $4.15 alternative. When comparing the $3.10 alternative to the $4.15 alternative, it should be noted the irrigated acreage declines (3.9 percent) over time as natural gas prices increase. At the same time, dryland production increases. When comparing the $3.10 to $4.15 alternatives, the Great Plains shows an increase in irrigated acreage over the entire time horizon while the South Central Zone declines. When natural gas prices change from $3.10 to $4.15/ mcf, a 600,000/acre decline in irrigation is projected for the South Central Zone. While irrigated acreage declines as natural gas prices change from $3.10 to $4.15/mcf, dryland acreage increases 400,000 acres. Thus, land that is presently being irrigated reverts back to dryland. It must be noted that as the model is solved over the time frame 1982- 1987, in either pricing alternative, the irrigated acreage decreases are much more pronounced that the acreage decreases resulting from changes in the natural gas price.

Energy use

Energy is consumed by the agricultural sector through its machinery, irrigating, and crop drying activities. In addition, the model determines the quantity of energy inherent in fertilizers and pesticides. The model solution indicates that approximately 1.3 quads[3] per year of energy is used in both the $3.10 alternative and $4.15 alternative. The $4.15 alternative show a slight decline in energy use reflecting the increased cost of natural gas. In addition, the solutions indicate that over 426 billion cu. ft.[4] of natural gas is consumed per year, either directly through irrigation or indirectly through the production processes used to make fertilizers and pesticides. This decreases by nearly 4 billion cu. ft. in the $4.15 alternative. Most of this decline is caused by the decline in irrigation in the South Central part of the United States.

COMMODITY PRODUCTION, PRICES AND NET RETURNS

Examining the average $3.10 solution, feed grain production[6] varies from 7,771 million bushels in 1982 and 1986 to 8,521 million bushels in 1983 (Table 5). Soybeans stay at their upper production limit of 2,183 million bushels while wheat is at the lower limit of 1,884 million bushels. Beef moves from 48.85 billion pound's liveweight in 1982 to 40.01 in 1983. It fluctuates between these two levels throughout the study. As natural gas prices increase to the $4.15 level, no changes are projected in commodity production. The changes in natural gas prices are not sufficient enough to alter commodity production. Because commodity production does not change as gas prices change, neither do the estimated commodity prices. As natural gas prices increase, however, net returns to land and management decline by $13 million.

LIMITATIONS

While natural gas prices will not cause an increase in the price of the raw food commodity, the cost of food preparation may be affected. Examination of this facet in the agri-business and household sectors is not included in the analysis. In addition, it must be pointed out that this study examines the production of feed grains (corn, oats, barley, and sorghum), soybeans, wheat, cotton, hay silage, as well as livestock commodities -- beef, pork, and milk. It does not attempt to incorporate the production of specialty crops such as fruits and vegetables. The study was completed before the announcement of the Payment In-Kind Program. With the participation rate announced in this program and reduced acreage being planted, the demand for fertilizers and energy by the agricultural production sector will be reduced, thus reducing the impacts of changing natural gas prices. Finally, the results of the study are not predictions, rather they are projections made under given assumptions.

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FOOTNOTES

[1]In 1973-1974, there was a perceived fertilizer shortage which drove prices up. However, if the 1976 price for Anhydrous Ammonia ($191 per ton) is adjusted to 1981 dollars ($305 per ton), there is a real price decrease.

[2]Endogenous and exogenous are terms used to divide that which is incorporated within the model to which is not. The adjustments which are referred to in the footnoted sentence are determined prior to model solution and, therefore, this procedure is exogenous.

[3]One quad equals 1×10^{12} BTU's.

[4]A cubic foot of natural gas is assumed to contain 1,016 BTU's.

[5]This is pure nitrogen and not nitrogen plus inert materials.

[6]Feed grains consist of barley, corn, oats, and sorghum.

BIOGRAPHY OF AUTHORS

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Burton C. English is a staff economist for the Center for Agricultural and Rural Development (CARD) at Iowa State University, Ames, Iowa.

He received his Ph.D. in agricultural economics at Iowa State University and his Masters of Science in agricultural economics at New Mexico State University.

Dr. English has done extensive research in the fields of energy, agriculture, and regional impacts of energy policy. Additionally, he is involved in refinement of a national programming model of the agricultural sector, developed at CARD, for the USDA.

George E. Oamek

George E. Oamek is a pre-doctoral Research Associate at CARD. His work has centered on energy demand modelling and agricultural impacts of energy policy. He received his Masters of Science degree in agricultural economics at Colorado State University.

Earl O. Heady

Earl O. Heady was born in Nebraska. He received his B.S. and M.S. degrees from the University of Nebraska and a Ph.D. degree from Iowa State University in 1945. Dr. Heady's academic career has been at Iowa State University. He was named the first Distinguished Professor of Agriculture in 1956. His academic and professional honors are numerous. Among them: Fellow of the America Agricultural Economics Association, the Econometric Society, and the American Statistical Association and, more recently, member of the Soviet Academy of Science. Currently, he serves as professor of economics and as the Director of the Center for Agricultural and Rural Development at Iowa State University.

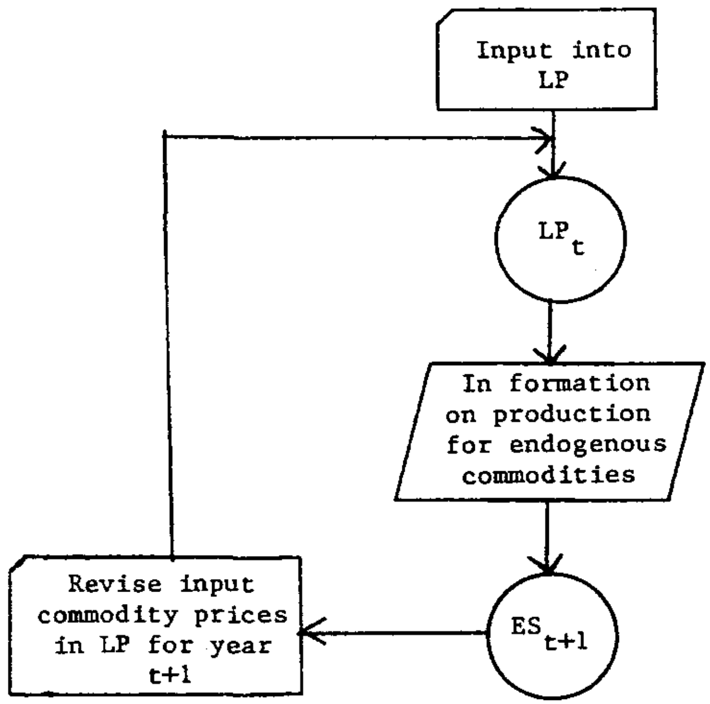

Figure 1. A schematic diagram of the Recursive Adaptive Hybrid model.

	Dry rotations	Irrigated rotations	Water: Surface	Water: Ground	Water: Transfer	Natural gas buy	Nitrogen buy	Crop sell	Dry irrigation conversion	Livestock production	RHS
Objective function	$X_{1,1}$	$X_{1,2}$	$X_{1,3}$	$X_{1,4}$	$X_{1,6}$	$X_{1,7}$	$X_{1,8}$	$X_{1,9}$	$X_{1,10}$	$X_{1,11}$	
Dryland	1								1		R_2
Irrigatable land		1							-1		R_3
Water		$-X_{4,2}$	1	1	$X_{4,6}$						R_4
Nitrogen	$-X_{5,1}$	$-X_{5,2}$					1			$X_{5,11}$	R_5
Crop production producing area	$X_{6,1}$	$X_{6,2}$						-1		-1	
Livestock feed										$X_{7,11}$	
Crop production national	$X_{8,1}$	$X_{8,2}$									R_8
Natural gas			$X_{9,3}$	$X_{9,4}$		-1				$X_{9,11}$	
BOUNDS			B_3	B_4	B_6						

Figure 2. Schematic diagram of the CARD-RCA linear programming model

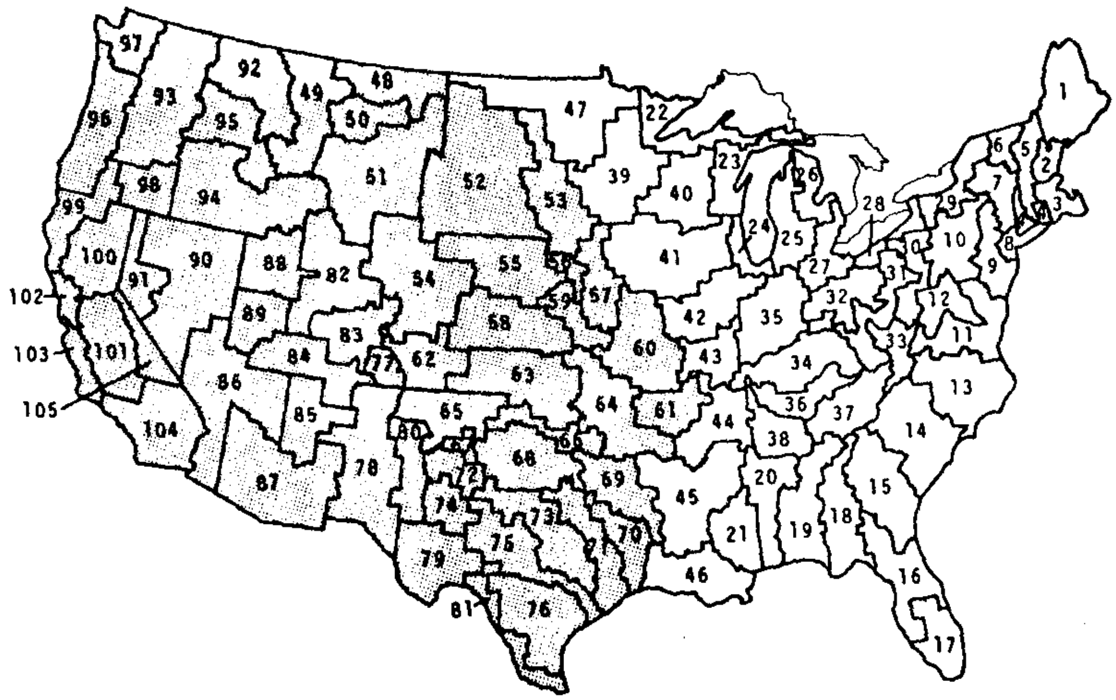

Figure 3. The Producing Areas with irrigated lands (shaded).

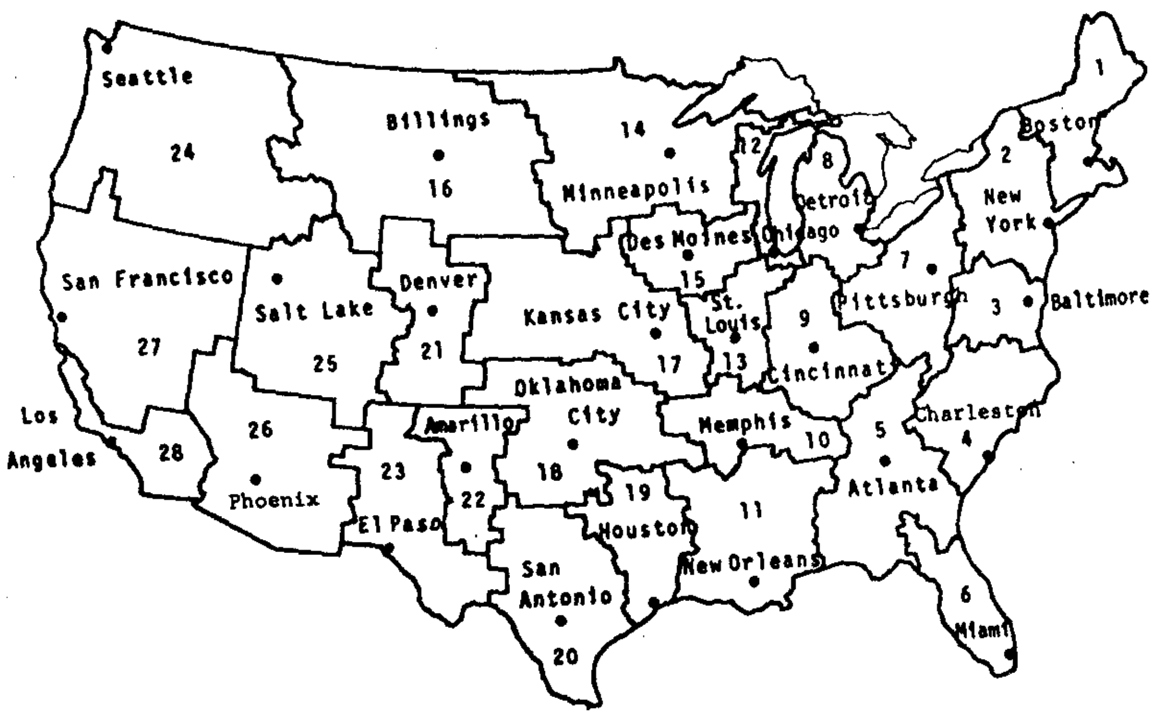

Figure 4. The 28 market regions.

Table 1. Econometric model's equations

Crop	Equation
Barley	BLPR = 1.80 - 4.91 (10^{-8}) (CNQP) - 0.0000026 (BLQP) + 0.24 (SNPRL1)
Corn	CNPR = 1.48 - 0.0000077 (POP) + 0.00031 (NDURGD) - 2.26 (10^{-7}) (CNQP) + 0.30 (DUM73) + 0.20 (SNPRL1) + 0.26 (SNPR) + 3.2 (10^{-6}) (PKQP)
Oats	OTPR = 28.97 -0.014 (YEAR) - 5.09 (10^{-7}) (OTQP) + 0.045 (AWPRL1) + 0.28 (CNPRL1);
Sorghum	SGPR = 0.77 - 3.73 (10^{-7}) (SGQP) + 0.45 (DUM74) + 0.61 (DUM73) + 0.54 (CNPRL1)
Soybeans	SNPR + -4.33 + 1.33 (DUM73) + 0.59 (CNPRL1) + 0.053 (CTPRL1) - 1.05 (10^{-5}) (BEQPL1) + 2.41 (10^{-5}) (BEQP)
Wheat	AWPR = 161.59 - 0.08 (YEAR) - 7.83 (10^{-7}) (AWQPL1) -1.40 (DUM7379) + 0.25 (SNPR)
Beef	BEPR = - 1706.68 + 0.89 (YEAR) + 25.15 (CNPRL1) - 6.58 (DUM74) + 12.41 (DUM730 + 10.99 (DUM5052) - 48.54 (LOG(CNPRL1)) -0.00014 (BEQP) + 8.86 (10^{-5}) (PKQP)
Pork	PKPR = 692.77 - 0.32 (YEAR) + 0.76 (BEPR) -0.00011 (PKQPL1) + 7.08 (10^{-5}) (BEQP) -0.00028 (PKQP)

Table 2. Variable definitions

Variable name	Definition
AW	Wheat
BE	Beef
BL	Barley
CN	Corn
CT	Cotton
DUM73	Dummy variable where 1973 = 1
DUM74	Dummy variable where 1974 = 1
DUM7379	Dummy variable where 1950 through 1972 = 1
DUM5052	Dummy variable where 1950 through 1952 = 1
L1	Indicates the variable was lagged one year
LOG	Natural logarithm
NDURGD	Nondurable good expenditures
OT	Oats
PK	Pork
PR	Price adjusted to real 1972 dollars in dollars per unit
POP	National population in millions of people
QP	Is national quantities in units as folows: Barley, corn, oats, sorghum, soybeans, and wheat in 1000 bushels; cotton in 1000 bales beef and pork in 1000's of 100 pounds of live-weight
SG	Sorghum
SN	Soybeans
YEAR	The year where 1980 = 1980

Table 3. Some measures of the accuracy of the estimated equations and of the forecasts over the historical period

Crop	MSE[a]	R^2[a]	RMSE[c]	RMS%E[d]	UM[e]	UR[e]	UD	
Barley	0.030	0.81	0.307	0.183	0.00	0.44	0.56	0.140
Corn	0.015	0.95	0.277	0.154	0.00	0.30	0.70	0.88
Oats	0.006	0.88	0.128	0.129	0.00	0.13	0.87	0.149
Sorghum	0.027	0.86	0.218	0.135	0.00	0.16	0.84	0.084
Soybeans	0.124	0.82	0.520	0.133	0.00	0.27	0.73	0.037
Wheat	0.078	0.88	0.319	0.158	0.00	0.00	0.99	0.059
Beef	5.765	0.88	3.481	0.118	0.00	0.24	0.76	0.004
Pork	3.906	0.88	2.423	0.087	0.00	0.00	0.99	0.003

[a]MSE is mean square error of estimated equation.

[b]R^2 is a measure of the proportion of the variation in the variable explained by the seemingly unrelated equation estimated.

[c]RMSE is the root-mean-square error of the forecasts.

[d]RMS%E is the root-mean-square percent error of the forecasts.

[e]UM, UR, and UD are the bias proportion, regression proportion and disturbance proportion decompositions of the mean square error of the forecasts [Maddala 1977, p. 345].

[f]UI is Theil's U_1 statistic measuring the accuracy of forecast [Maddala 1977, p. 346].

Table 4. 1985 acquisition cost range and corresponding retail prices for agricultural and commercial users[a]

Market Region	1985 acquisition cost in 1982 dollars		
	3.10	3.55	4.15
1	6.98	7.43	8.03
2	5.23	5.68	6.28
3	5.47	5.92	6.52
4	4.67	5.12	5.72
5	4.42	4.87	5.47
6	4.38	4.83	5.43
7	3.98	4.43	5.03
8	4.30	4.75	5.35
9	4.21	4.66	5.26
10	3.49	3.94	4.54
11	4.21	4.66	5.26
12	4.13	4.58	5.18
13	4.13	4.58	5.18
14	4.40	4.85	5.45
15	4.06	4.51	5.11
16	5.67	6.12	6.72
17	3.97	4.42	5.02
18	3.97	4.42	5.02
19	5.16	5.61	6.21
20	4.07	4.52	5.12
21	3.92	4.37	4.97
22	4.17	4.62	5.22
23	4.77	5.22	5.82
24	6.12	6.57	7.17
25	3.67	4.12	4.72
26	3.95	4.40	5.00
27	5.13	5.58	6.18
28	4.35	4.80	5.40

[a]Retail price equals the estimated 1985 acquisition cost plus the transmission margin.

Table 5. Commodity production by year for the four alternative solutions

Alternative and commodity	Unit	Average by years		
		1982-1983	1984-1985	1986-1990
		(million units)		
Average $3.10				
Feed grains	bu.	8146.0	7918.5	7893.5
Soybeans	bu.	2183.0	2183.0	2183.0
Wheat	bu.	1884.0	1884.0	1884.87
Cotton	bale	12.1	12.4	12.2
Beef	100 lbs.	444.3	444.3	444.2
Pork	100 lbs.	210.0	210.0	210.0
Average $4.15				
Feed grains	bu.	8146.0	7918.5	7889.0
Soybeans	bu.	2183.0	2183.0	2183.0
Wheat	bu.	1884.0	1884.0	1884.2
Cotton	bale	12.1	12.4	12.2
Beef	100 lbs.	444.3	444.3	444.0
Pork	100 lbs.	210.0	210.0	210.0