THE EFFECTS OF INCREASED ENERGY PRICES ON U.S. AGRICULTURE: AN ECONOMETRIC APPROACH

by

Douglas A. Christensen
Raymond Joe Schatzer
Earl O. Heady
Burton C. English

CARD Report No. 104

Center for Agricultural and Rural Development
Iowa State University
578 East Hall
Ames, Iowa

October 1981

PREFACE

Although the contents of this manuscript remain the responsibility of the authors, we wish to thank a group of reviewers for the time and conscientious effort they put forth to solidify this final draft. Andrew Morton, Brian Holding, Wesley Buchele, and Arnold Paulsen deserve much credit for their questioning, comments, and support in this endeavor.

We also wish to thank a fine clerical staff for their work on this project and especially Mary Shearer for her accuracy and expedience.

The Authors

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

The Era of Oil: An Overview

Our country is in a transition period when people are beginning to move away from a previously dominant form of energy--oil. What the United States is moving to is not certain, but it is certain that this is not the first energy transaction that our country has experienced. Figure 1 illustrates a wood to coal transition in the 1880s and a coal to petroleum transition in the mid 1940s. As shown in Figure 1, it takes a long time for an energy source to gain or lose its dominance. This period is lengthy due to the fact new technology and new investment must come about over time to set the stage for new energy forms.

Supply of oil

Our present dominating form of energy, petroleum, has been a very good energy source in terms of reliability, versatility, transportability and price for many decades. But the current available supply is rapidly decreasing. According to a widely held view, the United States reached its production peak in 1970 [Lönnroth, Steen, Johnasson, 1980]. Predictions also have production for the world as a whole, peaking before 2000 [Lönnroth, Steen, Johnasson, 1980]. Figure 2 provides data from 1935-1970 on world production, reserves, and a reserve to production ratio. This figure indicates that while annual production and new oil finds increase over time, the reserve production ratio is in a tailspin.

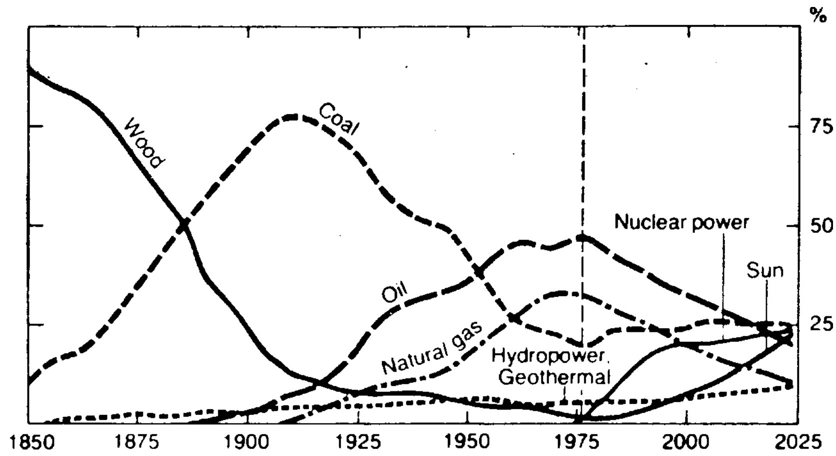


Figure 1. U.S. energy supply from different sources as a percentage of total use during 1850-1975 and a projection to 2020 [Lönnroth, Steen, Johnasson, 1980]

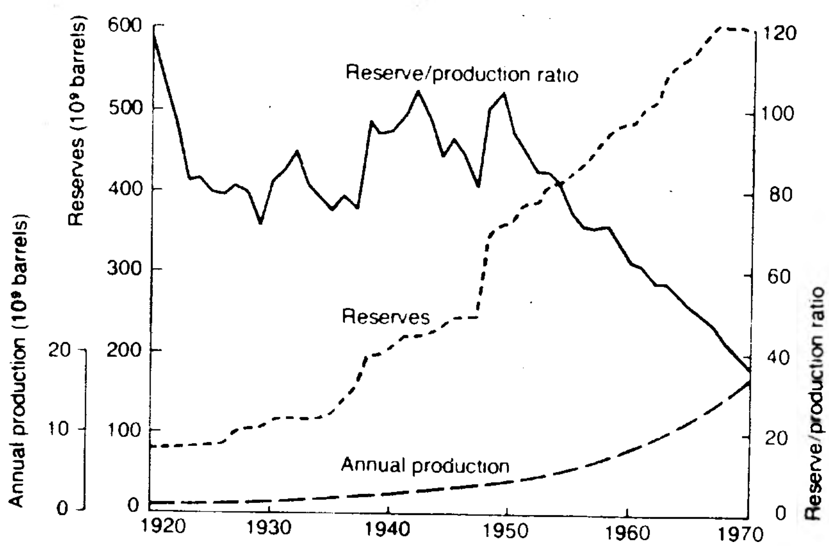


Figure 2. World production of oil, reserves, and ratio of reserves to production, 1920-1970 [Lönnroth, Steen, Johnasson, 1980]

Thus, even with new oil finds around the world, production usage will far outreach new reserves.

The demand for oil and oil prices

Real energy prices to consumers for the 1920-1977 time period are presented in Figure 3. In the 1930s and 1940s, real petroleum prices were relatively high due to initial capital costs and embodied costs of technology. As the U.S. oil industry strengthened, costs for petroleum products fell substantially in real terms. But due to surging demand for this new energy source, U.S. production could not keep up. Thus, the United States began importing cheap oil for a number of years in and beyond the 1960s. Then came OPEC, the Organization of Petroleum Exporting Countries. An economic cartel for oil price manipulation and with a large share of the world's oil, OPEC has been able to raise real oil prices substantially in the 1970s. Throughout the 1970s and today, with over half the U.S. oil consumption[1] supplied through imports, a 'control hysteria' has enveloped our nation. Not only has our domestic oil production peaked, but our suppliers abroad have put restraints on imported oil in the form of embargoes and higher prices.

The United States is somewhat helpless in the short run due to inadequate domestic petroleum production. Since U.S. strategic petroleum reserves contain only 90 million barrels, they are unreliable because at our current import and consumption rate, this oil would last only about

---

[1] The United States has 5 percent of the world's population, yet consumes 35 percent of the total energy [Gaddy, 1977].

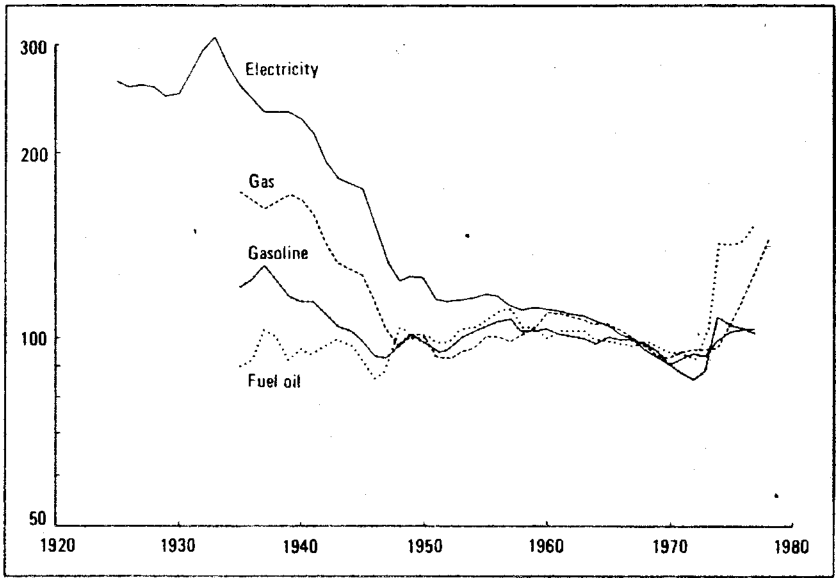


Figure 3. Trends in real energy price to personal consumers, 1967=100 [Schun, Darmstadter, Perry, Lamsay, Russel, 1979]

11 days if imports were cut off. It is obvious our national security is in danger along with our current comsumptive way of life.

Recently, the situation has improved as consumption for all petroleum products in the United States fell in 1980 by 3.7 percent. Accompanying this consumptive decrease was an import decline of 21.6 percent in 1980 [World Oil, 1980 and U.S. Energy Administration, 1981]. This turnaround in demand is impressive and will probably serve as an important lesson--proving that conservation can be practices successfully in the United States. (It is interesting to note that seven U.S. optimizing models developed to evaluate OPEC oil pricing policy, unanimously concluded current petroleum prices are higher than OPEC's long-run interest would dictate [Hammoudeh, 1979].

In summary there is one notable difference between our present energy transition and the past two. Wood and coal were not replaced because they were a depleted source. Wood and coal were replaced because new forms of energy were simpler, cheaper to handle and transport, and permitted new types of machinery. In other words, the new forms of energy were economically superior. Our present transition will not be a transition from cheap energy to cheaper energy. It involves the movement from an energy source rapidly depleting to new, more reliable sources which are not necessarily cheaper.

Objectives of the Study

This study projects the effects of various energy environments on the agricultural production sector to 2000 using an econometric simulation model. The varying energy price paths to 2000 are chosen (guided by past economic relationships) to represent the future with the intention of bounding reality. It is hoped that given an accurate bracketing of reality in our energy price assumptions to 2000, the analysis of the effects of various energy costs on the agricultural production sector will be useful whatever path energy prices take.

The agricultural study itself includes a pre-input, input and output analysis of major U.S. crops and livestock. First, a base is developed which assumes that real petroleum prices will remain constant to 2000 at 1980 levels. To this base, alternative scenario runs are compared with different petroleum price assumptions. These scenarios or alternatives are explained later in the report.

Survey of Energy Projections to 2000

The primary purpose of this section of the study is to compile a data base of energy price projections for comparison of alternative energy scenarios in the year 2000. The brief literature search presented here covers energy supply, demand and price projections to 2000. (It is important at this point to emphasize that this study does not attempt to project energy prices to 2000. In this study, a variety of energy price scenarios are compared. Given these chosen energy price scenarios, this study describes the effects of each alternative future outcome on U.S. agriculture.)

Energy supply to 2000

The U.S. energy supply can be categorized into two parts: renewable and nonrenewable sources. Over 95 percent of U.S. consumption in 1979 came from nonrenewable sources including oil, natural gas, coal, and nuclear. Oil and natural gas alone accounted for three quarters of the energy used in 1979. Table 1 shows that our energy problems stem from the use of a natural resource (oil) with little domestic supply. Three-fourths of the 1979 U.S. energy consumption came from natural resources accounting for 7 percent of our reserves. Our problem does not come from a lack of energy reserves. "Our (energy) reserves[1] could last from 70 to 170 years and resources[2] could last from 250 to 230 years" [Tyner, 1980]. Table 2a shows Exxon's projection of U.S. supplies of energy. The figures for supplies in 2000 vary slightly from those in Table 1 but are essentially within the same bounds. Table 2b estimates potential oil supplies today and to 1990 and 2000. The shifts from imported and domestic conventional sources to domestic synthetic sources of oil is dramatized in this table. U.S. dependency on foreign energy will be declining, but slowly. Coal and nuclear energy will be important in the move towards U.S. energy self-sufficiency.

The former discussion has concentrated on nonrenewable energy. Although renewable sources account for less than 5 percent of total

---

[1] Energy reserves are the amount of energy sources (oil, coal, etc.) already discovered that can be produced from the earth at a given cost.

[2] Resources of energy are the total amount of oil, coal, etc. in the earth's crust in such a form that its economic extraction is potentially feasible including undiscovered sources.

Table 1. 1979 U.S. energy consumption reserves, resources and a consumption projection for 1990 and 2000

Resource type	Consumption 1979	1990	2000	Reserves	Resources
	- - -(percent) - -			- - -(percent[a])- - -	
Oil	47	39	27	3	1
Natural gas	26	23	14	4	1
Coal (includes oil shale)	19	20	37	89	96
Nuclear	4	15	8	4	1
Other	4	3	14	--	1
TOTAL	100	100	100	100	100

[a]Figures are for 1979 excluding Breeder Reactor.

SOURCES: [USDA, 1980], 1990 projections [Gaddy, 1977].

Table 2a. Estimated U.S. energy supply for 1980, 1990 and 2000

Resource type	1980	1990	2000
	(percent of total energy supply)		
Oil	46	38	33
Gas	26	22	17
Coal	19	26	33
Nuclear	4	9	12
Other	5	5	5
TOTAL	100	100	100

SOURCE: [Exxon, 1979].

Table 2b. Estimated U.S. oil supply for 1980, 1990 and 2000

Type of oil	1980	1990	2000
	(percent of total oil supply)		
Domestic			
Conventional	55	37	38
Synthetic	--[a]	6	28
Imports	45	57	34
TOTAL	100	100	100

[a]Less than 2 percent.

SOURCE: [Exxon, 1979].

supplies today, there is a good future ahead for these energy forms. Renewable energy forms which seem viable in the future include solar, hydropower, and biomass. Table 3 shows various predictions of solar energy as a percentage of total energy consumption in 2000. Differences between the projections come from differing assumptions about: a) prices of competing fuels, b) overall levels of domestic energy consumption, c) rate of federal investment in solar energy, d) rate of advancement of solar technologies, and e) rate at which institutional barriers to solar will be overcome [Strobaugh, Yugin, 1979].

The general category of biomass contains sources such as wood, crop residues, grains, and municipal wastes. Currently about 2 quads[1] of energy are produced from biomass, primarily from forest products. The most immediate new energy source seems to be alcohol from feed grains. Ethanol capacity of 60,000 barrels per day (bpd) oil equivalent is projected by 1983 and 145,000 bpd oil equivalent by 1990 [Meekhof, Mohinder, Tyner, 1980]. Beyond grain alcohol production, we will likely see more uses of wood and crop residues for alcohol production. Estimates for biomass energy production in 2000 range from barely above the 2 quads presently produced to almost triple that amount. Again, different assumptions yield different results.

Commercial sny-fuels production, electric vehicles and methanol from coal are other alternatives to petroleum use, which could make a strong developmental bid in the next two decades. These three sources could account for as much as 1 million barrels daily (mbd) oil equivalent by 1990.

---

[1]Quadrillion BTUs.

Table 3. Estimated solar contribution by 2000

Studies	Solar energy (oil equivalent million barrels/day)	Total energy consumption (oil equivalent million barrels/day	Solar as a percentage of a total
President's Council on Environmental Quality (CEQ)	12	50	23
Sanford Research Institute 1[a] (business as usual)	5	73	7
Stanford Research Institute 2[a] (low solar cost)	10	70	13
Stanford Research Institute 3[a] (high fuel cost)	6	45	12

[a]The Stanford Research Institute developed three scenarios. The first is a business-as-usual scenario. The two remaining scenarios are solar-emphasis scenarios. In case 2 the emphasis is achieved by lowered solar costs, whereas in scenario 3 the change comes primarily from increased prices of competing fuels.

SOURCE: [Stobaugh, Yugin, 1979].

No analysis of U.S. energy supply can be considered complete unless some mention is given to oil imports. The United States imports almost half the oil it consumes and projections indicate this trend will continue at least to 1990, Table 4.

World oil supply, outside communist areas, will probably plateau well before the year 2000 at around 65 million bpd [Popcock, 1979]. Length of this plateau depends on the willingness of producers to continue producing, which, depends on their production incentives.

Table 4. Estimated oil supplies outside communist areas for 1978, 1990, and 2000 in million barrels/day (mbd)

OIL/NGL	1978		1990		2000			
			Optimistic[a]	Pessimistic[b]	Optimistic		Pessimistic	
	mbd	%			mbd	%	mbd	%
OPEC	30.3	62	NA	NA	37	59	45	62
Non-OPEC	18.3	38	NA	NA	27	41	27	38
Total	48.6	100	60	70	64	100	72	100

[a]High economic growth, social cooperation, alternative energy programs and energy efficiency.

[b]Depressed economy, divided world and delays in energy programs.

SOURCE: [Popcock, 1979].

Table 4 shows actual energy supplies for 1978 and projected supplies for the noncommunist world. It is obvious OPEC does control a majority of this supply and has potential for expansion in the future. The outlook for U.S. imports is one of restricted supply and shortages unless consuming nations can continue to restrain demand and/or OPEC producers increase output at reasonable prices.

Energy demand to 2000

U.S. energy demand is now around 80 quads, annually. It had, until the last couple of years, been growing steadily larger with no variations. Economic growth, measured by GNP, and energy demand were widely accepted as joint partners of an upward trend. The growth of both was commonly tied together, locked in the name of progress. But recently, the shackles have been broken. In 1979, total energy use in the United States declined, yet GNP continued to rise in real terms. Elliott Marshall writes: "It now takes 10 percent less energy to produce a dollar's worth of GNP than it did in 1973. The fact that energy demand is growing more slowly than the economy could wreck the plans of some energy suppliers."

The new trends in energy demand have caused energy forecasters to adjust their forecasts accordingly. Table 5 shows energy demand forecasts for 2000 and 2010 developed from 1972-1978 bases. It is obvious that in any of the growth categories, projections have been sliding downwards. Low growth advocates' 1972 projections for year 2000 are at the level of the high growth advocates in 1977. One should also realize these forecasts do not incorporate the recent doubling of oil prices. This accelerating price trend could continue to lower future demand projections as forecasters adjust for increasing rates of price-reduced conservation. For example, a private consulting group, in a May 1980 publication, predicts that U.S. gasoline demand will drop by 20 percent in the 80s [Marshall, 1980]. In 1972, no such prediction would have been taken seriously.

U.S. energy demand is separated by consuming sector in Table 6. In 1975 the industrial sector was the largest user of energy as it consumed over 40 percent of total energy demanded that year. Regardless of sector, liquids (petroleum) and gas were by far the form of energy most consumed. These two forms of fuel made up almost 65 percent of the total energy consumed in all sectors. Close to half of this amount was consumed in the transportation sector. Projections for the year 2000 are also included in Table 6. Again the industrial sector is projected to be the largest consuming sector (50 percent), doubling its 1975 consumption of 28.9 quads to almost 57 quads in 2000. The energy demand share of the transportation

Table 5. Energy demand forecasts to 2000 or 2010 from 1972-1978 in quads

Year of forecast	Low growth advocates	Moderate conservationists	Government scenarios	High growth advocates
1972	125 (Lovins)	140 (Sierra)	160 (AEC)	190 (FPC)
1974	100 (Ford zeg)	124 (Ford tf)	140 (ERDA)	160 (EEl)
1976	75 (Lovins)	89-95 (Von Hippel)	124 (ERDA)	140 (EEl)
1977-78	33 (Steinhart)	67-77 (NAS I, II)	96-101 (NAS III, AW)	124 (Lapp)

Abbreviations: Sierra, Sierra Club; AEC, Atomic Energy Commission, FPC, Federal Power Commission; Ford zeg, Ford Foundation zero energy growth scenario; Ford tf, Ford Foundation technical fix scenario; Von Hippel, Frank Von Hippel and Robert Williams of the Princeton Center for Environmental Studies; ERDA, the Energy Research and Development Administration; EEl, Edison Electric Institute; Steinhart, 2050 forecast by John Steinhart of the University of Wisconsin; NAS I, II, III the spread of the National Academy of Sciences Committee on Nuclear and Alternative Energy Systems (CONAES); AW, Alvin Weinberg study done at the Institute for Energy Analysis, Oak Ridge; Lapp, energy consultant Ralph Lapp.

Amory Lovins put together this table showing the downward drift in forecasts. Figures represent total U.S. energy demand in year 2000 or 2010.

SOURCE: [Marshall, 1980].

Table 6. Primary energy demands by sector

	Delivered fuel forms	1975 (actual) (percent of total demand)		2000 (estimated) (percent of total demand)	
		- - quads - -		- - quads - -	
Residential-commercial sector	Liquids	4.74	(06.6)	3.78	(03.3)
	Gas	7.59	(10.5)	7.78	(06.8)
	Coal	0.25	(00.3)	0.46	(00.4)
	Electricity	12.24	(17.0)	22.72	(20.0)
	Solar	---		0.80	(00.7)
	Geothermal	---		0.27	(00.2)
	Biomass	---		0.22	(00.2)
Subtotal		24.82	(34.4)	36.03	(31.7)
Transportation sector	Liquids	17.75	(24.6)	17.99	(15.8)
	Gas	0.60	(00.8)	0.54	(00.5)
	Electricity	0.05	(00.1)	2.32	(02.0)
Subtotal		18.40	(25.5)	20.85	(18.3)
Industrial sector	Liquids	7.02	(09.7)	8.79	(07.7)
	Gas	8.55	(11.8)	8.25	(07.2)
	Coal	3.81	(05.3)	15.84	(13.9)
	Electricity	7.95	(11.0)	20.47	(18.0)
	Industrial waste	1.57	(02.2)	2.92	(02.6)
	Solar	---		0.05	(0.04)
	Geothermal	---		0.49	(0.40)
	Biomass	---		0.06	(0.05)
Subtotal		28.90	(40.1)	56.87	(50.0)
All sectors	Liquids	29.51	(40.9)	30.56	(26.9)
	Gas	16.74	(23.2)	16.57	(14.6)
	Coal	4.06	(05.6)	16.30	(14.3)
	Electricity	20.24	(28.1)	45.51	(40.0)
	Industrial waste	1.57	(02.2)	2.92	(02.6)
	Solar	---		0.85	(00.7)
	Geothermal	---		0.76	(00.7)
	Biomass	---		0.28	(00.2)
Total demand		72.12	(100)	113.75	(100)

SOURCE: [USDA, 1976].

sector has decreased substantially, although its consumption increases slightly. This 1976 study would be considered a moderate forecast study as described in Table 5. Yet had these same results been developed in 1978, this study would have been one of high growth.

A big reason for the slowdown in the growth of energy demand is conservation. Whether it has developed through price induction or moral suasion, the United States is learning to restrain its seemingly insatiable energy appetite. Table 7 shows Exxon's projections for U.S. energy conservation to 2000 compared to the U.S. pre-embargo demand trends:

Table 7. Projected U.S. energy demand reduction by sector in percent[a]

	1980	1990	2000
Industrial	12	21	25
Transportation	17	39	55
Residential/Commercial	13	25	29
Overall	13	27	35

[a]Compared with the demand level that would have been expected if prices and consumption were trended from pre-embargo levels.

SOURCE: [Exxon, 1979].

In industry, savings are expected from retrofitting of equipment, newly developed processes, and overall energy management. The transportation sector should get large savings due to increased automobile fleet efficiency as dictated by the Energy Policy and Conservation Act of 1975 which established the following standards: (although relaxed under the new administration)

Year	MPG	Year	MPG
1978	18	1980	20
1979	19	1985	27.5

Automobiles are expected to increase mileage through decreased weight, projected to average 1,700 pounds in 2000 as compared to 3,100 pounds in 1979. The Residential/Commercial sector will reduce demand through reduced winter temperatures and increased summer temperatures, improved insulation, the use of heat pumps, and retrofitting of existing homes.

In a recent report of the National Academy of Science [CONAES, 1980] this fundamental conclusion is reached: "There is much more flexibility toward reducing energy demand than has been assumed in the past."

Petroleum prices to 2000

Predicting the supply or demand for petroleum to the year 2000 is a difficult task. But predicting petroleum prices to 2000 seems nearly impossible. In the past, petroleum has been a bargain compared to other fuels. Figure 4 illustrates this, showing a decline in the real price of diesel fuel from 1954 to 1972 and again from 1974 to 1979. The real price for imported crude oil reflects the same declining pattern from 1974-1979 as shown in Table 8.

Since the U.S, will continue to import large volumes of OPEC oil, we must examine past and future price patterns for this foreign commodity closely. In July 1978, the real price of Saudi crude had actually dropped 3 percent for the United States from the October 1974 price. Although OPEC constantly raised the nominal price of oil since 1974, it

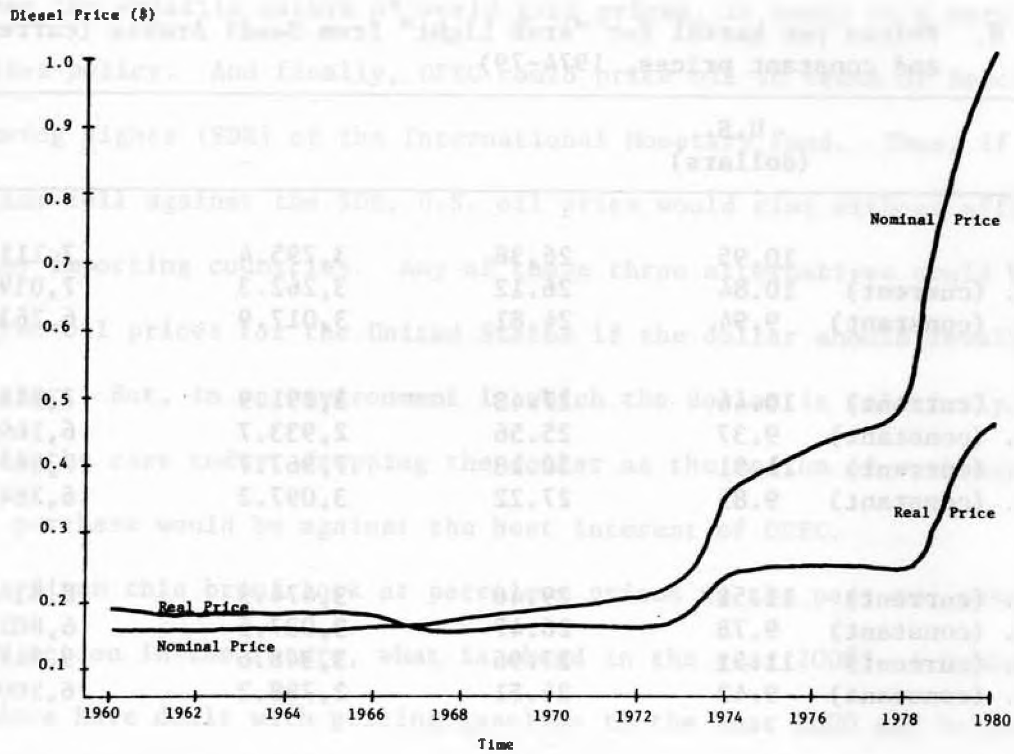


Figure 4. Diesel prices paid by farmers, real and nominal, 1960-1980 (1967=100) [USDA, ESCS, 1981]

was more than counterbalanced by U.S. inflation and the devalued dollar. Thus, OPEC has had large trade losses since 1974 by sticking with the dollar as its medium of payment [Ecklund, 1980].

Table 8 also shows prices paid to Saudi Arabia from other importing countries. The dollar's decline (because it is the currency in which oil payments are made), further reduced real prices paid in countries such as Germany, Japan, and Italy. Even after a large July 1979 OPEC price increase, Japan paid 5 percent less for oil (in real terms) than it did in 1974, although the U.S. paid 19 percent more. Could OPEC drop the dollar as the medium of exchange for oil purchase? Certainly, and

Table 8. Prices per barrel for "Arab Light" from Saudi Arabia (current and constant prices, 1974-79)

	U.S. (dollars)			
1974				
Jan.	10.95	26,38	3,295.4	7,111.3
Oct. (current)	10.84	26.12	3,262.3	7,039.8
Oct. (constant)	9.94	24.81	3,017.9	6,263.2
1975				
Jan. (current)	10.46	27.43	3,191.9	7,149.9
Jan. (constant)	9.37	25.56	2,933.7	6,169.1
Oct. (current)	11.51	30.18	7,867.7	7,867.7
Oct. (constant)	9.85	27.22	3,097.2	6,284.1
1976				
Jan. (current)	11.51	29.46	3,474.9	8,836.9
Jan. (constant)	9.78	26.47	3,037.5	6,802.9
Oct. (current)	11.51	27.96	3,348.6	9,841.9
Oct. (constant)	9.42	24.51	2,788.2	6,500.6
1977				
Jan. (current)	12.09	28.90	3,519.2	10,629.4
Jan. (constant)	9.76	25.09	2,896.4	6,689.4
Jul. (current)	12.70	29.01	3,363.2	11,207.2
July (constant)	9.93	25.42	2,677.7	6,596.4
1978				
July (current)	12.70	26.08	2,538.7	10,752.6
July (constant)	9.63 (-3)[a]	21.22 (-14)[a]	1,924.7 (-36)[a]	5,647.4 (-10)[a]
1979				
Jan. (current)	13.34	24.64	2,637.6	11,257.6
Jan. (constant)	9.31	19.83	1,999.7	5,507.6
July (current)	18.00	32.83	3,895.4	14,769.0
July (constant)	11.86 (+19)[a]	25.52 (+3)[a]	2,864.3 (-5)[a]	6,694.7 (-7)[a]

[a]Percentage change from the October 1974 price in constant terms.

SOURCE: [Ecklund, 1980].

OPEC has three alternatives. First, it could use each industrialized countries' own currency. Thus, the returns to OPEC would not be whittled away by U.S. inflation. Secondly, OPEC could tie oil prices to the price of gold. This too would avoid devaluation of a foreign currency but given the volatile nature of world gold prices, it would be a very speculative policy. And finally, OPEC could price oil in terms of Special Drawing Rights (SDR) of the International Monetary Fund. Thus, if the dollar fell against the SDR, U.S. oil price would rise without affecting other importing countries. Any of these three alternatives could mean higher oil prices for the United States if the dollar should devalue further. But, in an environment in which the dollar is relatively strong, as is the case today, dropping the dollar as the medium of exchange for oil purchase would be against the best interest of OPEC.

Given this brief look at petroleum prices in the past and possible OPEC action in the future, what is ahead in the year 2000? A number of studies have dealt with pricing gasoline to the year 2000 and beyond. A brief description is provided for each projection below, followed by the author's name so a more complete documentation may be obtained.

a. CONAES-A CONAES stands for the Committee on Nuclear and Alternative Energy Systems. The model projects energy demands and is essentially an accounting model. Scenario A is the case with very high energy prices and large conservation efforts in effect [CONAES, 1980].

b. CONAES-C This is the same study as "a" with the case of small price increases [CONAES, 1980].

c. SRI-S This report descrives alternative futures in the United States with implications for transportation. This is the "success" case for both energy supply and conservation technologies [Stanford Research Institute, 1977].

d. SRI-T This is the same study as "c" with the "transformation" case where half the U.S. population is living an energy conserving lifestyle [Stanford Research Institute, 1977].

e. TEC Gasoline prices are estimated by the DATA Analysis branch of the Transportation Energy Conservation (TEC) Division, ERDA [Transportation Energy Conservation Division, 1977].

f. TECNET A simulation model divided by International Research and Technology, Inc. during the summer of 1977 [International Research and Technology, Inc., 1978].

Figure 5 illustrates gasoline projections from these studies to the year 2000. Since the studies were started in 1975, comparisons are available for the actual gasoline price increase to the projected ones to 1980. Regular gasoline at the pump varied from $1.10 to over $1.25 depending on the region during September 1980. Table 9 gives the approximate 1980 and 2000 projections for each study cited.

Table 9. 1980 and 2000 projected price per gallon of gasoline (current dollars

Study	Interpolated price per gallon	
	1980	2000 (1980 dollars)
ONAES-A	1.15	2.70
TECNET	.95	1.40
SRI-R	.90	1.22
SRI-S	.88	1.05
TEC	.85	1.32
CONAES-C	.78	.88

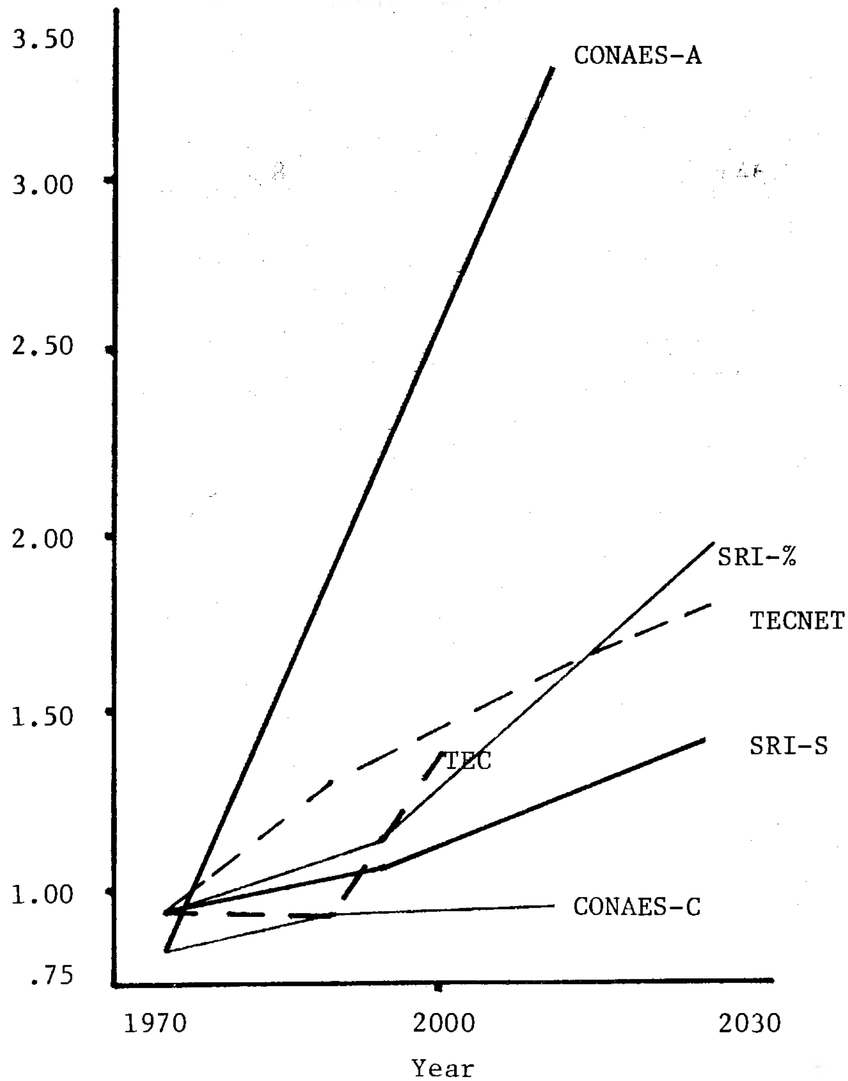


Figure 5. Gasoline price projections from various sources in 1980 dollars [Transportation Energy Conservation Division, ERDA, 1977]

A majority of the projections appear to underestimate the rate at which gasoline prices would rise, even five years into the future. This illustration exemplifies the difficulties involved in projecting the price for a commodity as unstably priced as gasoline. Yet, these studies are valuable because they coordinate information and methodologies which can be used and updated.

In summary, we see from Table 8 that imported crude oil prices shot up in real terms since 1978. Refined petroleum in the form of diesel fuel has increased in real price terms nearly twofold since 1978 (Figure 4). It seems that if the U.S. refuses to significantly cut demands for foreign oil voluntarily, we may be facing a shortage of imported oil, severe balance of payments problems, or both, Shekh Yamani of Saudi Arabia made this suggestion: "Saudi Arabia itself might be encouraged to explore and develop new acreages of high prospectively but only if the nation could be guaranteed an attractive return (in real terms) on the invested proceeds of any oil made available" [Popcock, 1979]. It seems certain that if foreign supplies of petroleum are available for U.S. import, they could be very expensive.

Energy Costs in Agriculture

Energy costs in farm production

U.S. agriculture has gone through many changes in the past fifty years, but the change which has most affected this sector has been the substitution of capital inputs for labor in the production process. Farmers once produced most of their own inputs but in today's commercialized farming, producers purchase the vast majority of their inputs from the industrial sector. Table 10 illustrates the historical reduction of labor inputs per hectare of U.S. corn. It also shows the increase in purchased inputs since 1945.

Table 10. Inputs in U.S. corn production per hectare for selected years

Inputs (units)	1945	1950	1954	1959	1964	1970
Labor (hours)	57	44	42	35	27	22
Fuel (liters)	140	159	178	187	197	206
Nitrogen (kg)	8	17	30	46	65	125
Phosphorus (kg)	8	11	13	18	20	35
Potassium (kg)	6	11	20	34	46	67
Seeds for planting (kg)	11	13	16	19	21	21
Insecticides (kg)	0	.11	.34	.78	1.12	1.12
Herbicides (kg)	0	.06	.11	.28	.43	1.12
Drying (kcal)	9,880	34,580	74,100	163,020	247,000	296,400
Electricity (kcal)	79,040	133,380	247,000	345,800	501,410	765,700
Transportation (kcal)	49,400	74,100	111,150	148,200	172,900	172,900
Corn yield (kg/ha)	2,132	2,383	2,572	3,387	4,265	5,080

SOURCE: [Pimentel, Lynn, MacReynolds, Hewes, Rush, 1974].

Most purchased capital inputs are either directly or indirectly dependent on petroleum products. Since agriculture has become increasingly dependent on capital inputs it also depends on the energy used to derive those inputs. Table 11 summarizes the historical pattern of inputs used per hectare of corn in energy equivalents (kcal). "Invested energy," that is the energy used to derive petroleum based fertilizer and herbicide, has had a dramatic increase in use to the 1970s. Although the energy return/input ratio has fallen over time, the difference between energy return and energy input has risen to 1970. Thus, the substitution of energy for labor has continued.

Table 11. Energy inputs in U.S. corn production per hectare for selected years in kcal

Inputs	1945	1950	1954	1959	1964	1970
Labor	31,022	23,947	22,859	19,049	15,695	11,974
Machinery	44,600	617,500	741,000	864,500	1,037,400	1,037,400
Fuel	1,339,800	1,521,630	1,703,460	1,789,590	1,885,290	1,971,420
Nitrogen	140,800	299,200	528,000	809,600	1,144,000	2,200,000
Phosphorus	25,520	35,090	41,470	57,470	63,800	111,650
Potassium	13,200	24,200	44,000	74,800	101,200	147,400
Seeds for planting	77,440	91,520	112,640	133,760	147,840	147,840
Irrigation	103,740	128,440	148,200	170,430	187,720	187,720
Insecticides	0	2,662	8,228	18,876	27,104	27,104
Herbicides	0	1,452	2,662	6,776	10,406	27,104
Drying	9,880	34,580	74,100	163,020	247,000	296,400
Electricity	79,040	133,380	247,000	345,800	501,410	765,700
Transportation	49,400	74,100	111,150	148,200	172,900	172,900
Total inputs	2,314,442	2,987,701	3,784,769	4,601,821	5,540,765	7,104,612
Corn yield	7,504,640	8,388,160	9,053,440	11,922,240	15,012,800	17,881,600
kcal return-kcal input	5,190,198	5,400,459	5,268,671	7,320,419	9,472,035	10,776,988
kcal return/kcal input	3.24	2.81	2.39	2.59	2.71	2.52

SOURCE: [Pimental, Lynn, MacReynolds, Hewes, Rush, 1974].

In 1978, agricultural production consumed 2 quads of energy, which is only 3 percent of the total energy used in the United States. Still, this amount was up 7 percent from 1974. Types of energy used in agriculture are illustrated in Table 12 for 1974 and 1978. Diesel fuel consumption alone increased 26 percent for the four-year period. This large diesel use increase was only slightly offset by a 5 percent decline in gasoline use. The gasoline-to-diesel trend will probably continue as most new tractors are diesel-powered. Consumption of other major energy forms

Table 12. Energy used in U.S. agricultural production by type of fuel in 1974 and 1978

Fuel	Unit	1974 (amount)	1978 (amount)	Percent change
Gasoline	1,000 gallons	3,709,390	3,515,656	(- 5.2)
Diesel	do.	2,620,459	3,307,747	(+26.2)
Fuel oil	do.	292,126	292,869	(+ .2)
LP gas	do.	1,375,476	1,424,835	(+ 3.6)
Natural gas	Million cu. ft.	137,434	140,063	(+ 1.9)
Coal	Tons	32,725	36,552	(+11.7)
Electricity	Million kWh	31,755	31,909	(+ .5)

SOURCE: [USDA, 1977].

remained virtually unchanged from 1974 but the total energy consumption increase still mirrors a basic continuation of the mechanical revolution in agriculture.

Given the fact that agriculture has become more energy dependent and that nominal petroleum prices have risen in past years (Figure 4) how has this affected variable costs? Table 13 illustrates the fact that fuel costs have increased since 1975 as a share of variable costs as well as per acre. The share of production costs in agriculture contributed by capital inputs is rising because energy prices are rising. And, they are rising because the usage of capital inputs derived from energy has risen over time relative to other inputs. Since farmers are price takers, the short run effects of higher production costs will be seen in a reduction of the individual farmer's total output. But in the long run, higher costs will be reflected in higher food prices at the retail level and probably higher aggregate farm income.

Table 13. Average fuel cost per acre and variable cost per acre, 1975-79

Year and crop	Fuel cost per acre	Total variable cost per acre	Fuel as a share of variable cost (percent)
Corn:			
1975	$ 5.72	91.21	6.3
1976	6.00	86.39	7.0
1977	7.89	96.41	8.2
1978	8.41	98.27	8.6
1979	11.10	104.80	10.6
Wheat:			
1975	4.72	39.50	10.4
1976	4.55	36.20	12.6
1977	4.80	37.24	12.8
1978	5.19	37.64	13.8
1979	6.85	41.35	16.5
Cotton:			
1975	8.43	143.99	5.9
1976	8.98	152.17	5.9
1977	11.45	168.21	6.8
1978	11.98	162.54	7.3
1979	15.81	175.61	9.0

SOURCE: [Parton, 1979].

Energy costs in food processing and marketing

Farm production is not the only segment of the agricultural sector affected by energy price increases. In fact, farm value accounts for only 32 percent of farm food expenditures, Figure 6. Food processing and marketing costs are the major component of retail food prices, accounting for over 60 percent of the retail product value [Farrell, 1979]. The cost of packaging materials (12 percent of marketing costs) is expected to rise as plastic packaging materials become more expensive, reflecting the higher petroleum prices. Food transportation costs (8 percent of marketing costs) are expected to increase due to higher

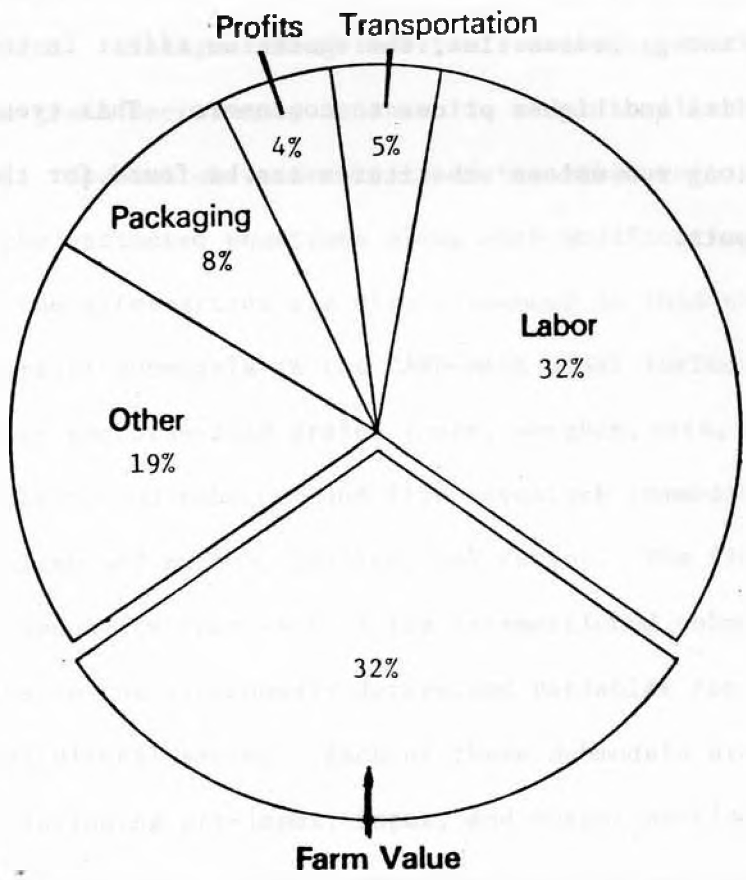


Figure 6. Components of consumer farm food expenditures: marketing costs vs farm value [Farrell, 1980]

freight rates imposed in response to increasing fuel costs. Higher energy costs also affect store owners as heating and cooling costs rise.

Because the nonproduction segments of the agriculture sector are also dependent on energy, they too will be affected by a changing energy environment. As energy prices rise, the short-run effect in these sectors will be lost profits and higher prices to consumers. This trend will continue in the long run unless substitutes can be found for the high-priced energy inputs.

II. THE MODEL

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

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

The pre-input section determines the stocks of such fixed resources as machinery, land and buildings, and on-farm commodity inventories. Levels of the variable inputs such as fertilizer, seed, machinery services, real estate services, and labor requirements are determined in the input sector based on information provided by the pre-input section and from other previously determined variables. Production, commodity prices, and income estimates resulting from the resource levels committed in the pre-input and input sections are obtained from the output section.

Generally, the model's structure is recursive. However, there are portions of the model which fail to meet all the recursiveness criteria. For a model to be recursive, two conditions must prevail. First, the matrix of coefficients for endogenous variables must be triangular. If this conditions prevails, the structural equations of the model can be solved sequentially without the use of reduced form equations or iterative techniques. Secondly, the variance-covariance matrix of structural equation disturbances must be diagonal [Johnston, 1972]. Thus, the disturbance term of any one equation must not be correlated with the disturbance of any other equation in the model.

Portions of the output section do not meet the first criterion. These portions, therefore, are block recursive.[1] There are also portions of the model that do not meet the second criterion. These violations imply simultaneous and autoregressive estimation techniques are necessary for some equations in the model.

All applicable data and results are in constant 1978 dollars. Therefore, inflation projections are not needed and bias occurring from the comparision of nominal values is avoided.

Statistical Methods

Annual time series data are used to estimate the structural parameters of the model using regression techniques. Most equations are

[1] The term block recursive indicates that both simultaneous and recursive portions are represented.

Six regression techniques are used to estimate the model's parameters. Ordinary least squares are used for those equations that are recursive. The recursive equations with autocorrelated errors are estimated by autoregressive least squares. Two-stage least squares are used to estimate the farm-retail margin equations in the beef, pork, chicken, and turkey submodels as they are determined simultaneously with their respective farm prices. Three-stage least squares or autoregressive three-stage least squares are used on equations which are not simultaneous, but had disturbances correlated with disturbances of other equations in the model [Roberts, Heady, 1979].

Feed Grain Submodel (Representative Submodel)

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

Feed grain pre-input section

Figure 7 is a schematic diagram of the pre-input section with definitions of the variables appearing in Appendix B. The pre-input section determines the levels of physical assets committed to the production of feed grains. Harvested acreage, machinery purchases, machinery stocks, on-farm commodity stocks, and land and building value per harvested acre are estimated through regression techniques, with the machinery and

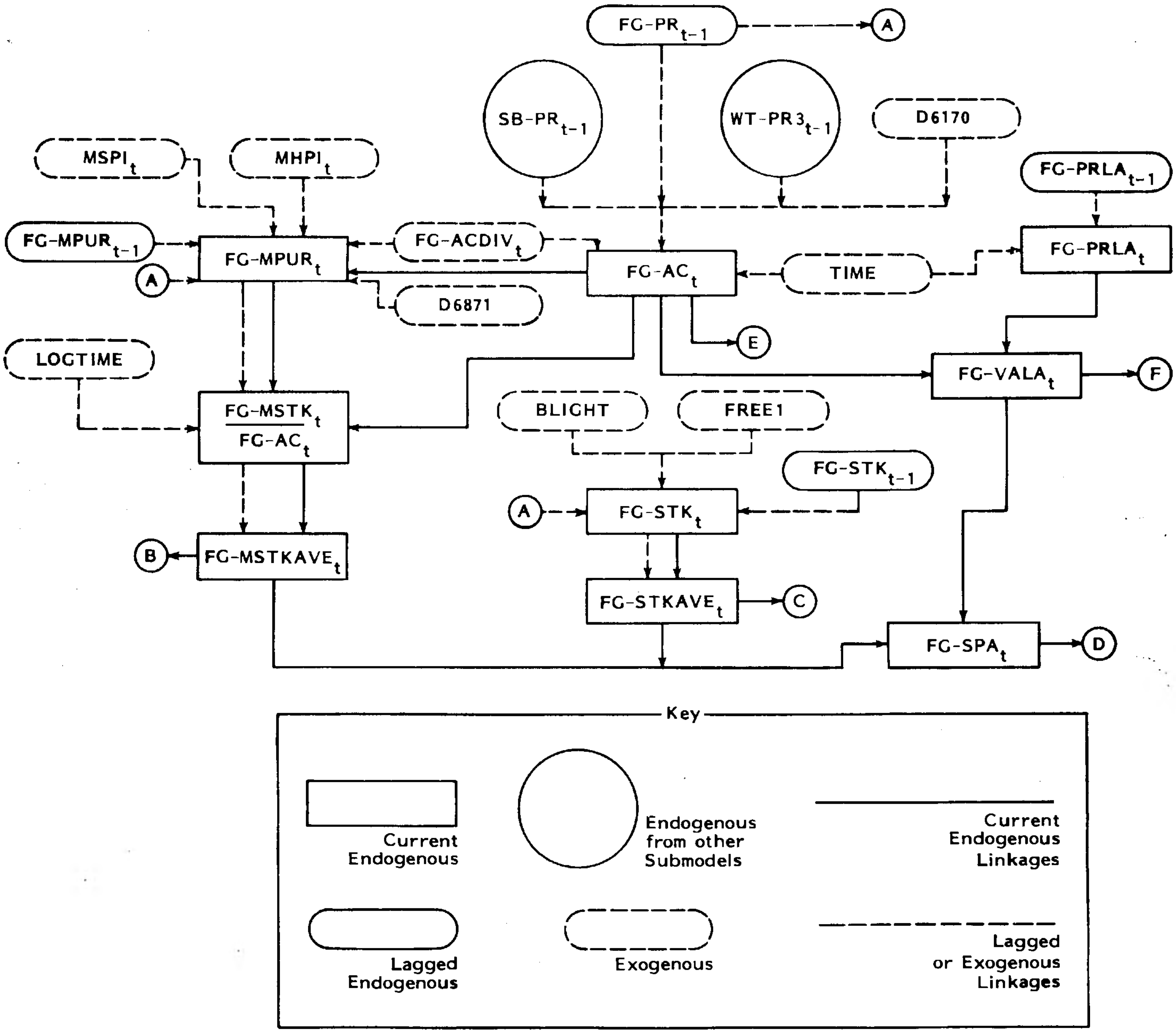


Figure 7. Schematic diagram of the feed grain pre-input sector [English, Schatzer, Roberts, Heady, 1981]

commodity stock averages, total land and building value, and stocks of physical assets determined through identities.

Feed grain harvested acreage (FG-AC) is determined first with lagged feed grain (FG-PR), soybean (SB-PR), and wheat (WT-PR) price ratios used to capture competition among the commodities for land. A time trend (TIME) and a feed grain base program dummy variable (D6170) along with the feed grain diversion program (FG-ACDIV) are also included in the equation. The index of the per acre price of land and buildings (FG-PRLA) for feed grains is estimated using a time trend (TIME), and lagged FG-PRLA as explanatory variables. The total value of land and buildings (FG-VALA) is then derived by multiplying the feed grain harvested acreage by the price of land.

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

U.S. motor supplies price and machinery purchase indices (MSPI and MHPI, respectively), dummy variables representing the feed grain diversion program (FG-ACDIV) and the Vietnam War (D6871), lagged feed grain prices (FG-PR), and the lagged machinery purchases (FG-MPUR) are the variables included in the estimation of machinery purchases. These purchases then are used to determine the per acre stock of machinery (FG-MSTK/FG-AC) along with the log time (LOGTIME) and the FG-AC). The average stock of machinery (FG-MSTKAVE) is then computed by dividing the sum of the current and lagged stocks by two.

The final variable computed in the pre-input section is the stock of physical assets. It is formed by summing the values of land and buildings, on-farm feed grains, stock average, and the machinery stock average.

Feed grain input section

Endogenous variables estimated in the pre-input sector are used to determine the variable input expenditures in the feed grain input sector. The flow of these variables is shown in Figure 8 with variable input expenditures expressed in constant dollars. Variables determined in the input section include real estate taxes (FG-RETX), real estate (FG-REEX), miscellaneous inputs (FG-MISC), fertilizer (FG-FERT), seed (FG-SEED), fuel oil and repairs (FG-FOR), machinery (FG-MACH), man-hours of labor (FG-LABR), and interest on feed grain stocks (FG-INT). Real estate, miscellaneous inputs, per acre fertilizer, seed, fuel oil and repairs, and machinery expenses and labor are computed through econometrically estimated equations with real estate taxes and interest on commodity stocks determined by identities.

Value of land and buildings from the pre-input sector is used to derive real estate taxes and expenses. Real estate taxes are estimated by multiplying the exogenously determined feed grain real estate tax rate (FG-TXRT) by the estimated value of land and buildings used in feed grain production. Estimated value of land buildings along with the log of time are the explanatory variables used in determining the real estate expenses for feed grain production. Miscellaneous input

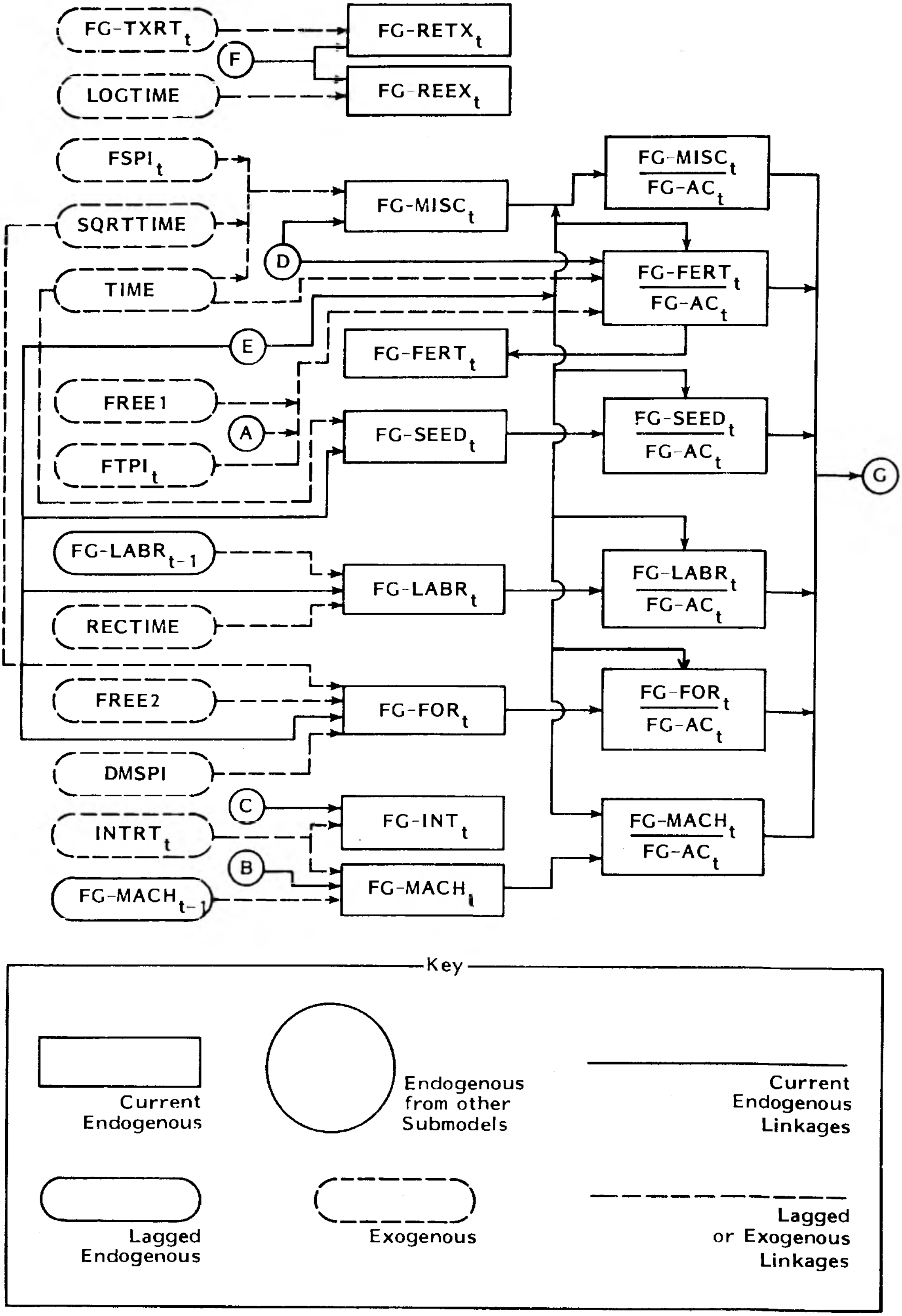


Figure 8. Schematic diagram of the feed grain input sector

expense (FG-MISC) is determined as a function of farm supplies price index (FSPI), the square root of time (SORTIME), time, and the stock of physical assets.

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

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

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

Feed grain output section

A schematic diagram of the feed grain output section is shown in Figure 9. The price received by farmers (FG-PR), feed grain commercial demand (FG-CDEM), and the gross income from feed grain production (FG-GINC) are determined by econometric equations, while production (FG-PRD), supply

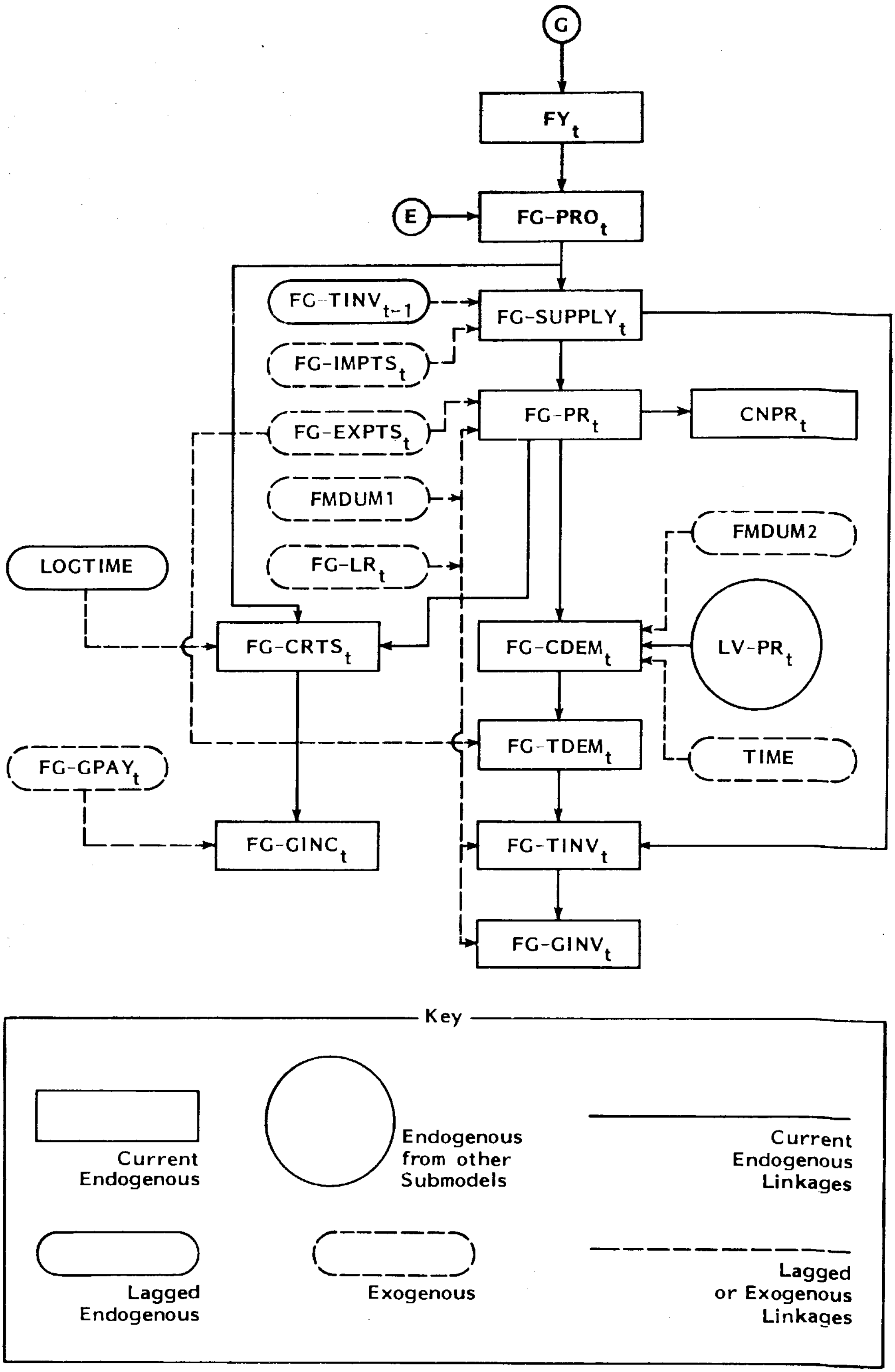


Figure 9. Schematic diagram of the feed grain output sector [English, Schatzer, Roberts, Heady, 1981]

(FG-SUPPLY), total noninventory demand (FG-TDEM), and end-of-year stocks (FG-TINV) are determined through identities. A yield per harvested acre is also determined from a production function which uses estimated elasticities of production for six inputs from the input section.

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

$$FY_t = FYB_t \cdot \quad 1.0 + \Sigma \quad E_i * \frac{I_{it} - B_{it}}{B_{it}} \tag{1}$$

where:

FY is the per harvested acre feed grain yield;

FYB_t is the BASE Run per harvested acre feed grain yield in year (t);

E_i is the elasticity of production of the ith input;

I_{it} is the predicted level of the ith input in year (t); and

B_{it} is the BASE Run level of the ith input in year (t).

The input elasticities of production are estimated from factor share data using methodology in [Tyner, Tweeten, 1965]. Per acre BASE input use and yields are obtained from a BASE run which projects crop yields. These crop yields and input quantities are then exogenous inputs into subsequent model alternatives. In these subsequent simulations, yields will vary about the BASE according to the above equation.

Harvested acreage is multiplied by feed grain yield to reflect annual production. Production, imports (FG-IMPTS), the beginning inventories are summed to derive total supply, which then is used to determine the feed grain price.

The recursive structure of the output section complies with the biological production process of most agricultural commodities. Price uncertainty exists at the time when farmers plant their crops. Thus, an expected price is used when making their planting decisions. At the estimated price level, the quantity supplied equals the total quantity demanded (total quantity demanded equals the sum of domestic requirements (FG-CDEM), exports (FG-EXPTS), and inventories (FG-TINV)). Domestic demand is estimated econometrically as a function of the current year's price, while exports are determined exogenously and ending inventories are determined using an identity equaling commercial demand plus exports, less supplies. The feed grain loan rate (FG-LR), and exogenous export levels are also required variables for price determination.

The feed grain commercial demand equation includes three variables--time, (TIME), livestock price (LV-PR), and a dummy variable reflecting the free market years of 1974 to 1976. The livestock price is an average price and allows the livestock sector to influence commercial demand.

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

Assumptions for the BASE Run

The BASE run provides a base for 1980-2000 with which the alternatives can be compared. It is made by setting the exogenous variables of the model equal to their most likely levels (time trend based on past data), for the 1980-2000 period and by modifying some of the coefficients of the statistically estimated equations. Exogenous variable projections are reported in Appendix A.

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

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

Adjustments of the BASE run for the energy alternatives analyzed

Table 14 shows the energy use categories which account for most of the energy consumption in U.S. agriculture. Crop production operations account for the largest segment of U.S. agricultural energy use. Of this amount, motor fuel for field operations, energy for production and delivery of fertilizer, and energy for irrigation are most energy intensive. Livestock production, on the other hand, is not highly energy intensive relative to crop production and accounts for only 11 percent of the energy used in agriculture.

Table 14. Energy use in U.S. agriculture, 1978

	Percent
Cropping uses (89 percent)	
1. Field operations	35
2. Crop drying	4
3. Irrigation	12
4. Fertilizer	34
5. Pesticides	3
6. Miscellaneous	3
Livestock uses (11 percent)	
Total uses (100 percent)	100 percent

SOURCE: [USDA, 1980].

Energy uses are accounted for in a number of ways, within the input section of the model. The fuel, oil and repairs (FOR) variable includes farm fuel, drying and irrigating costs[1] [Hoffman, 1980]. Fuel, oil and repairs (FOR) is affected by the motor supply price index (MSPI) which in turn is affected by fuel price changes, (an increase in the real diesel price of one dollar will raise the MPSI .9 points). Fertilizer is affected directly by the MPSI which is again affected by fuel prices [Roberts, 1980]. Pesticides are included in miscellaneous expenses (MISC) and are affected similarly. A schematic illustration is presented in Figure 10 for the feed grain sector and the specific equations are presented in Figure 10 for the feed grain sector and the specific equations are presented in Roberts and Heady, 1980.

[1]Effects of higher energy costs on irrigation has been studied in depth by Christensen, et al., 1981.

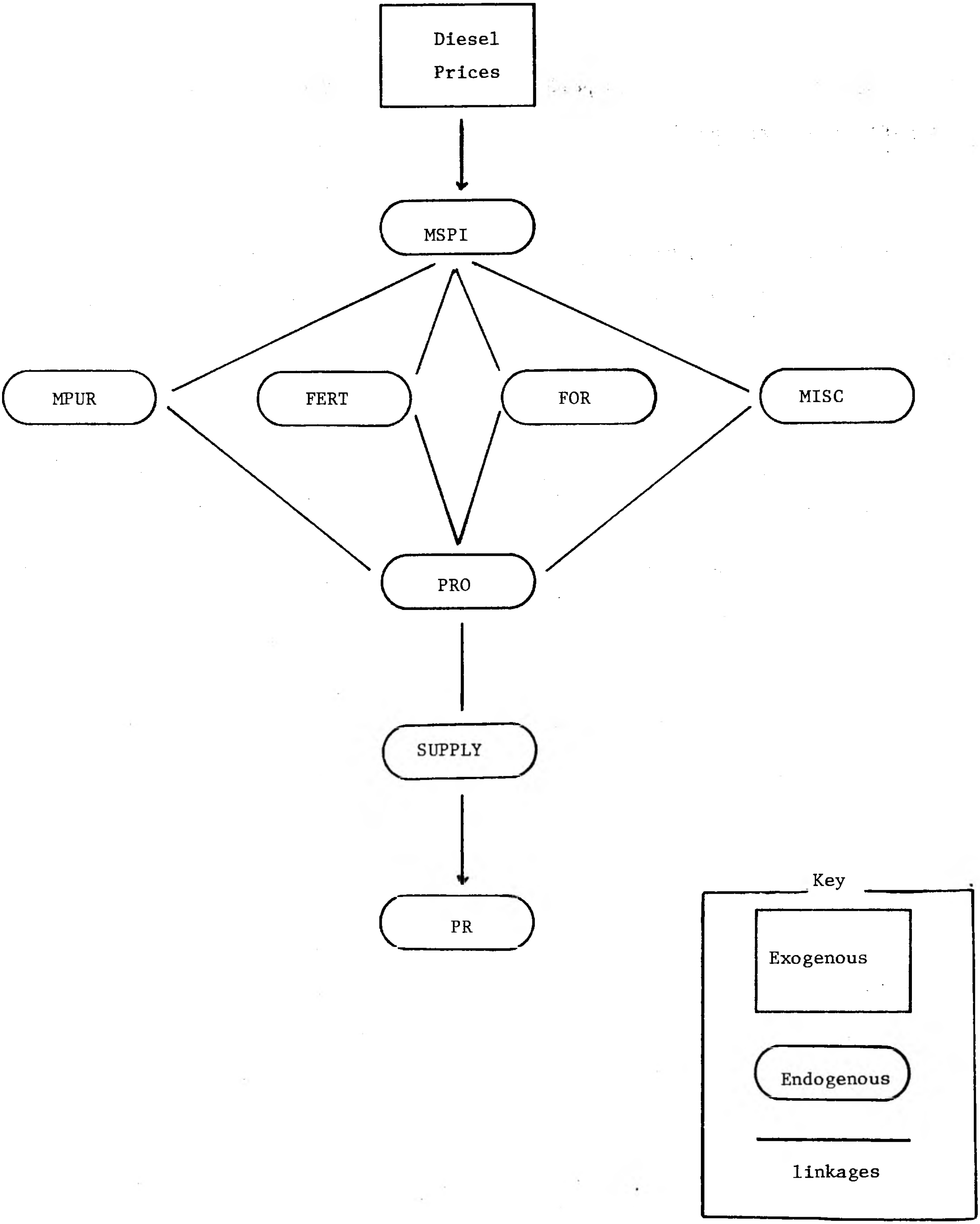


Figure 10. Schematic diagram of the cropping energy sector

The livestock sector's use of energy is reflected in the livestock fuel, oil and repairs (LV-FOR) which is affected by the MSPI and therefore fuel prices. A schematic for the livestock sector is presented in Figure 11.

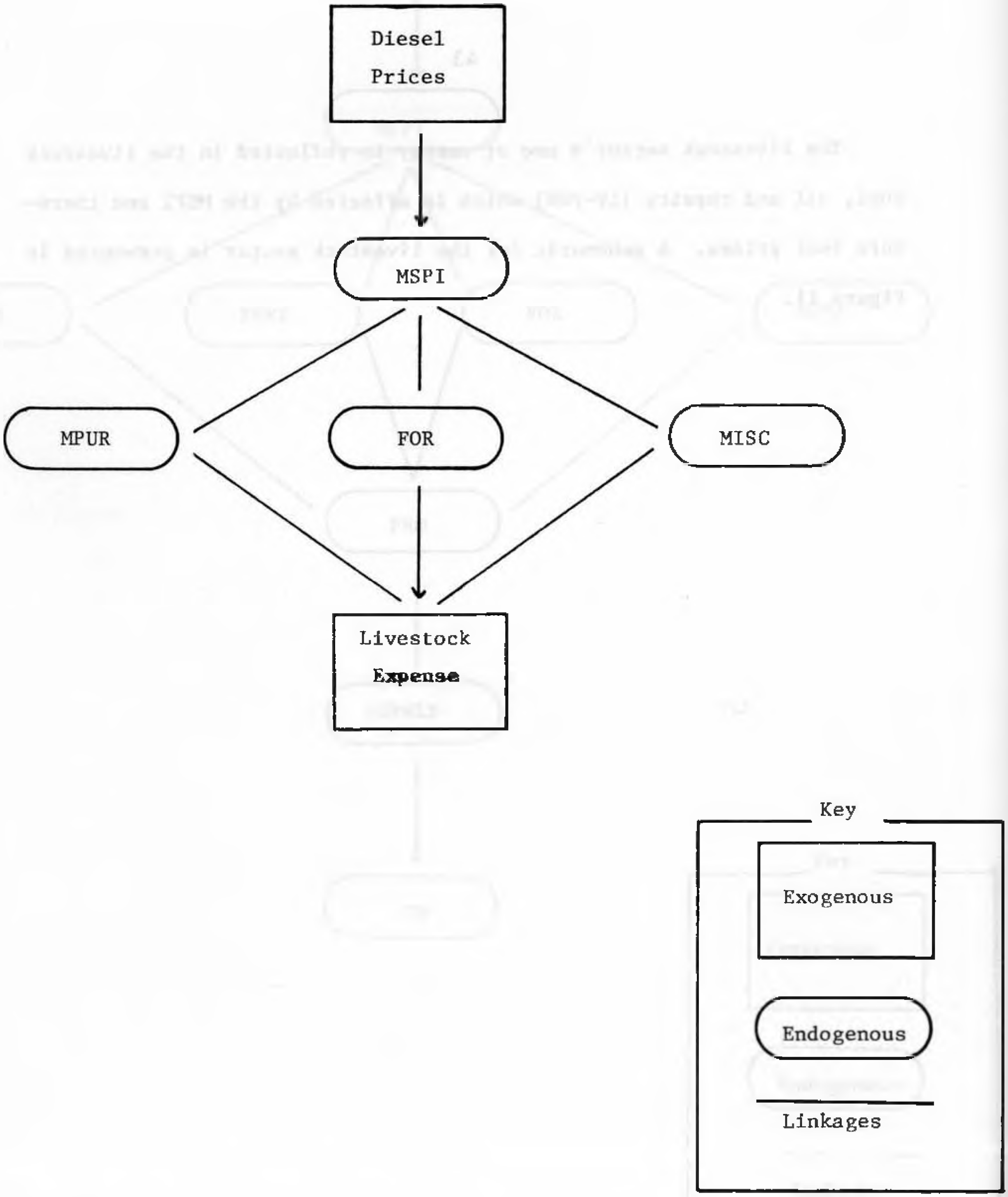


Figure 11. Schematic diagram of the livestock energy sector

III. ENERGY SCENARIO ALTERNATIVES

An assessment of the agricultural environment 10 or 20 years into the future is essential for intermediate and long-term planning by agriculturists. But, forecasting most situations so far into the future is difficult and a long-term forecast involving petroleum-based energy is hard to develop due to the illusive routines which our energy future can take. A forecast of our agricultural environment 20 years from now can be based on past and present relationships and trends. A scenario based on the past serves as a valuable benchmark from which we may better view our agricultural future and increase the value of the role we play in shaping that future. Going beyond the benchmark formulation, one could develop forecasts based on a parameterized energy outlook to give planners an opportunity to compare these results to the benchmark. Examples of alternative scenarios for comparison with a trended benchmark include such things as adjustments for energy technology, energy supply reduction and energy demand decreases through conservation. These alternative assumptions can be translated into alternative paths of petroleum prices to 2000.

In this study, we use five alternative paths of diesel fuel prices to the year 2000. They are:

Base (BASE)

Moderate with increased technology (MOD-T)

Moderate (MOD)

High with increased technology (HIGH-T)

High (HIGH)

These alternative energy alternatives are illustrated graphically in Figure 12. These alternatives are based on a synthesis of available literature as reported in the section entitled, "Survey of Energy Projections to 2000" on page 6. Included in the literature examined are a number of studies which project energy supplies, demands and prices to the year 2000. Other studies examine possible technological advances which would facilitate the use of alternative energy sources.

The basic guidelines for the five alternatives chosen were obtained from the gasoline price projections shown in Figure 5 and described in the corresponding text. It should be noted the BASE alternative in this study goes below those projections in Figure 5 and the HIGH alternative extends above them. Thus, the diesel fuel price alternatives in this study include, in their range, all the previous gasoline price projections examined in the literature search.

Base (BASE)

This alternative serves as a benchmark scenario for the study. In it we assume that diesel fuel prices remain constant in real terms at the 1980 level of one dollar per gallon to 2000. Although this alternative is very optimistic, and hence a bit unrealistic, it is valuable for purposes of comparison with other scenarios. It is helpful to view this BASE alternative as a scenario which includes little drastic change in energy variables of the agricultural sector.

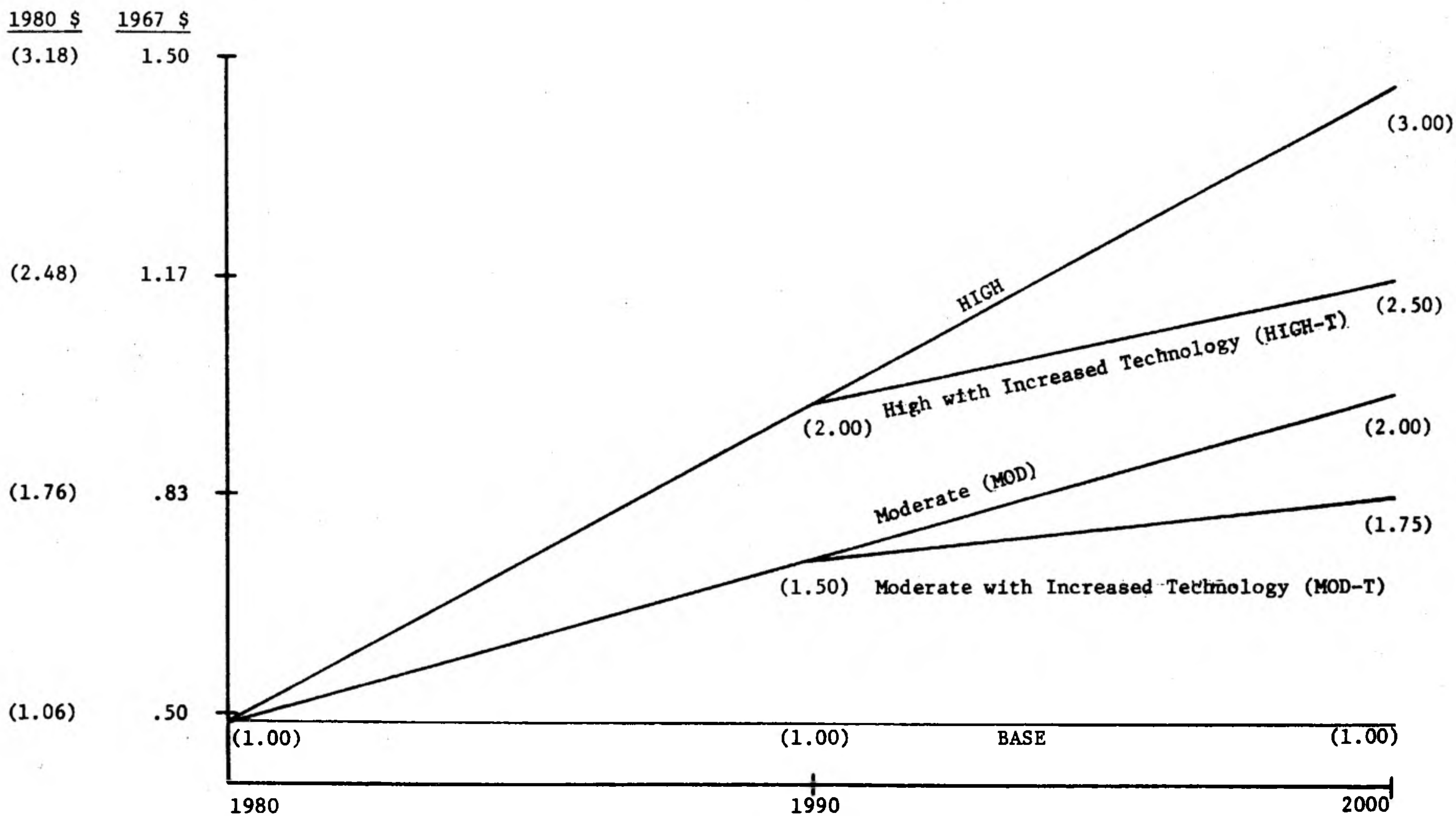


Figure 12. Five diesel fuel price alternatives to the year 2000 in 1967 and (1980) dollars

Moderate With Increased Technology (MOD-T)

This alternative is made up of two linear trends in real diesel prices; one from 1980-1990 and one from 1990-2000. The first trend is an approximated average of the gasoline price projections to 1990 in Figure 12. This trend increases the real price of diesel fuel in 1990 by 50 percent and is a less optimistic view of the U.S. energy future than that of the BASE alternative. The absolute change in real fuel price in this 10-year trend can be viewed similarly to the historical increase from 1968-1978 where real prices also increased 50 percent.

The second linear trend for 1990-2000 in this alternative portrays a smaller increase in diesel fuel prices than the 1980-1990 trend. This linear section supposes the movement from nonrenewable energy sources to alternatives ones including synthetics, solar and biomass. Most studies indicate that little substitution to alternative fuels will be accomplished before 1990, but most studies estimate a significant move in this direction by 2000. As alternative fuels are developed and used, expensive imports are expected to decrease, lowering the real price paid for petroleum products.

Moderate (MOD)

This alternative increases real diesel fuel prices at the same rate as the 1980-1990 trend of MOD-T, and extends this trend to 2000. In this scenario, no assumptions about alternative fuel sources are made and fuel prices are doubled in real terms by the year 2000.

High With Increased Technology (HIGH-T)

This alternative contains two trends of diesel fuel prices; one each for 1980-1990 and 1990-2000. The first trend is 10 percent higher than the highest gasoline price projections to 1990 in Figure 12. This trend doubles the real price of diesel fuel by 1990 and can be compared to the 1979-1980 rate increases.

The second segment of this alternative (1990-2000), portrays a smaller increase in diesel fuel price than the 1980-1990 trend. This again reflects the movement to alternative fuels in the last decade of this century.

High (HIGH)

This alternative is the most pessimistic of the five and triples real diesel fuel prices linearly to 2000. An increase in prices at this rate could be caused by supply shocks such as embargoes and other intermediate or long-term import interruptions such as cessation of supply sources on a political or other basis. The switch from dollars to some other form of currency as a medium for the exchange for oil could also have such negative effects, in an environment in which the value of the dollar is falling. This fifth alternative is 10 percent above the highest gasoline projections to 2000 by previous studies in Figure 12.

In summary, this study presumes five alternative energy environments to the year 2000. Chosen on the basis of previous information and projections, these alternatives effectively bound past predictions in order to provide a wide range of coverage. The five alternatives include

BASE, Moderate (MOD) and High alternatives which linearly trend real diesel prices equal to 1980 levels, two times 1980 levels and three times 1980 levels, respectively, to 2000. Two additional alternatives, Moderate With Increased Technology (MOD-T) and High Increased Technology (HIGH-T), follow Moderate and High alternative trends, respectively, to 1990. Both upward trends are then slowed from 1990-2000 to simulate the increased substitution of alternative fuel sources (solar, synthetics, biomass) for petroleum based fuels.

An additional scenario, the Low Export Scenario, is developed to simulate a reduction in the ability of other countries to purchase U.S. farm commodities as energy prices rise. This scenario makes use of the MOD-T, MOD, HIGH-T, and HIGH energy alternatives but also restricts 1986-2000 crop exports to the 1985 level. The results of this scenario can be found in Chapter IX.

As a final note, one should realize that a reasonable parameterization of trends in real diesel prices was the objective in picking alternatives for use in this study. It was not possible to arbitrarily pick the exact path of prices or export levels to 2000. For use in explaining rising petroleum price effects on U.S. agriculture, this range of linearly trended pricing alternatives within two export scenarios will serve to include most predicted paths that fuel prices could take. As time goes on, the exact shape of the true diesel fuel pricing path will emerge. If the choice of alternatives was successful, the true path of prices will begin to emerge somewhere within this range. Thus, the study's results will serve as an extrapolated guide to the future of U.S. agriculture.

V. PRE-INPUT SECTOR RESULTS

This section includes an analysis of the BASE and four increased energy price alternatives with regard to pre-input variables. These variables include farmland use, irrigation, land price, and machinery purchases (crops and livestock). In this sector, livestock production is aggregated and will not be reported by individual animal unit. Crop production is disaggregated, however, into tobacco, feed grains, wheat, soybeans, and cotton with major reporting emphasis on the latter four crops.

In each commodity sector, the dependent variables are functions of exogenous variables, predetermined variables and endogenous variables that have been treated as dependent variables earlier in the pre-input section.

Agricultural Land Use and Irrigation

BASE alternative (real petroleum prices are held constant at 1980 levels to 2000)

The trends in harvested acres of the four major crops (feed grains, wheat, soybeans, and cotton) have historically been affected by relative commodity prices and government programs. These variables were significant in the model and affect the BASE projection accordingly through the year 2000. Table 15 contains the predicted harvested acreage for the endogenous crops at two year averages to 1986 and five-year averages thereafter to 2000 for the BASE run. Historically, harvested corn acreage has

Table 15. Estimated U.S. crop harvested acreage for five alternatives

Year	Alternative				
	BASE	MOD-T	MOD	HIGH-T	HIGH
	- - - - - Feed grains (million acres)- - - - -				
1981-1982	97.89	97.93	97.93	97.98	97.98
1983-1984	97.56	97.73	97.73	97.93	97.93
1985-1986	97.43	97.68	97.68	98.97	97.97
1986-1990	96.58	97.03	97.03	97.44	97.44
1991-1995	94.54	95.15	95.61	97.31	97.40
1996-2000	93.25	95.12	95.59	97.82	98.32
	- - - - - - Wheat (million acres) - - - - - -				
1981-1982	59.36	59.37	59.37	59.39	59.39
1983-1984	59.93	60.04	60.04	60.16	60.16
1985-1986	59.71	59.97	59.97	60.28	60.28
1986-1990	58.68	59.24	59.24	59.77	59.77
1991-1996	56.92	57.80	57.88	58.00	57.84
1996-2000	55.74	57.09	57.10	57.89	57.26
	- - - - - - Soybeans (million acres) - - - - -				
1981-1982	65.43	65.62	65.62	65.61	65.61
1983-1984	67.64	67.60	67.60	67.55	67.55
1985-1986	69.62	69.56	69.56	69.49	69.49
1986-1990	72.34	72.27	72.27	72.23	72.23
1991-1995	77.80	77.90	77.82	77.87	77.91
1996-2000	83.07	83.12	83.11	82.92	82.94
	- - - - - - -Cotton (million acres)- - - - - -				
1981-1982	13.13	13.13	13.13	13.12	13.12
1983-1984	12.84	12.81	12.81	12.77	12.77
1985-1986	12.85	12.77	12.77	12.67	12.67
1986-1990	13.06	12.90	12.90	12.71	12.71
1991-1995	13.42	13.14	13.05	12.66	12.63
1996-2000	13.66	13.17	12.99	12.20	12.30

increased over time but sorghum, oats, and barley acreages have decreased faster over time. Thus, the agricultural sector has experienced a decrease in total feed grain acres harvested. This historical fall in acreage, and also the predicted decrease (Table 15) is due to relatively low feed grain prices as compared to soybean prices. It is estimated that a 10 percent increase in the soybean/feed grain price ratio results in a 1.1 percent decrease in the harvested acreage of feed grains [Schatzer, Roberts, Heady, Gunjal, 1980].

Wheat acreages are also predicted to fall. This is because of relatively lower wheat prices historically compared to other commodities, especially soybeans. The negative effects on harvested acreage due to an increase in the soybean price are even higher for wheat than for feed grains [Schatzer, Roberts, Heady, Gunjal]. Government programs have also influenced wheat and feed grain acreage. Programs such as acreage diversion, acreage allotments and the soil bank reserve tend to give incentives for harvested acreage reductions.

Soybean acres, on the other hand, are expected to increase by 6 percent in 1985 and by over 10 percent by 1990. This is due to the relatively high prices paid historically for soybeans and the continuously growing market for them.

Irrigated acreage is influenced by machinery stocks and total acreage in this model. Given these variables, the model predicts an increase in acres irrigated of 15 percent by 2000 in the BASE run, Table 16. Although the actual numbers predicted for the endogenous crops are low compared to other estimates, the trend is comparable. The added irrigated

Table 16. Irrigated acres of endogenous crops to the year 2000 for five alternatives (million acres)

Year	BASE	MOD-T	MOD	HIGH-T	HIGH
1981-1982	14.3	14.2	14.2	14.1	14.1
1983-1984	14.4	14.0	14.0	13.7	13.7
1985-1986	14.7	14.1	14.1	13.4	13.4
1986-1990	15.0	14.0	14.0	13.1	13.1
1991-1995	15.6	14.1	14.0	13.4	13.2
1996-2000	16.5	15.0	14.7	14.4	14.0

land comes from new land developed and not as a favorable consequence of higher energy prices. The higher energy prices are expected to limit irrigation acreage. One might expect that an economically justified variable in the irrigation equation would be the cost of fuel for pumping water. This variable was used initially but was statistically insignificant in explaining the dependent variable. This is due to the fact that the real price for fuel, except for two or three jumps, has been relatively constant while irrigated acres have risen steadily over the sample period.

Increased petroleum price alternatives

Table 15 displays the harvested acre forecasts for various crops under alternatives which depict increasing costs of petroleum-based products. The MOD-T, MOD, HIGH-T and HIGH alternatives assume trends in real petroleum prices that increase the BASE price by 1.75, 2.0, 2.5, and 3.0 times, respectively, by the year 2000. For the purposes of this report, these alternatives serve as a continuum of energy price trends between current energy price levels and a trend which triples present levels by the year

2000. The results, therefore, also will generally be a continuum. The results for the MOD and MOD-T alternatives will be exactly the same to 1990 as will the HIGH and HIGH-T alternatives. This is consistent with the definitions of the alternatives which state that the high technology trends, (MOD-T and HIGH-T), will not be realized until after 1990.

When comparing the higher energy price alternatives to the BASE alternative (Table 15), feed grain and wheat harvested acreages show an increase as petroleum prices rise. In fact, the downward trends seen in the BASE run are slowed to the extent that these acreages actually remain fairly constant through time for feed grain and wheat in the HIGH alternative. Soybean acreage for the HIGH alternative remains much like the BASE and cotton acreages actually decrease as prices for petroleum rise. The changes in harvested acres for each crop from the BASE to consecutively higher petroleum price alternatives is a direct result of commodity price changes. As energy prices rise, feed grain and wheat prices rise relatively more than the other crops when comparing across alternatives. Price changes are explained in a later section.

Table 16 also shows the model's predictions of irrigated acres for endogenous crops to 2000. In general, the increasing trend of irrigated acres in the BASE run is neutralized as petroleum prices rise in the MOD-T and MOD runs, and reversed as prices continue to rise in the HIGH-T and HIGH alternatives. Although higher fuel prices do not enter directly into the irrigated acreage equation, they do negatively affect machinery stocks and costs which in turn decrease irrigation.

Land Prices

BASE alternative

Two variables included in the model have large positive effects on the price of land. Farm size is one important variable because as farms become more capital intensive, efficient use of this capital is obtained by buying more land. The second explanatory variable is the value of production of a crop divided by acres harvested of that same crop. As this value of crop production per acre rises, one expects the value of the land also to rise.

Figure 13 illustrates how agricultural land prices are expected to rise over time in the BASE alternative. Since farm size (Table 17) and productivity per acre are projected to increase, the upward response in land prices is economically consistent.

Table 17. Predicted U.S. farm size and number of farms in the BASE alternative to 2000

Year	Farm size (acres/farm)	Number of farms (millions)
1981-1982	414.9	2.5 [2.5][a]
1983-1984	423.3	2.5
1985-1986	431.5	2.4 [2.4][a]
1986-1990	441.4	2.4 [2.3][a]
1991-1995	460.1	2.2 [2.2][a]
1996-2000	477.4	2.1 [2.1][a]

[a]Figures in brackets are trend projections by the National Economics Division of the ESCS, USDA in Technical Bulletin No. 1625 [USDA, 1980].

Increased petroleum price alternatives

As energy prices rise, the value of production per harvested acre increases. The reason for this effect is illustrated in the results

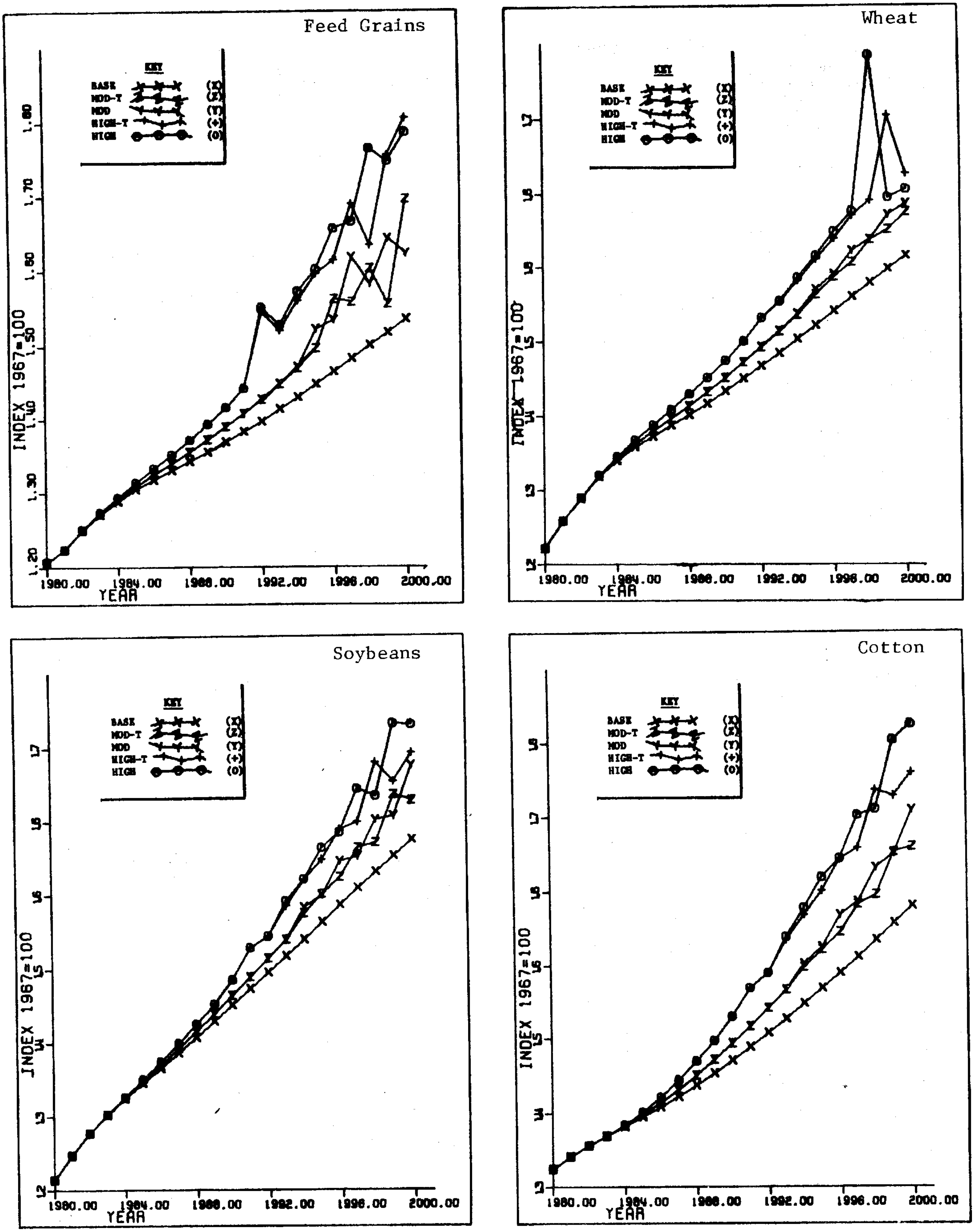


Figure 13. Predicted land price index of four crops for five alternatives to 2000

chapter for the financial sector, Chapter XIII. But for now, the increase in that ratio has a direct positive effect on land prices. Figure 13 shows that land prices are indeed increased as petroleum prices rise. (Farm size is assumed unaffected by energy price increases in the model so therefore has nothing to do with land price index variations from the BASE run.)

The land price variations between crops is due to different production values per acre for different crops. The crop with the highest production value per acre is cotton followed by soybeans, wheat, feed grains, and tobacco.

Machinery Purchases

Base alternative

The amount of machinery purchased by farmers depends on a number of economic variables including price of the machinery (negative affect), cost of maintaining and operating that machinery (negative affect), and the prices farmers receive for their products, (positive affect). Other variables which are statistically significant include harvested acres (with a positive sign), a dummy variable for the Vietnam War years (1968-1971) when machinery availability was decreased (negative sign), and the government diverted acreage programs which also negatively affect machinery purchases.

Table 18 illustrates the BASE alternative predictions of machinery purchases for various crops and livestock. Purchases of machinery for feed grain and wheat production is not predicted to change much over time. But, cotton, soybean, and livestock producers are predicted to

Table 18. BASE run estimated crop and livestock machinery purchases by U.S. farms in constant millions of dollars

Year	Feed grains	Wheat	Soybeans	Cotton	Livestock
1981-1982	2,334	586	1,556	227	272
1983-1984	2,423	602	1,622	220	351
1985-1986	2,459	613	1,655	222	393
1986-1990	2,426	596	1,710	229	404
1991-1995	2,391	570	1,861	245	414
1996-2000	2,456	576	2,054	257	427

invest in new machinery at an increasing rate as time goes on. In fact, the value of machinery purchased by the soybean sector alone will begin to approach the projected level for feed grains in 20 years. The reasons for the large projected increase in soybean machinery purchases relative to other crops' machinery purchases are its price and acres harvested. With relatively high prices for soybeans, farmers are induced to invest in equipment which will increase their efficiency in producing soybeans. And, when farmers expand the amount of soybeans they plant, more and more machinery is needed to do so.

Increased petroleum price alternatives

As the price of petroleum rises, the cost of operating machinery also rises. Likewise, the relative price of machinery may rise as petroleum derived parts become more costly to build. This combination of effects is projected to put downward pressure on machinery purchases by all crops and livestock, thus reducing machinery stocks in the future. On the average, total machinery purchases are predicted to fall 10, 15, 23, and 30 percent by 1995 under the MOD-T, MOD, HIGH-T, and HIGH alternatives, respectively. But, it is very important to consider that individual farm size is predicted to increase by over 15 percent in the next 20 years. Therefore, machinery purchases per farm will not necessarily be so drastically affected by higher petroleum prices as seen in Figure 14. Granted, the negative effect of higher energy prices on machinery purchases per farm is substantial, (as seen by the deviations from the BASE run in Figure 14), yet the only actual decrease over time in machinery purchases per farm occurs under the two highest petroleum price alternatives, HIGH-T and HIGH. Another interesting result is illustrated with machinery purchases per farm in Figure 14 in the early 1990s. The downward trend in machinery purchases in the 80s actually reverses and purchases per farm began increasing from 1990 for the four increased petroleum price alternatives. This increase continues through 2000 for the four alternatives and surpasses the 1980 level in all but the HIGH alternatives. The explanation for this trend reversal comes from two strong but opposite "forces" at work in this scenario. The first is the increasing cost of petroleum products which show a downward effect on machinery purchases. The other force is the price farmers receive for their commodities. This force has a positive effect on machinery purchases. As evident in Figure 14, the increasing cost of petroleum will dominate the struggle and force machinery purchases to remain relatively constant, (MOD-T and MOD), or actually decrease, (HIGH-T and HIGH) through the 80s. But, as this report explains later, increases in petroleum costs will actually increase the prices paid for farm commodities because food demand is inelastic. These commodity price

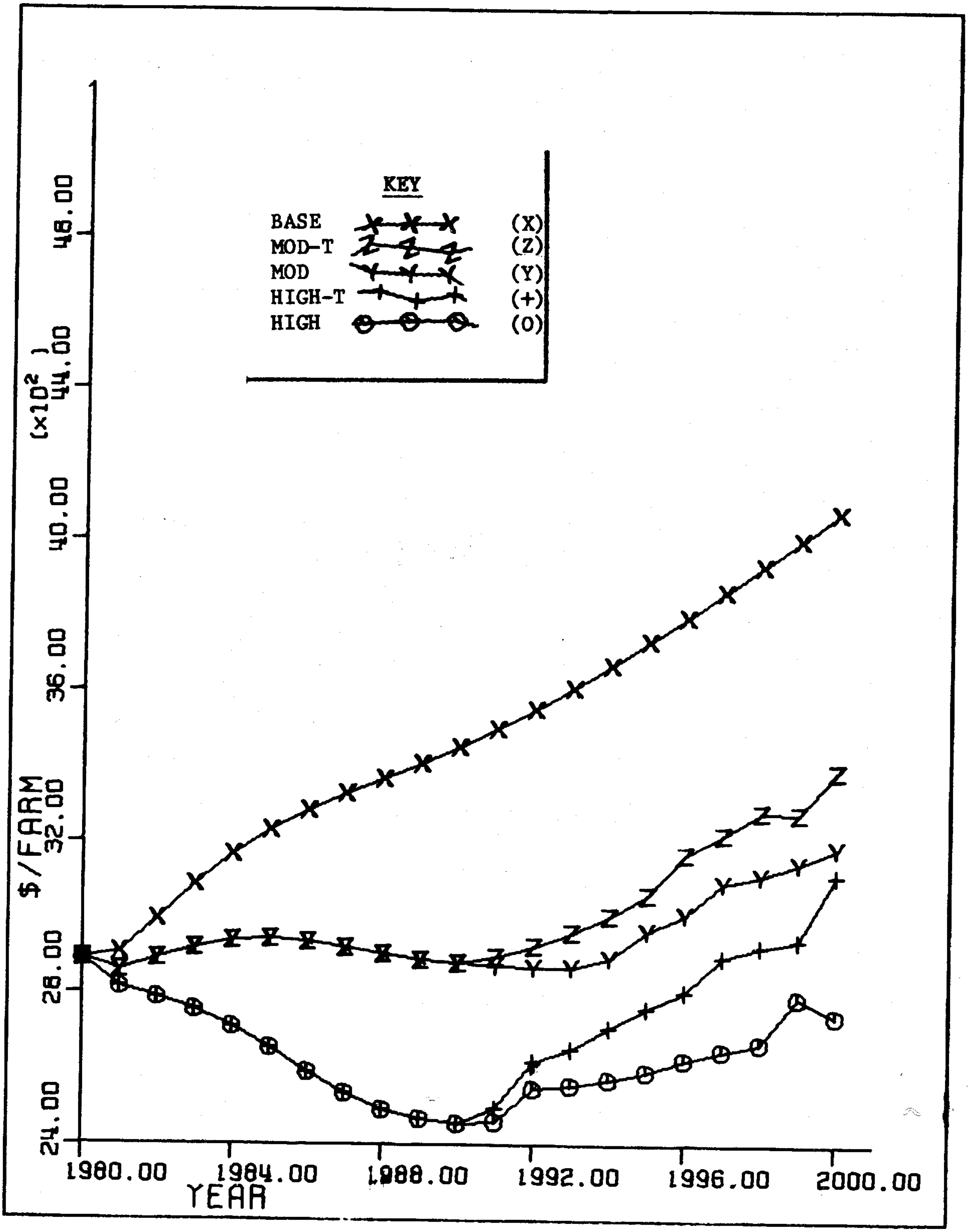


Figure 14. Machinery purchases per farm under 5 petroleum price alternatives to 2000

increases and resulting income changes could begin to positively offset the decreasing machinery purchases and work to reserve the trend from about 1990 on. In summary, deviations from the BASE run are steady or increasing to 1990, then decreasing due to commodity price stimiulated machinery investment to the year 2000.

V. INPUT SECTOR RESULTS

The inputs from the model reported in this section include fuel, oil and repair expenses (crops and livestock), fertilizer use, labor (crops and livestock) and miscellaneous expenses (including pesticide expense). Livestock production is aggregated and crop production disaggregated by crop in this sector as it was in the input sector.

Fuel, Oil and Repair Expenses (FOR)

BASE alternative

This set of inputs includes expenses for machinery repairs and products to maintain and operate farm machinery. Also included is irrigation machinery repairs and the fuel to operate the irrigation equipment. In the estimation of this expenditure for each commodity, the motor supply price index (MSPI), harvested acres and machinery stock are proxies for the price of fuel and repairs, the number of acres farmed and the number of machines used, respectively in the United States. The variables for harvested acreage and machinery stock, as expected, carry positive signs in each FOR equation while the MSPI has a negative sign.

The model predicts a continuous increase in aggregate FOR to 2000 as shown in Table 19. This can be explained by examining the data from which the equations were estimated. During the sample period, harvested acreages decreased slowly and machinery stocks increased as U.S. agriculture expanded. For the same period, relatively little increase was seen in

Table 19. Fuel, oil and repair expenses for five alternatives to 2000 (constant million dollars)

Year	Base	MOD-T	MOD	HIGH-T	HIGH
1981-1982	7,389	7,315	7,315	7,241	7,241
1983-1984	7,422	7,330	7,330	72,39	7,239
1985-1986	7,471	7,356	7,356	7,243	7,243
1986-1990	7,522	7,379	7,379	7,249	7,249
1991-1995	7,624	7,471	7,432	7,384	7,303
1996-2000	7,746	7,591	7,533	7,513	7.409

the MSPI until the last decade. Therefore a projection based on this data should no doubt perform accordingly for a base run.

Increased petroleum price alternatives

As energy prices rise, not only does the MSPI rise, but machinery stocks fall, as reported in the previous chapter. These combined effects decrease expenditures on fuel, oil, and repairs as petroleum prices rise when compared to the BASE. In fact, under the HIGH alternative, FOR remains virtually constant to 1990 with only a 2 percent increase to 2000.

Fertilizer

BASE alternative

In 1977, almost one quad of energy was used by U.S. farmers in the indirect form of fertilizers. The energy invested in fertilizers far exceeds that used in any single direct farm production operation as seen in Figure 15 [USDA, 1978].

Fertilizer demands were estimated for each crop in the model using a number of independent variables including the fertilizer price index (FTPI); lagged cash receipts, (an estimate of the ability of farmers to

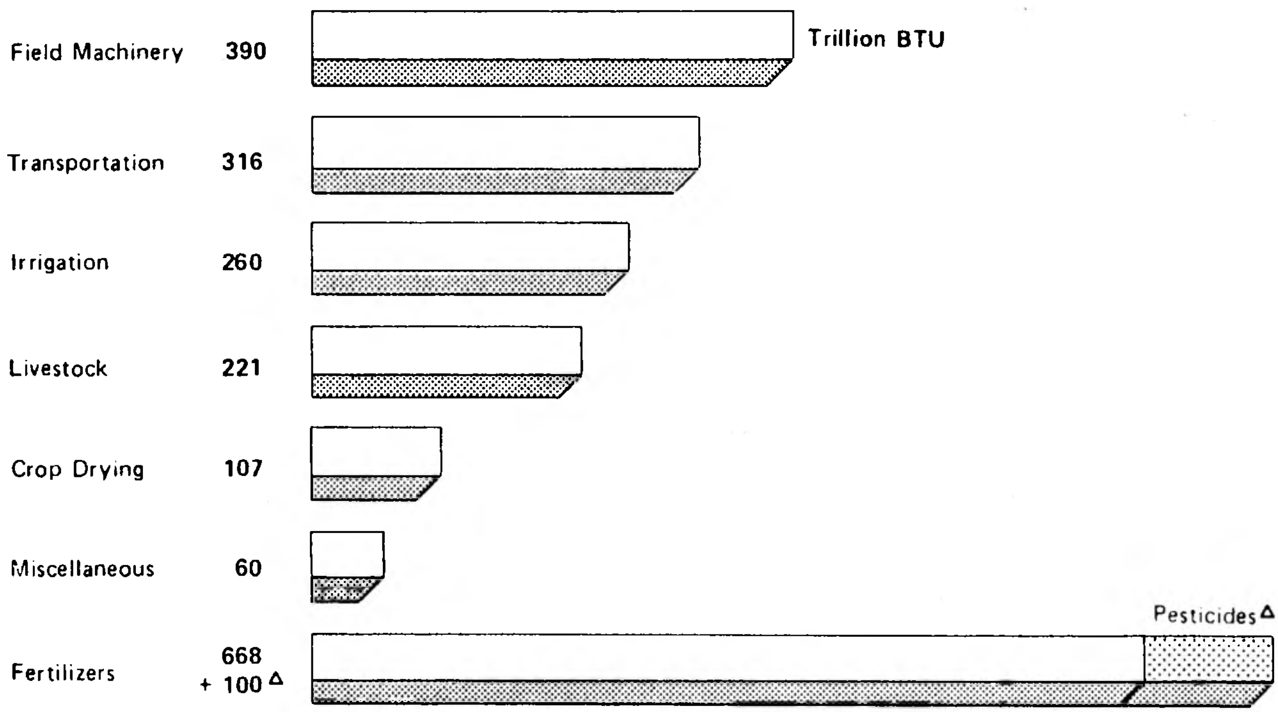


Figure 15. 1977 energy use on farm by operation [USDA, 1980]

purchase inputs); the stock of physical assets (an estimate of farmers' ability to borrow money to purchase inputs); the motor supply price index (MSPI) (used to reflect the correlation between higher fuel prices and higher fertilizer prices); and commodity prices. These explanatory variables and the resulting signs of these variables seem consistent with economic theory and other fertilizer demand studies including those by Heady, Yeh, 1959, Heady, Tweeten, 1967, and Roberts, Heady, 1979.

Our model in the BASE run predicts a consistently rising investment in fertilizer by farmers to 2000 as shown in Table 20. In the BASE run, expenses for fertilizer and lime increase 10 percent by 1990 and 30 percent by 2000. One explanation for this prediction is the general historically downward trend in the real price of fertilizer. In 1972, the real price

Table 20. Fertilizer and lime expense for the BASE alternative to 2000 (constant million dollars)

Year	Base	Year	Base
1981-1982	6,274	1986-1990	6,938
1983-1984	6,518	1991-1995	7,439
1985-1986	6,722	1996-2000	8,115

of fertilizer was 60 percent of the price in 1955. After a jump in price from 1973-1975 the price of fertilizer settled to about 90 percent of the price in 1955. Therefore, since the relative price of fertilizer has remained low for the last two decades, it is not surprising that the model predicts increasing fertilizer usage to 2000. A graphical representation of the BASE fertilizer use prediction can be found in Figure 16 and 17 for feed grains and soybeans.

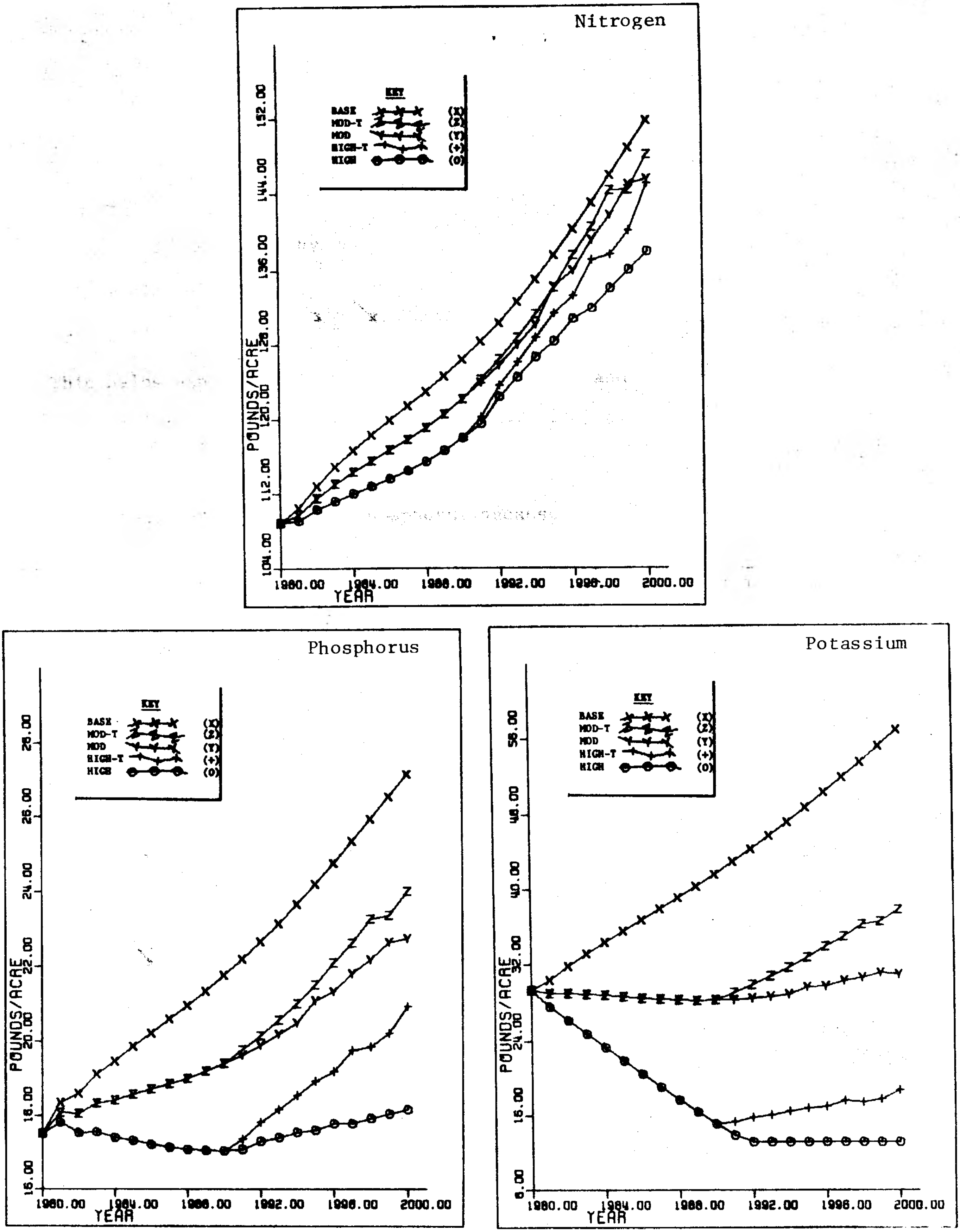


Figure 16. Predicted nutrient usage for feed grain by specific fertilizer for five alternatives to 2000

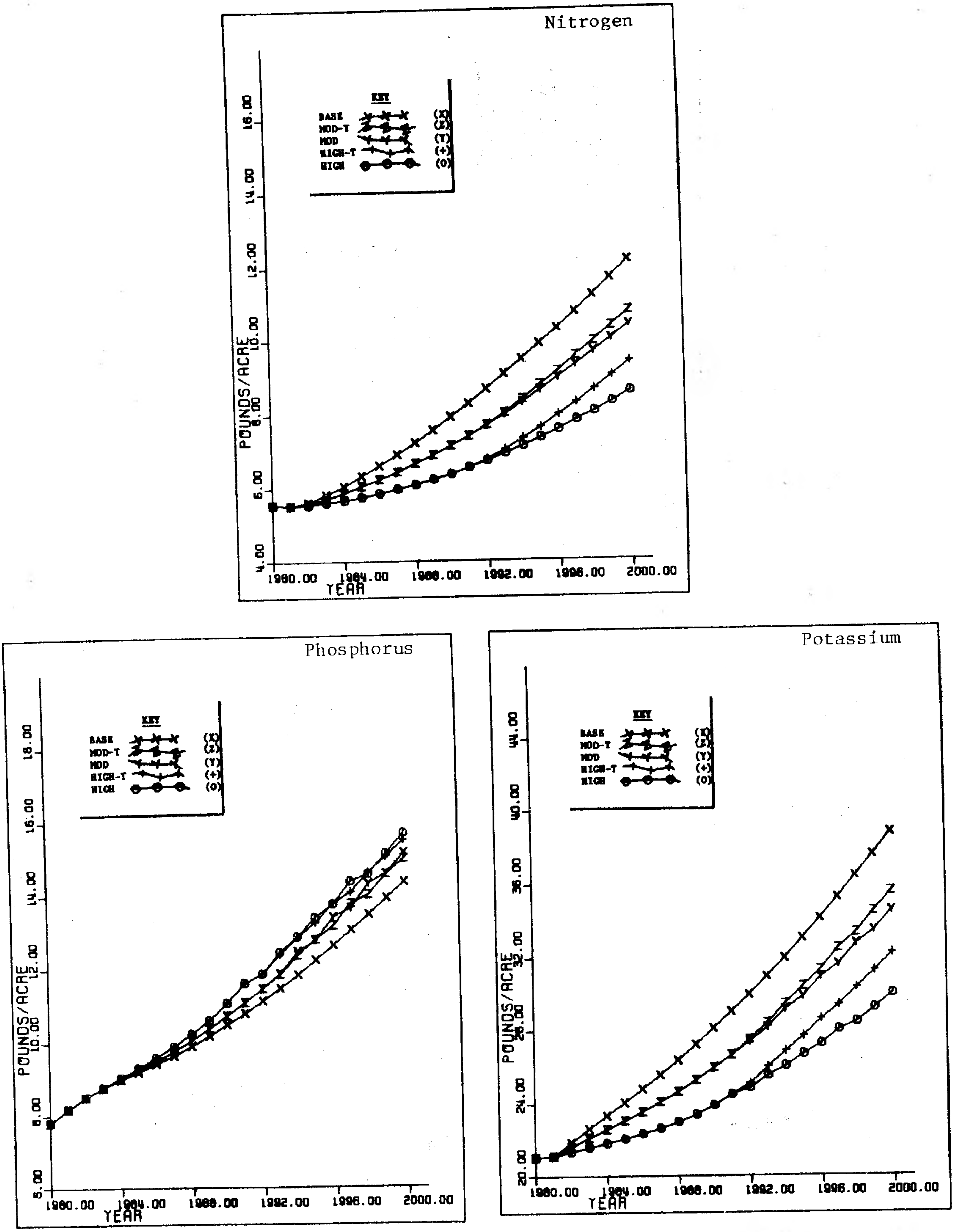
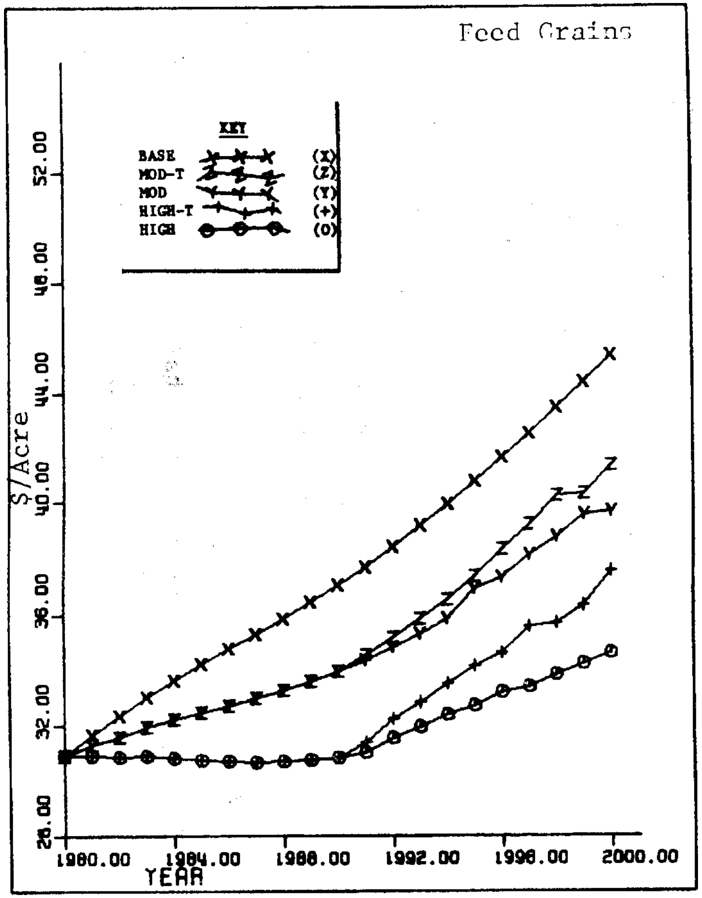


Figure 17. Predicted nutrient usage for soybeans by specific fertilizer for five alternatives to 2000

Increased petroleum price alternatives

Figure 18 illustrates the decrease in fertilizer and lime expense for feed grains and soybeans as petroleum prices rise. (Lime application is assumed uneffected by changes in energy prices in the model.) The estimated cross-price elasticities of demand for N, P and K per harvested acre of corn with respect to the MSPI are -.753, -1.064, -3.058, respectively. This helps explain the varying response of N, P and K usage in feed grains to a rise in energy prices shown in Figure 18. The downward response in potassium use for higher petroleum price alternatives is larger, percentage-wise, than the decrease in phosphorus because potassium use is more responsive to energy changes. Both are larger than the decrease in nitrogen usage because nitrogen is least responsive to a change in the MSPI. The estimated elasticities of demand for N, P and K per harvested acre of soybeans with respect to the MPSI are generally less (in absolute value) than the corn elasticity estimates. Since soybeans do not rely as heavily on fertilizers as do feed grains, their cutback response to increased energy prices would not likely be as pronounced.

Figure 18 illustrates the effects of increased energy prices on total fertilizer and lime expense for feed grains and soybeans. Comparison of these two graphs highlight the differing dependence of feed grains and soybeans on applied fertilizers. Soybean fertilizer purchases are reduced but slightly as petroleum prices rise. The purchase of fertilizer for feed grain production, on the other hand, is reduced more significantly, especially under the HIGH alternative. The actual percentage reductions from the BASE run are summarized in Table 21.



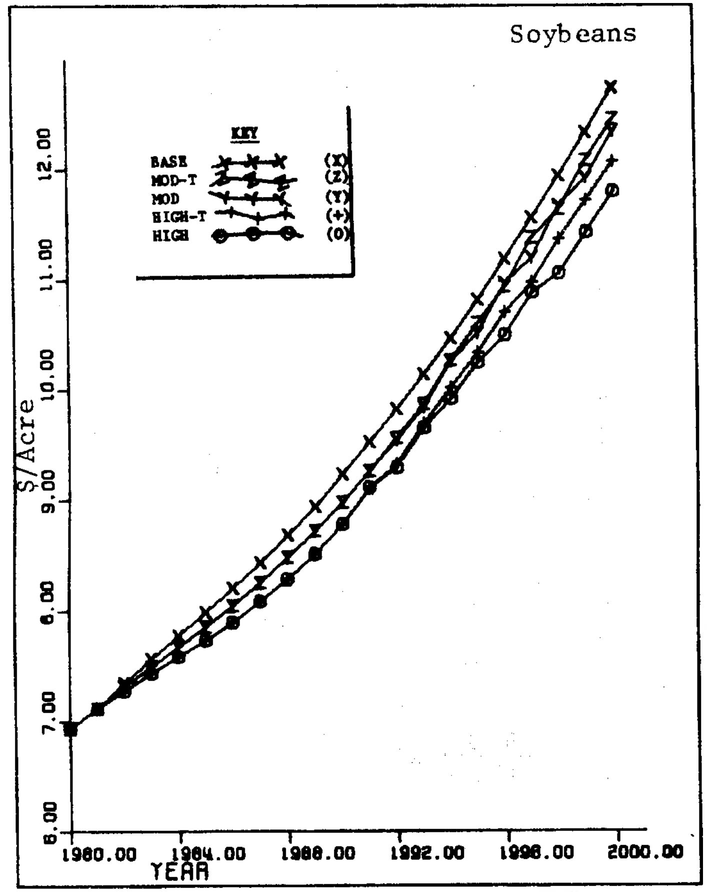


Figure 18. Predicted fertilizer and lime expense per acre for two crops under five alternatives to 2000

Table 21. Percentage reduction in fertilizer use from the BASE for four energy price alternatives in 2000

Fertilizer	MOD-T		MOD		HIGH-T		HIGH	
	Feed grains	Soybeans	Feed grains	Soybeans	Feed grains	Soybeans	Feed grains	Soybeans
	-percentage-							
Nitrogen	- 2	- 8	- 3	-12	- 5	-25	- 9	-29
Phosphorus	-11	- 2	-15	- 3	-22	- 5	-33	- 8
Potassium	-32	-10	-46	-13	-70	-18	-73	-23
Total fertilizer	- 7	- 2	-11	- 2	-17	- 4	-22	- 6
Total fertilizer (All crops)	-5		-7		-10		-14	

For feed gains, nitrogen fertilizer makes up a large portion of the total fertilizer requirement and its usage is not drastically reduced as petroleum prices rise. Therefore, even though potassium and phosphorus usage is cut back significantly by increased petroleum prices, total fertilizer usage in feed grains is not drastically reduced. The use of fertilizer in soybean production is affected even less by increasing energy prices. On the average, total fertilizer use by all crops in the model is reduced by less than 15 percent from the BASE run under the HIGH energy alternative, and reduced as little as 5 percent from the BASE run under the MOD-T alternative. These relatively small decreases in fertilizer use seem consistent with other predictions including one by Heady, 1980 to a Resource for a future seminar where he states "While fertilizer and chemical prices began to rise sharply in 1980, I do not expect a large slash in their use. Farmers will still buy them but use them more carefully."

Labor

BASE alternative

The long-term substitution of capital for labor is predicted to continue to 2000 in the BASE solution (Table 22). The variables which determine the labor prediction in the model include harvested acres with a positive effect on labor use, a time trend, and machinery stocks both with negative effects. The model contains labor equations for four crops and livestock although Table 22 reports this information as an aggregate for all production activities.

Table 22. Labor use on U.S. farms for the BASE alternative to 2000

Year	Labor (million man-hours)	Year	Labor (million man-hours)
1981-1982	4,584.8	1986-1990	4,486.3
1983-1984	4,560.9	1991-1995	4,342.5
1985-1986	4,540.0	1996-2000	4,238.7

Because farm numbers are predicted to fall in the future, the labor usage per farm is predicted to rise in the BASE solution by about 10 percent in 2000, Figure 19. Yet, even though labor use per farm may increase, overall historical trends in total labor usage reduction will continue on into the future.

It is interesting to investigate the projected trend in hired labor, that is, human capital not supplied by the farm household. The hired labor equation in this model relies on machinery stocks and a lagged labor variable to explain and forecast hired labor expense to 2000. The model predicts hired labor expenses to fluctuate slightly around 6.5 billion dollars per year out to the year 2000. It may be more useful to look at these predictions on a per farm basis. The BASE solution in Figure 19 shows an increase of almost 20 percent in the expenses paid by farmers to hired labor on a per farm basis from 1980-2000. This increase is due to falling farm numbers, not increasing labor usage.

Increased petroleum price alternatives

As petroleum prices rise, we have found that input use such as fertilizer, pesticides, machinery purchases and fuel, oil and repairs are

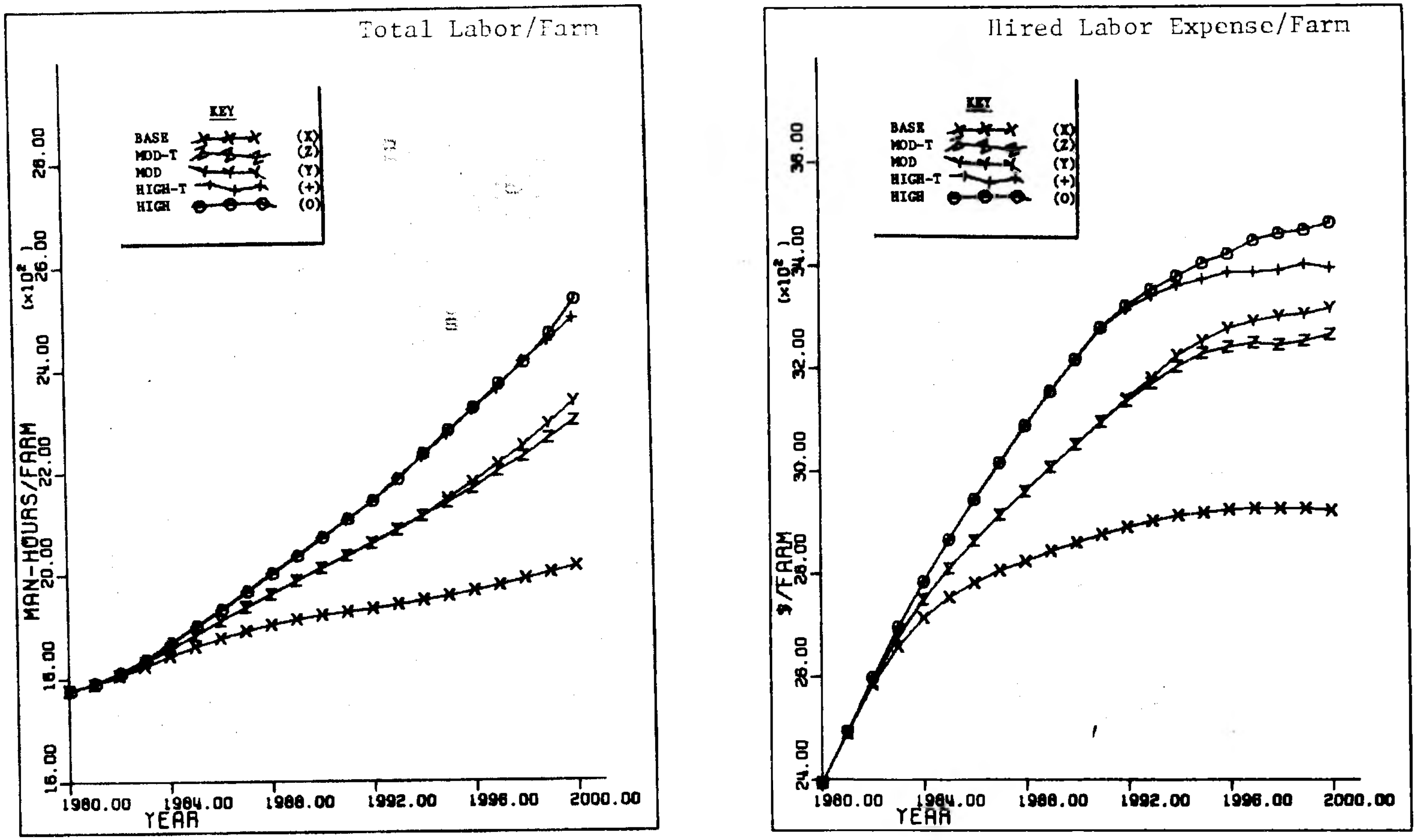


Figure 19. Predicted total labor per farm and hired labor expense per farm under five alternatives to 2000

reduced. Yet, we also found harvested acreages increased with rising petroleum prices. These two findings seem mutually exclusive until we observe Table 23. The long standing substitution of capital for labor in U.S. agriculture may be slowed as petroleum prices rise. It may be farmers will work longer hours and hire more labor instead of automatically buying bigger machinery when their production increases. They may also substitute more labor for pesticides when reducing certain weed populations and tillage methods. Farmers will still purchase larger machines as they expand their farm size, but to a lesser extent than before.

Table 23. Percentage change in labor use and hired labor expense from the BASE for four alternatives

Year	MOD-T	MOD	HIGH-T	HIGH
	(percent change in labor use from BASE)			
1985	+ 1	+ 1	+ 3	+ 3
1990	+ 3	+ 3	+ 5	+ 5
2000	+12	+13	+21	+22
	(percent change in hired labor expense from BASE)			
1985	+ 3	+ 3	+ 5	+ 5
1990	+ 5	+ 5	+ 9	+ 9
2000	+11	+13	+16	+18

On a per farm basis, the increase in farm labor and hired labor are even more pronounced as seen in Figure 19. This is because farm numbers are projected to decrease in addition to the predicted increases in farm labor use. Thus, the percentage increases from the BASE run are larger on a per farm basis (Table 24) than on a U.S. total basis (Table 23).

Table 24. Percentage change in labor use per farm and hired labor expense per farm from the BASE for four alternatives

Year	MOD-T	MOD	HIGH-T	HIGH
	(percentage change in labor use per farm from BASE)			
1985	+1	+1	+3	+3
1990	+5	+5	+9	+9
2000	+15	+16	+25	+27
	(percentage change in hired labor expense per farm from BASE)			
1985	+2	+2	+4	+4
1990	+7	+7	+12	+12
2000	+12	+14	+16	+21

Miscellaneous Expenses

Miscellaneous expenses in this model include all input expenses which do not fit into other categories already mentioned. This category includes expenditures for pesticides, telephone, veterinary services, hand tools, hardware, etc. The variables used to explain the miscellaneous demand function by crop include the stock of physical assets, (+), farm supply price index, (-), and time. These five crop equations plus one livestock equation predict a continuous increase in expenditures to 2000 in real terms. This prediction is based on the historically steady rise in farm assets and relatively low prices for farm supplies over time.

As the price of petroleum rises, we see a slight decrease in miscellaneous expenditures. This is due to an increase in the relative price of petroleum-based farm supplies (including pesticides). Because of the aggregated function, assumptions cannot be made about pesticide use specifically. But in general, the usage of inputs in this category is reduced slightly as petroleum prices are increased.

VI. CROP OUTPUT SECTOR RESULTS

This section includes an analysis of the BASE relative to four increased energy price alternatives with regard to crop output variables. These variables include crop production, yield, prices, and demand.

Production and Yields

BASE alternative

Crop production output in this model is developed by multiplying harvested acreage times yield per acre for each crop. Harvested acreage is predicted to decrease in the BASE alternative for all crops but soybeans as reported in Chapter IV. Table 25 shows the assumed BASE alternative crop yields which are projected exogenously by time trends. The yields for the alternatives in this model are estimated as a function of past yields and various input elasticities of production, Chapter II. These input elasticities of production are estimated from factor share data using methodology by Turner and Tweeten, 1965.

Table 25. Yields for four crops to 2000 under the BASE alternatives

Year	Feed grains	Wheat	Soybeans	Cotton lint
	(tons/acre)	(bushel/acre)	(bushel/acre)	(bales/acre)
1981-1982	2.34	36.63	29.23	1.09
1983-1984	2.44	37.89	29.78	1.10
1985-1986	2.54	39-14	30.33	1.11
1986-1990	2.66	40.70	31.01	1.13
1991-1995	2.91	43.83	32.39	1.15
1996-2000	3.16	49.96	33.76	1.17

The yield increases in the BASE overcome crop acreage decreases in the future and production, therefore, is expected to rise. Table 26 illustrates the extent to which crop production will increase by 2000. The largest increase in production occurs with soybeans. This increase results since soybean acreage as well as soybean yields are expected to rise. Other crops will experience reduced acreages, which tend to counteract the yield increases in the model, leading to lower total production increases.

Table 26. Crop production predictions for four crops under the BASE alternative to 2000

Year	Feed grains	Wheat	Soybeans	Cotton lint
	(million tons)	(million bushels)	(million bushels)	(million bales)
1981-1982	229	2,174	1,918	14.31
1983-1984	238	2,271	2,014	14.15
1985-1986	247	2,337	2,111	14.30
1986-1990	257	2,388	2,243	14.70
1991-1995	275	2,494	2,520	15.42
1996-2000	295 (29)[a]	2,617 (20)[a]	2,805 (46)[a]	15.98 (12)[a]

[a]Percentage increase in production from 1981 to 2000.

Increased petroleum price alternatives

Crop yields decline slightly as petroleum prices rise (Figure 20). Most of this decrease is due to less fertilizer usage per acre. Yet, even though fertilizer usage is cut 5 to 14 percent from the BASE run (Table 27), yields are reduced only 3 to 6 percent depending on the alternative examined. This is because farmers are operating on a low elasticity portion of the production function at present levels of

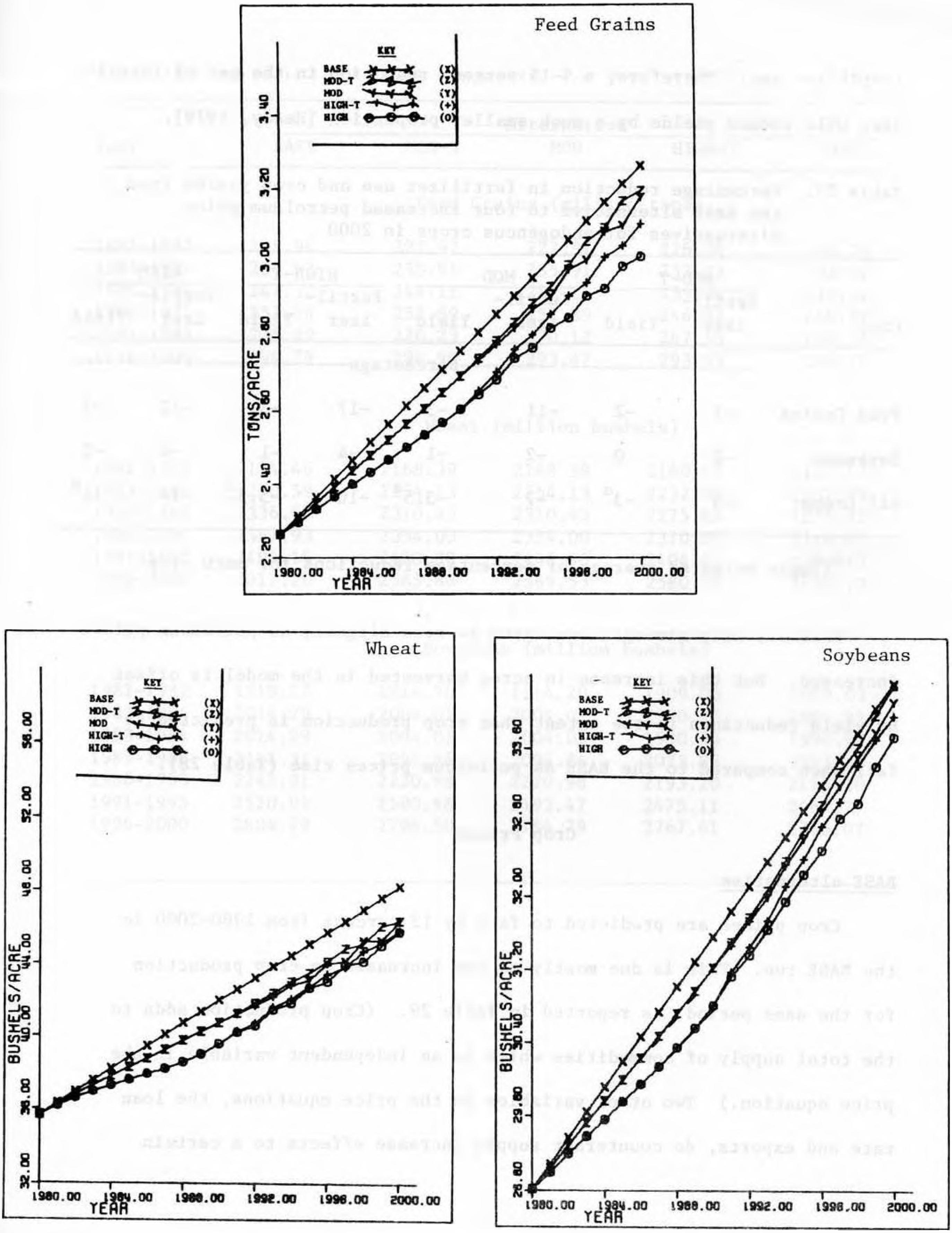


Figure 20. Predicted yields for three crops under five alternatives to 2000

fertilizer use. Therefore, a 5-15 percent reduction in the use of fertilizer will reduce yields by a much smaller proportion [Heady, 1979].

Table 27. Percentage reduction in fertilizer use and crop yields from the BASE alternative to four increased petroleum price alternatives for endogenous crops in 2000

Crop	MOD-T		MOD		HIGH-T		HIGH	
	Fertilizer	Yield	Fertilizer	Yield	Fertilizer	Yield	Fertilizer	Yield
	percentage							
Feed Grains	-7	-2	-11	-3	-17	-5	-22	-7
Soybeans	-2	0	-2	-1	-4	-1	-4	-2
All Crops	-5	-3[a]	-7	-3.5[a]	-10	-5.5[a]	-14	-6[a]

[a]Simple weighted average of percentage reductions for each crop.

Earlier, crop acreages were seen to rise slightly as petroleum prices increased. But this increase in acres harvested in the model is offset by yield reductions to the extent that crop production is predicted to fall when compared to the BASE as petroleum prices rise (Table 28).

Crop Prices

BASE alternative

Crop prices are predicted to fall by 12 percent from 1980-2000 in the BASE run. This is due mostly to the increases in crop production for the same period, as reported in Table 29. (Crop production adds to the total supply of commodities which is an independent variable in the price equation.) Two other variables in the price equations, the loan rate and exports, do counteract supply increase effects to a certain

Table 28. Estimated U.S. crop production for five alternatives to 2000

Year	Alternative BASE	MOD-T	MOD	HIGH-T	HIGH
			Feed Grains (million tons)		
1981-1982	228.96	227.97	227.97	226.70	226.70
1983-1984	237.92	235.91	235.91	233.32	233.32
1985-1986	247.32	244.11	244.11	239.94	239.94
1986-1990	257.16	252.89	252.89	246.92	246.92
1991-1995	275.29	270.23	270.12	267.50	266.22
1996-2000	294.79	294.98	293.47	293.99	289.16
			Wheat (million bushels)		
1981-1982	2174.46	2168.39	2168.39	2160.67	2160.67
1983-1984	2270.59	2254.13	2254.13	2232.99	2232.99
1985-1986	2336.64	2310.43	2310.43	2275.82	2275.82
1986-1990	2387.93	2354.00	2354.00	2310.07	2310.07
1991-1995	2494.16	2488.88	2440.90	2404.13	2389.43
1996-2000	2617.10	2585.86	2569.53	2580.24	2538.70
			Soybeans (million bushels)		
1981-1982	1918.27	1914.20	1914.20	1909.03	1909.03
1983-1984	2014.29	2004.01	2004.01	1990.95	1990.95
1983-1984	2014.29	2004.01	2004.01	1990.95	1990.95
1985-1986	2111.31	2094.84	2094.84	2073.85	2073.85
1986-1990	2243.91	2220.98	2220.98	2193.20	2193.20
1991-1995	2520.09	2500.68	2493.47	2475.11	2467.27
1996-2000	2804.79	2796.50	2784.79	2767.61	2746.07

Table 29. Estimated U.S. crop prices received by farmers for five alternatives to 2000, in 1978 prices

Year	BASE	MOD-T	MOD	HIGH-T	HIGH
	Feed grains ($/ton)				
1981-1982	83.74	84.40	84.40	85.25	85.25
1983-1984	81.03	83.04	83.04	85.61	85.61
1985-1986	75.84	79.86	79.86	85.05	85.05
1986-1990	69.64	76.94	76.94	86.61	86.61
1991-1995	63.34	80.51	81.05	110.59	116.33
1996-2000	63.00	93.33	100.15	124.84	140.55
	Wheat ($/bushel)				
1981-1982	2.56	2.58	2.58	2.60	2.60
1983-1984	2.53	2.60	2.60	2.69	2.69
1985-1986	2.32	2.47	2.47	2.66	2.66
1986-1990	2.10	2.36	2.36	2.69	2.69
1991-1995	1.88	2.38	2.42	2.99	3.05
1996-2000	1.85	2.57	2.74	3.57	4.43
	Soybeans ($/bushel)				
1981-1982	8.24	8.27	8.27	8.30	8.30
1983-1984	8.01	8.13	8.13	8.28	8.28
1985-1986	7.64	7.92	7.92	8.27	8.27
1986-1990	7.38	7.94	7.94	8.87	8.87
1991-1995	7.30	8.70	8.97	10.84	11.05
1996-2000	7.61	9.84	10.48	13.08	13.85

extent. But historically, technological advances in agriculture have increased the supply of agricultural commodities at a faster rate than exports or government programs have been able to increase demand. Thus, the real price of agricultural commodities is predicted to continue to fall, given a linearly projected trend in exports. (The possible effects of export levels which differ from the historical trend will be discussed later in this report.)

Increased petroleum price alternatives

Earlier crop production was shown to decrease as petroleum prices rose because yields are reduced. And, since the demand for farm commodities is relatively inelastic with respect to the price of those commodities, a decrease in agricultural output supply (supply = production + inventories + imports) should have a positive effect on prices. But, the decrease in crop production due to a rise in petroleum prices is relatively small to 1990 (Table 28). In fact, feed grain, wheat, and soybean production under the highest energy price scenario (HIGH) is expected to decrease only 4, 3, and 2 percent respectively from the base run in 1990. And these percentages actually decrease when calculated for year 2000. Table 29 shows that the increase in crop prices for each higher energy price scenario when compared to the BASE is also relatively small to 1990. But the price for commodities rise substantially from 1990-2000. If crop production decreases from the BASE are small from 1990-2000, as reported earlier, what makes the price rise so drastically during this time period. The answer lies in the effect on the stocks of these commodities. In the 80s, crop production under higher petroleum prices will be less than under the BASE price and stocks will begin to deplete. This depletion of stocks will be much more profound as time goes on and energy prices rise, hitting lows for this model by 2000. Since decreasing stocks have a large negative effect on total crop supply and prices rise when supplies decrease, a cumulative result with much higher real prices for the 90s than in the 80s is expected, and somewhat higher real prices in the 80s than at the present.

Demands for Crop Commodities

In this model, total noninventory demand for crop commodities is defined as commercial demands plus exports. Exports are trended exogenously based on historical data. Commercial demand is predicted within the model in an endogenous manner.

Exports (exogenous)

Crop exports are projected by time trends and a dummy variable. The dummy variable takes into account apparent structural shifts in the levels of exports. Exports of feed grains, wheat, and soybeans took a dramatic jump in 1972 and seem to have maintained these high levels. The following equations are used to project crop exports.

$$\text{FG-EXPTS}_t = \underset{}{1.3124} + \underset{(7.394)}{17.7277\ \text{DUM1}} + \underset{(4.435)}{13.6004\ \text{DUM2}} + \underset{(9.577)}{1.0885\ \text{TIME}}, \quad (2)$$

OLS, $R^2 = .9646$, MSE = 13.2085, DW = 1.6122

$$\text{WT-EXPTS}_t = 196.4143 + \underset{(3.045)}{353.5923\ \text{DUM1}} + 16.7191\ \text{TIME}, \quad (3)$$

ALS, $R^2 = .85.77$, MSE = 13818.1281, DW = 2.1739/

$$SB\text{-}EXPTS = -96.9637 \underset{(2.404)}{+ 66.3653\ WAR2} \underset{(2.124)}{+ 56.9442\ DUM1}, \qquad (4)$$

$$\underset{(4.631)}{+ 149.3029\ DUM2} \underset{(13.522)}{+ 21.2192\ TIME},$$

$$OLS,\ R^2 = .9735,\ MSE = 1441.7286,\ DW = 1.7123.$$

CT-EXPTS = 4.5 which is the 1972-76 average for cotton. (5)

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

For the purpose of projection from 1980-2000, DUM1 and DUM2 are set equal to one under the assumption that crop exports will remain at a higher level through 2000. WAR2 is set equal to zero and the time trend is increased by one unit per year up to 52 in 2000.

Table 30 displays projected levels of crop exports with 1972-76 averages of actual observations for comparison. Of the four crops, soybean exports are projected to increase the most. They reach 1,062.3 million bushels in 2000 which is 108 percent higher than the 1972-76 average. The projected level of feed grain exports for 2000 is 60 percent higher than 1972-76. Wheat exports are estimated to increase by 38 percent over the same period. Cotton exports are constant at 4.5 because of the lack of correlation with trend or dummy variables.

Table 30. Projected level of feed grain, wheat, soybean, and cotton lint exports for 1980, 1990, and 2000, with actual 1972-76 average exports for comparison

Commodity	1972-76[a]	1980	1990	2000
Feed grain (million tons)	47.3	53.9	64.7	75.6
Wheat (million bushels)	1,098.6	1,201.6	1,362.0	1,511.5
Soybeans (million bushels)	511.7	638.7	850.5	1,062.3
Cotton lint (million bales)	4.5	4.5	4.5	4.5

[a]SOURCE: [Economics, Statistics, and Cooperative Service, 1976, 1977, United States Department of Agriculture, 1977].

Commercial demand

Commercial demands for feed grains, wheat, and soybeans are a function of commodity prices (negative) and the price of livestock (positive). Since BASE commodity prices are projected to fall relative to the price of livestock, the model forecasts an increase in commercial demands for crops to 2000 (Table 31). Earlier it was shown increasing petroleum prices tend to increase commodity prices. This has a downward impact on commercial demand at each higher petroleum price alternative when compared to the BASE. Feed grain and soybean commercial demands decrease 4 percent from the BASE to the HIGH alternative in 2000 while wheat demand decreases over 10 percent.

Total noninventory demand

Total noninventory demand is merely the export trend added to commercial demand projections. In Table 32, increased energy prices have a similar downward effect on total demand as they did on commercial demand, Yet, the decreases in total demand from the BASE to the HIGH alternatives are

Table 31. Estimated U.S. crop commercial demand for three crops under five alternatives to 2000

Year	BASE	MOD-T	MOD	HIGH-T	HIGH
		Alternative			
	- - - - - - - - - Feed grains (million tons) - - - - - - -				
1981-1982	162.26	161.96	161.96	161.57	161.57
1983-1984	166.41	165.60	165.60	164.57	164.57
1985-1986	172.45	171.06	171.06	169.27	169.27
1986-1990	180.40	178.55	178.55	175.98	175.98
1991-1995	169.59	193.84	193.73	187.30	185.02
1996-2000	211.92	208.32	206.80	207.33	202.49
	- - - - - - - - - Wheat (million bushels)- - - - - - - - -				
1981-1982	390.81	389.94	389.94	288.82	388.82
1983-1984	380.25	376.25	276.25	271.14	271.14
1985-1986	384.95	376.21	376.21	364.84	364.84
1986-1990	399.51	385.91	385.91	367.89	367.89
1991-1995	428.08	412.54	410.09	397.16	394.56
1996-2000	452.21	445.64	440.02	436.01	390.23
	- - - - - - - - -Soybeans (million bushels)- - - - - - - -				
1981-1982	1,067.87	1,066.88	1,066.88	1,065.62	1,065.62
1983-1984	1,126.56	1,122.69	1,122.69	1,117.78	1,117.78
1985-1986	1,199.42	1,191.45	1,191.45	1,181.28	1,181.28
1986-1990	1,288.83	1,276.64	1,276.64	1,254.64	1,254.64
1991-1995	1,469.74	1,449.19	1,441.98	1,410.96	1,403.13
1996-2000	1,647.88	1,626.11	1,613.22	1,597.37	1,575.83

Table 32. Estimated U.S. crop total noninventory demand for three crops under five alternatives to 2000

Year	Alternative				
	BASE	MOD-T	MOD	HIGH-T	HIGH
	- - - - - - - - - Feed grains (million tons) - - - - - - -				
1981-1982	231.36	231.06	231.06	230.68	230.68
1983-1984	237.69	236.88	236.88	235.85	235.85
1985-1986	245.91	244.52	244.52	424.73	242.73
1986-1990	256.58	254.72	254.72	252.16	252.16
1991-1995	278.21	275.47	275.35	268.92	266.64
1996-2000	298.98	295.38	293.86	294.39	289.56
	- - - - - - - - - Wheat (million bushels)- - - - - - - - -				
1981-1982	2,225.12	2,224.12	2,224.12	2,222.83	2,222.83
1983-1984	2,255.87	2,251.33	2,251.33	2,245.53	2,245.53
1985-1986	2,302.62	,2292.74	2,292.74	2,279.87	2,279.87
1986-1990	2,369.82	2,354.22	2,354.22	2,333.60	2,333.60
1991-1995	2,504.34	2,484.94	2,482.14	2,464.74	2,461.66
1996-2000	2,636.67	2,624.40	2,617.52	2,606.80	2,553.64
	- - - - - - - - -Soybeans (million bushels)- - - - - - - -				
1981-1982	1,887.99	1,887.00	1,887.00	1,885.75	1,885.75
1983-1984	1,989.12	1,985.26	1,985.26	1,980.34	1,980.34
1985-1986	2,104.42	2,096.45	2,096.45	2,086.28	2,086.28
1986-1990	2,246.88	2,234.69	2,234.69	2,212.69	2,212.69
1991-1995	2,533.89	2,513.34	2,506.13	2,475.11	2,467.27
1986-1990	2,246.88	2,234.69	2,234.69	2,212.69	2,212.69
1991-1995	2,533.89	2,513.34	2,506.13	2,475.11	2,467.27
1996-2000	2,818.12	2,796.36	2,783.46	2,767.61	2,746.07

3 percent for all crops. This decrease is less than the decrease for commercial demand alone because of exports. Exports are projected to increase exogenously, therefore they are unaffected by energy prices. The increasing exports dampen the downward movement in commercial demand such that the decrease in total demand as energy prices rise is small.

VII. LIVESTOCK OUTPUT SECTOR RESULTS

Major concentration in this sector is on the four major livestock commodities: beef (cow/calf and feeders), pork, lamb and mutton, and chicken. Results for the turkey sector were obtained but not reported in this study. A description of the BASE alternative is given in great detail elsewhere [Schatzer et al.), therefore only a condensed version will be presented here. A more detailed explanation will be given for the high petroleum price alternatives in the latter portion of this section.

BASE Alternative

Table 33 presents a sampling of actual changes in various beef variables and estimated changes in those same variables to 2000. Lower feed costs and higher beef prices would spur beef production to record levels by 2000. Consumption of beef would increase at an even higher rate than production as imports also rise. Each person in the United States would consume almost 30 more pounds of beef per year in 2000 than in 1980. But, each pound would cost almost 15 cents more in real terms in 2000. The beef producer would receive 4 percent more return per pound from 1980 to 2000 compared to a 5.3 percent decline demonstrated by the historical data. This positive turnaround is due to higher retail prices and a relatively small projected increase in the farm-retail margin (which reflects small increases in processing costs). Price increases, coupled with increased production, would lead to a high rate of increase in cash receipts for the beef subsector by year 2000.

Table 33. Actual and estimated beef submodel variables for the BASE alternative

Variable	Actual[a] 1953-55	Actual[a] 1974-76	Actual[a] Change	Actual[a] Percent change	Estimated 1980	Estimated 2000	Estimated Change	Estimated Percent change
Production (million pounds)	12,979.7	24,360.7	11,381.0	87.7	25,925.8	36,798.8	10,873	41.9
Inventory (million pounds)	214.0	397.3	183.3	85.7	449.2	754.4	305.2	67.9
Civilian consumption (million pounds)	12,723.0	25,773.3	13,050.3	102.6	27,860.7	40,181.0	12,320.3	44.2
Per capita consumption (pounds/person)	79.9	122.0	42.1	52.7	125.5	153.2	27.7	22.1
Retail price (¢/pound)	153.0	160.9	7.9	5.2	195.6	210.0	14.4	7.4
Farm retail margin (¢/pound)	50.4	63.2	12.8	25.4	64.8	73.4	8.6	13.3
Farm price (¢/pound)	112.4	106.5	-6.0	-5.3	140.6	146.5	5.9	4.2
Cash receipts (million dollars)	11,465.2	20,761.3	9,296.1	81.1	34,347.1	52,199.5	17,852.4	52.0

[a]SOURCE: [Roberts, Heady, 1979].

Table 34 presents the projected levels of the endogenous variables for the pork subsector along with historical data. Pork production will increase slightly as consumption and inventories increase although per capita consumption is projected to fall somewhat by 2000. Retail prices for pork will rise while farm prices fall. This will occur as the farm-retail margin increases by over 20 percent, a larger increase than for beef. Because of higher production and lower farm prices, cash receipts will remain relatively constant for the 1980-2000 period.

The same variables are reported for the lamb subsector in Table 35. As with beef and pork, lamb production, inventories, and total consumption will rise by 2000. Consumption per capita will decrease, but far less than the decrease between 1953 and 1976. The 8 percent increase in retail price will occur mostly between 1980 and 1990, because after 1990, higher levels of production and consumption will tend to lower consumer responsiveness to increases in income. Farmers will receive higher prices for their mutton by 2000, which will tend to increase their cash receipts. But, farm prices increase more slowly than retail prices because the farm-retail margin also increases.

Every variable listed for the chicken subsector in Table 36 increases except for inventories which. remain constant. Chicken consumption is predicted to rise because of higher demand for chicken relative to other meats. This demand is increased as retail prices for chicken remain relatively low, when compared to beef and lamb to 2000. A small increase in the farm-retail margin combined with high production result in much higher cash receipts for chicken producers by 2000.

Table 34. Actual and estimated pork submodel variables for the BASE alternative

Variable	Actual[a] 1953-55	Actual[a] 1974-76	Actual[a] Change	Actual[a] Percent Change	1980	2000	Change	Percent Change
Production (million pounds)	10,288.7	12,574.7	2,286.0	22.2	13,331.3	14,560.0	1,228.7	9.2
Inventory (million pounds)	399.0	253.3	-145.7	-36.5	290.2	515.4	225.2	77.6
Civil consumption (million pounds)	10,094.0	12,633.7	2,539.7	25.2	13,493.7	14,873.4	1,379.7	10.2
Per capita consumption (pounds/person)	63.4	61.6	-1.8	-2.8	60.8	56.7	-4.1	-6.7
Retail price (¢/pound)	135.0	142.6	7.6	5.6	148.0	150.6	2.6	1.8
Farm retail margin (¢/pound)	51.1	57.3	6.2	12.1	62.0	76.5	14.5	23.4
Farm price (¢/pound)	93.5	93.4	-.1	-.1	93.0	81.2	-11.8	-12.7
Cash receipts (million dollars)	7,259.2	8,426.3	1,203.1	16.6	9,064.4	8,955.4	-109.0	-1.2

[a]SOURCE: [Roberts, Heady, 1979].

Table 35. Actual and estimated lamb submodel variables for the BASE alternative

Variable	Actual[a]				Estimated			
	1953-55	1974-76	Change	Percent change	1980	2000	Change	Percent change
Production (million pounds)	740.3	415.7	-324.6	-43.8	241.5	261.4	19.9	8.2
Inventory (million pounds)	11.0	13.0	2.0	18.2	12.9	31.7	18.8	145.7
Civil consumption (million pounds)	739.3	436.3	-303.0	-41.0	267.4	288.0	20.6	7.7
Per capita consumption (pounds/person)	4.6	2.1	-2.5	-54.3	1.2	1.1	-.1	-8.3
Retail price (¢/pound)	153.5	189.1	35.6	23.2	228.6	247.8	19.2	8.4
Farm retail margin (¢/pound)	63.1	85.2	22.1	35.0	102.5	114.0	11.5	11.2
Farm price (¢/pound)	106.3	115.3[c]	9.0	8.5	140.5	148.2	7.7	5.5
Cash receipts (million dollars)	722.4	433.9	-288.5	-39.9	300.8	342.6	41.8	13.9

[a]SOURCE: [Roberts, Heady, 1980].

Table 36. Actual and estimated chicken submodel variables for the BASE alternative

	Actual[a]				Estimated			
Variable	1953-55	1974-76	Change	Percent Change	1980	2000	Change	Percent Change
Production (million pounds)	3,627.3	9,146.3	5,519.0	152.2	11,041.2	18,019.8	9,231.4	83.6
Inventory (million pounds)	136.3	148.0	11.7	8.6	141.4	141.5	0	0
Civil consumption (million pounds)	3,503.0	8,788.3	5,285.3	150.9	10,608.2	17,484.6	6,876.4	64.8
Per capital consumption (pounds/person)	22.0	41.6	48.6	89.1	47.8	66.7	18.9	39.5
Retail price (¢/pound)	124.5	68.4	-56.1	-45.1	68.8	71.6	2.8	4.1
Farm retail margin (¢/pound)	45.1	30.6	-41.5	-32.2	33.2	35.0	1.8	5.4
Farm price (¢/pound)	79.5	37.8	-41.7	-52.5	35.6	36.6	1.0	2.8
Cash receipts (million dollars)	2,416.5	3,283.9	867.4	35.9	3,804.5	6,231.6	2,427.1	63.81

[a]SOURCE: [Roberts, Heady, 1980].

Increased Petroleum Price Alternatives

As petroleum prices rise, the price of grain also rises. This increases the cost of feed and puts downward pressure on livestock production. Conversely, the BASE alternative projects rising farm prices for all livestock but pork. This puts upward pressure on livestock production. The net result, Figure 21, is production of beef, lamb and chicken is virtually unchanged from the BASE as energy prices increase through the late 1980s. Around 1990, the downward pressures of higher feed costs overcome the projected livestock price increases and production of beef, lamb and chicken falls from the BASE. The most dramatic drop from the BASE to the HIGH alternative is seen in lamb production for 2000 (36 percent).

Since pork prices were estimated to fall in the BASE alternative, higher feed costs caused by increased petroleum prices tend to decrease production initially from 1980 to 2000. The production of pork decreases over 20 percent from the BASE to the HIGH alternative in 2000.

As production falls after 1990, inventories of livestock also fall when comparing the BASE to increased energy price alternatives shown in Figure 22. Since shifts in inventories are a direct result of production movements, the differences between the BASE and higher energy price alternatives in Figures 21 and 22 are similar. By 1990, the decrease in inventories, leading to an overall decrease in supply, spurs an increase in the farm price of all four commodities (Figure 23). This is passed on to the consumer via the farm-retail margin to an increase in the retail price. The farm-retail margin reflects increases in the costs of food processing

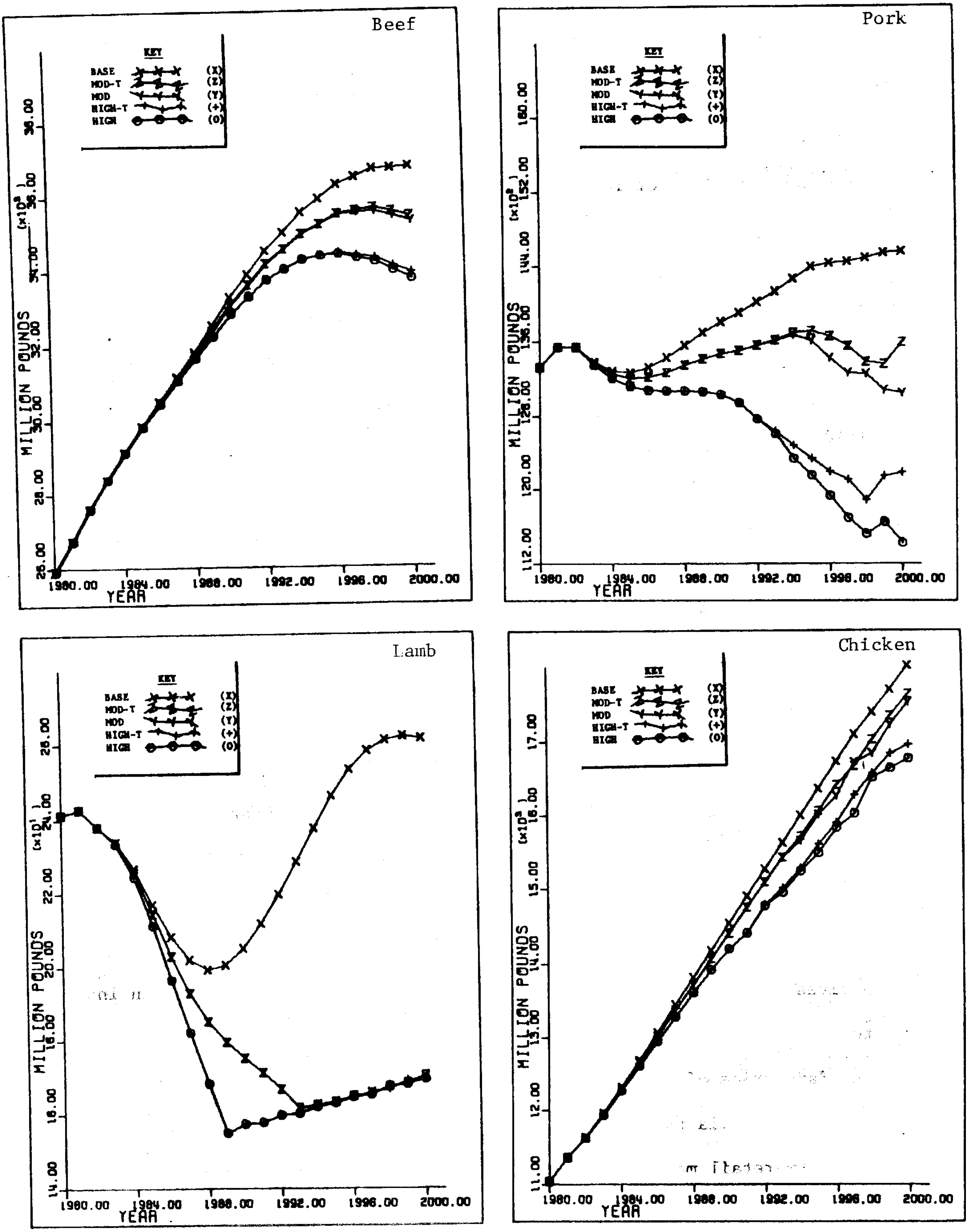


Figure 21. Predicted livestock production under five alternatives to 2000

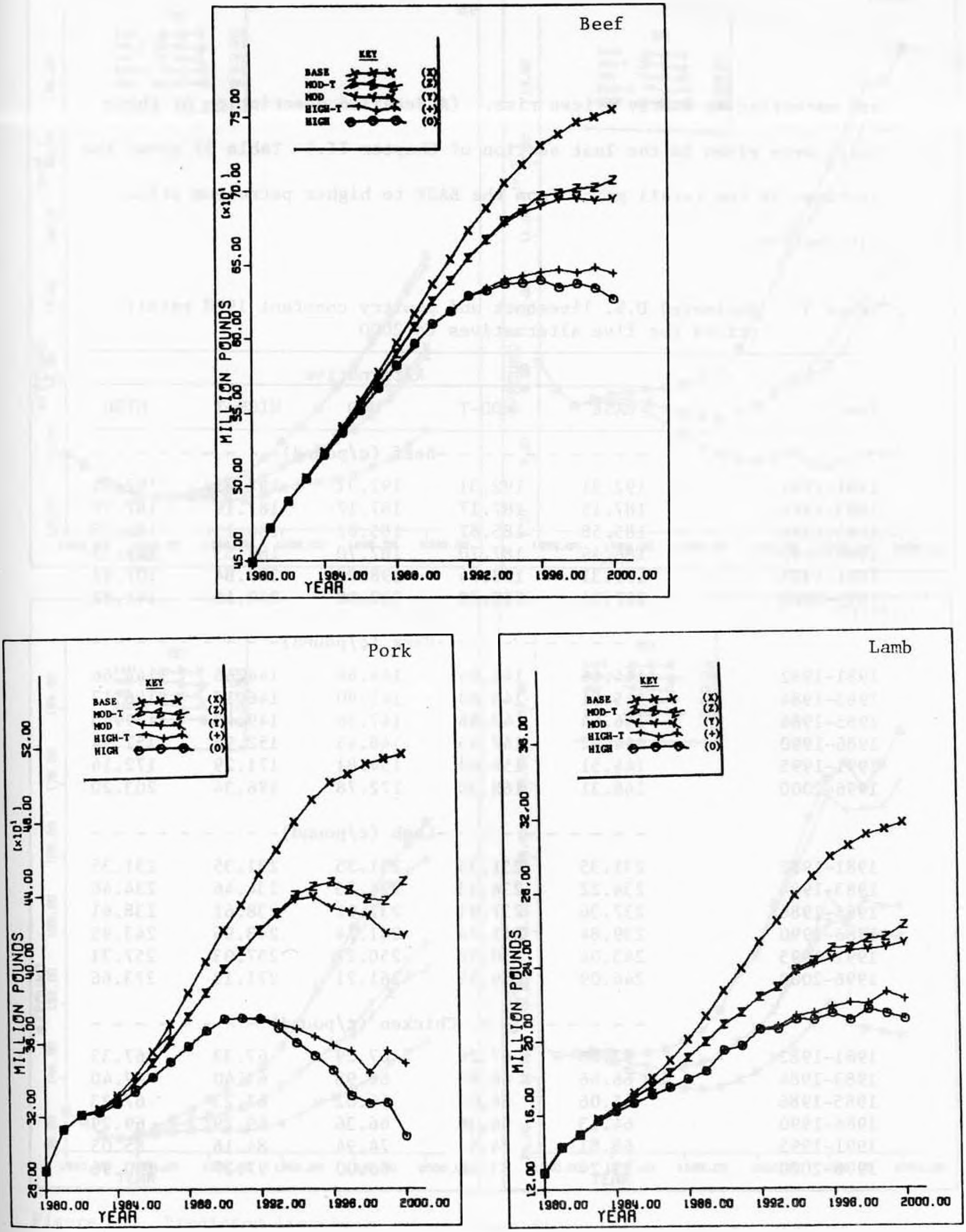


Figure 22. Predicted livestock inventories under five alternatives to 2000

and marketing as energy prices rise. (A detailed description of these costs were given in the last section of Chapter II.) Table 37 shows the increase in the retail price from the BASE to higher petroleum price alternatives.

Table 37. Estimated U.S. livestock and poultry constant 1978 retail prices for five alternatives to 2000

	Alternative				
Year	BASE	MOD-T	MOD	HIGH-T	HIGH
	-Beef (¢/pound)-				
1981-1982	192.31	192.31	192.31	192.31	192.31
1983-1984	187.15	187.17	187.17	187.19	187.19
1985-1986	185.58	185.82	185.82	186.13	186.13
1986-1990	186.19	187.70	187.70	189.53	189.53
1991-1995	191.31	198.74	198.77	207.84	207.91
1996-2000	202.04	218.70	220.08	240.16	241.82
	-Pork (¢/pound)-				
1981-1982	144.66	144.66	144.66	144.66	144.66
1983-1984	145.51	145.80	145.80	146.17	146.17
1985-1986	146.64	147.86	147.86	149.43	149.43
1986-1990	144.92	148.45	148.45	152.94	152.94
1991-1995	144.51	154.49	154.81	171.29	172.14
1996-2000	148.31	168.30	172.78	196.34	203.20
	-Lamb (¢/pound)-				
1981-1982	231.35	231.35	231.35	231.35	231.35
1983-1984	234.22	234.33	234.33	234.46	234.46
1985-1986	237.36	237.91	237.91	238.61	238.61
1986-1990	239.84	241.74	241.74	243.95	243.95
1991-1995	243.04	250.18	250.27	257.03	257.31
1996-2000	246.09	259.59	261.21	271.12	273.66
	-Chicken (¢/pound)				
1981-1982	67.26	67.29	67.29	67.33	67.33
1983-1984	66.66	66.98	66.98	67.40	67.40
1985-1986	65.06	66.02	66.02	67.23	67.23
1986-1990	64.13	66.36	66.36	69.29	69.29
1991-1995	68.81	74.51	74.94	84.16	85.05
1996-2000	73.24	83.46	86.00	97.27	100.96

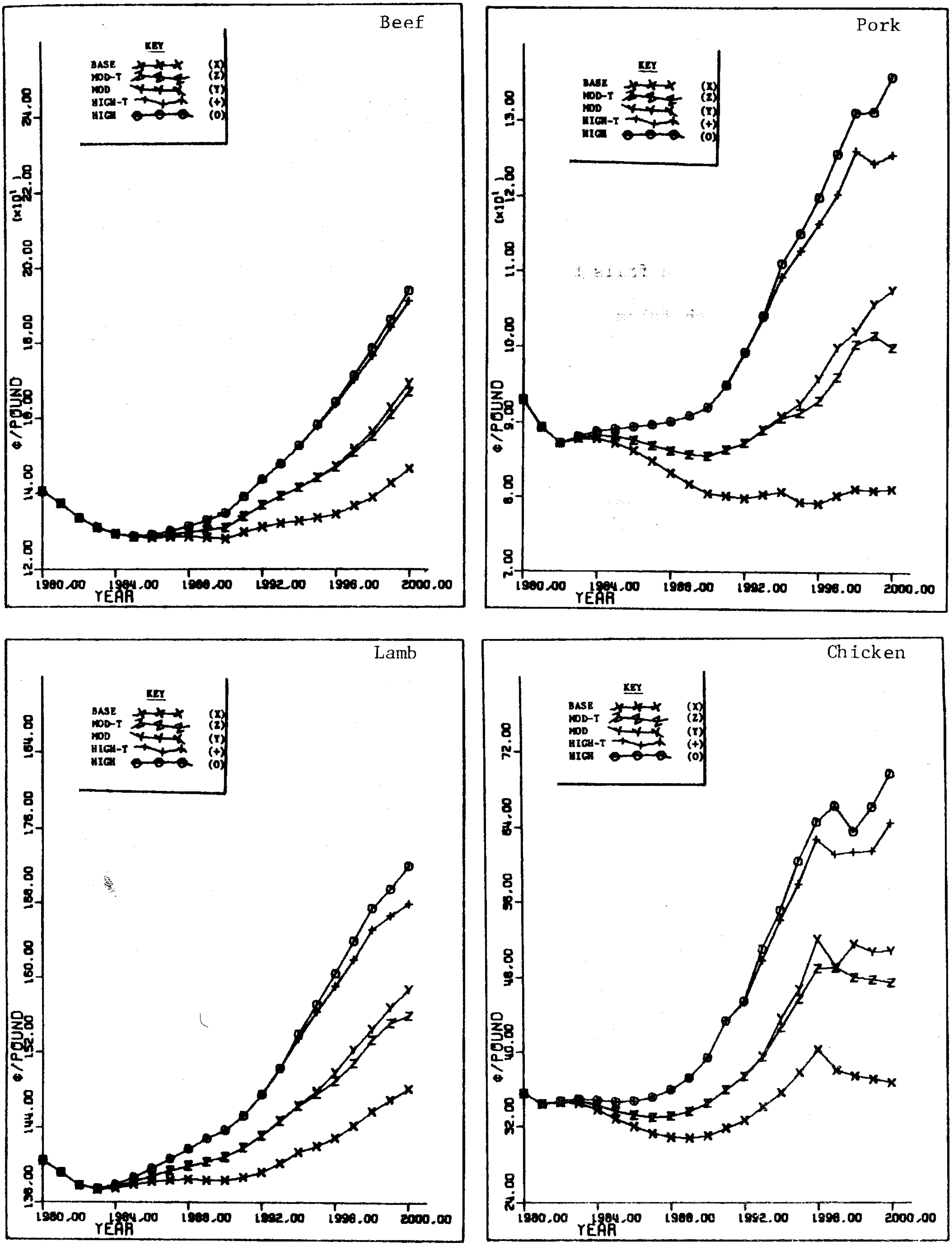


Figure 23. Predicted livestock prices under five alternatives to 2000

Because of the increase in the retail price of livestock commodities after 1990, consumers reduce their consumption of meat as petroleum prices rise, Figure 24. Compared to the BASE alternative in 2000, chicken consumption per person falls by 6 percent followed by beef, pork and lamb consumption which falls by 7, 21 and 32 percent respectively under the HIGH alternative.

In summary, higher petroleum prices reduce overall livestock production through producers' response to higher feed costs. The decrease in production lowers total livestock supply by 1990, which in turn increases the prices paid for farm and retail livestock products. The consumer responds to these higher prices by reducing beef and chicken consumption slightly and pork and lamb consumption more drastically by 2000.

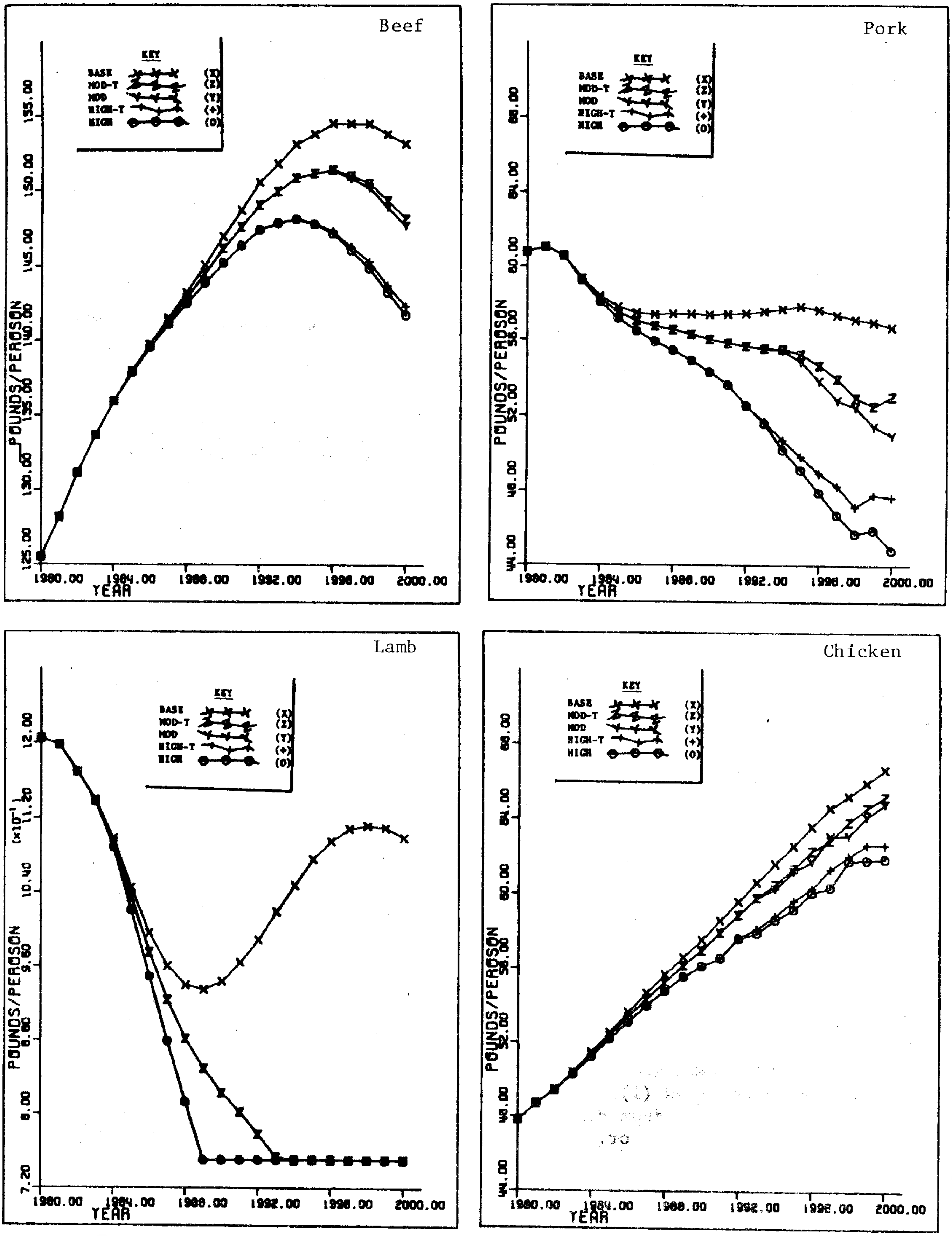


Figure 24. Predicted U.S. per capita consumption of meat under five alternatives to 2000

VIII. FINANCIAL SECTOR RESULTS

The financial sector of the model was developed in 1980 [Drabenstott], to closely follow the methodology of Melichar, 1973. The work of Penson, 1971, was also examined but seemed less appropriate for the highly aggregated needs of this model. The model focuses on the uses of capital flows. Sources of funds are considered only to the extent that a dichotomy between internal and external financing is recognized. In each of the endogenous subsectors, (crops and livestock), annual capital flow demands are estimated in five categories as follows:

(1) Land Capital Flow = (Land Price) * (Real Stock) *
(Percent Transferred by Discounting Proprietors)

(2) Machinery Capital Flow = Depreciation + Machinery Purchases

(3) Livestock Capital Flow = (Increase in Real Stock) * (Price)
(all except livestock sector)

(5) Building and Improvement Capital Flow = (Increase in Real Stock) * (Price)

In the aggregate finance sector, one further category is estimated:

(6) Financial Assets Capital Flow = Increase in Stocks of Currency, Time Deposits, Demand Deposits, U.S. Savings Bonds, and Investments in Cooperatives.

Summing categories (1) through (5) will give the total capital flow for one commodity subsector. Summing this quantity across all six commodity subsectors yields total production capital flow. Adding the financial assets capital flow (category (6)) and the exogenous subsector capital flow equals total annual capital flow for the United States.

U.S. net farm income may be derived from the output section of the model as follows:

(7) Net Farm Income = Gross Farm Income - Current Farm Expenses.

Given net farm income, internal financing of total capital flow may be estimated as:

(8) Internal Financing = (Savings Ratio) (Net Farm Income). The savings ratio is exogenously set according to its historical trend. Finally, external financing (credit requirements or increase in debt) is the residual financing of total capital flow.

(9) External Financing = Total Capital Flow - Internal Financing.

BASE Alternative

Capital flow demands (Table 38) are projected to increase by 20 percent over the next two decades to over $32 billion. Real estate flows account for the largest portion of this increase as they rise 30 percent in the same time period. Buildings, improvements and machinery flows also increase but by a lesser amount (10 percent).

Capital flows demands, (Table 39), are financed jointly by internal funds (savings ratio[1] x net farm income), and external funds (debt). The share financed by internal funds is projected to decrease as the growth in capital demand increases faster than net income. Thus, the remaining share is financed by a debt load which must expand to over $300 billion by 2000, doubling the 1980 level.

[1]Results of the BASE alternative under various savings ratios appear in Drabenstott, 1980.

Table 38. Capital flows in U.S. agriculture projected to 2000 under the BASE alternative

Year[a]	Real estate	+	Buildings and improvements	+	Machinery flow	+	Net change in financial assets	+	Net change in crop and livestock inventories	Total capital flow[c]
	(million 1978 dollars)									
1981-1982[b]	13,603		5,507		7,523		-672		763	26,728
1983-1984[b]	14,087		5,559		7,779		-372		438	27,492
1985-1986[b]	14,518		5,589		7,910		-154		512	28,376
1986-1990[b]	15,074		5,641		7,942		-959		540	29,082
1991-1995[b]	16,274		5,844		8,074		-1,268		466	30,268
1996-2000[b]	17,674		6,129		8,375		-2,613		397	32,008

[a]Two and five year averages

[b]Numbers to the right reflect capital flows/year

[c]May not add due to rounding

Table 39. Financing of capital flows and total debt load to 2000 under the BASE alternative

Year[a]	Total capital flow	=	Internal funds	+	Increase in debt	Net farm income	Total farm debt	Farm debt / Total assets
	(million 1978 dollars)							
1981-1982[b]	26,728		19,141 (72)[c]		7,587	31,379	153,112	.176
1983-1984[b]	27,492		18,524 (67)[c]		8,968	30,367	170,233	.188
1985-1986[b]	28,376		17,641 (62)[c]		10,735	28,919	190,890	.194
1986-1990[b]	29,082		17,150 (59)[c]		11,932	28,115 (70,850)[d]	220,438 (555,504)[d]	.209
1991-1995[b]	30,268		18,638 (61)[c]		11,630	30,554	290,334	.230
1996-2000[b]	32,008		21,408 (67)[c]		10,600	35,095	335,313	.237

[a]Two and five year averages

[b]Numbers to the right reflect capital flows financing/year

[c]Share of total capital flow financed by internal sources

[d]Nominal terms assuming 8 percent annual inflation

As the debt load increases relative to net income, the debt/asset ratio also rises (Table 39). The model predicts that farmers will become increasingly leveraged as time passes. One reason may be that farm assets will continue to yield cash income/capital gain return ratios of about one. Thus, increasing capital flow demands create a cash flow problem and must be financed in part by debt which is obtained through a strong equity position. Farmers will continue to finance internally as much as possible, but because of the relatively low cash income returns on farm assets, increased leverage is probable. Compared to the past decade (Table 40) the model predicts a higher rate of increase in the debt/asset ratio through 1990 and beyond.

Increased Petroleum Price Alternatives

Up to this point, rising energy prices are predicted to increase producers' input costs and increase the cost of agricultural products to consumers. A third effect of rising energy prices is an increase in the net incomes of farmers as a whole (Table 41). As agricultural output drops, and an inelastic demand for agricultural commodities expands, the resulting effect by 1990 is a 23 percent increase in net farm income over the BASE estimate under the HIGH energy price alternative.

Total capital flow is predicted to fall, but slightly, as petroleum prices rise when compared to the BASE (Table 42). Two effects are at work in the production of these results. First, a substitution effect can be isolated by examining machinery flows (Table 42). A decline in these flows results as higher energy prices elevate the cost of building and operating farm machinery. The second and opposite effect is an

Table 40. Debt/asset ratio for U.S. agriculture from 1950-1979 with projections to 2000 under the BASE alternative

Year	Debt/asset	Year	Debt/asset	Year	Debt/asset
1950	.093	1962	.130	1974	.155
1951	.085	1963	.138	1975	.158
1952	.086	1964	.146	1976	.157
1953	.096	1965	.151	1977	.160
1954	.103	1966	.156	1978	.171
1955	.105	1967	.160	1979	.169
1956	.108	1968	.165	1981-1982	.176
1957	.106	1969	.167	1983-1984	.188
1958	.107	1970	.168	1985-1986	.194
1959	.113	1971	.167	1986-1990	.209
1960	.118	1972	.168	1991-1995	.230
1961	.124	1973	.166	1996-2000	.237

SOURCE: [Hughes et al., 1980].

income effect. Rising net income is capitalized into the value of land and buildings (Table 42), and this increase in the value of land and buildings capital flow almost completely offsets the fall due to declining machinery flows. Thus, farmers total capital demand flows should not vary much from the BASE projections through time, even during periods of rising prices for energy.

As mentioned previously, the BASE projects a real increase in capital demands of agriculture over 20 percent by 2000. Under constant real energy prices (BASE), this increased demand will be financed by external funds (debt) at an increasing rate to 2000. But, as petroleum prices rise, net income will rise allowing the capital financing burden to shift away from debt sources. By 1985, the results of rising energy prices will be an increase in net income of 15 percent and a decrease in farm debt of 6 percent under the most extreme petroleum price alternative,

Table 41. Financing of capital flows and total debt load for five alternatives to 2000

Year	Alternative				
	BASE	MOD-T	MOD	HIGH-T	HIGH
	(Million 1978 Dollars)				
	Internal Funds				
1981-1982	19,141	19,273	19,273	19,418	19,418
1983-1984	18,524	19,028	19,028	19,611	19,611
1985-1986	17,640	18,797	18,797	20,163	20,163
1986-1990	17,150	19,558	19,558	22,753	22,753
1991-1995	18,637	25,125	25,648	29,297	29,100
1996-2000	21,407	32,169	32,340	32,909	32,958
	U.S. Net Farm Income				
1981-1982	31,378	31,596	31,596	31,833	31,833
1983-1984	30,367	31,193	31,193	32,149	32,149
1985-1986	28,919	30,815	30,815	33,055	33,055
1986-1990	28,115	32,063	32,063	37,301	37,301
1991-1995	30,554	41,189	42,140	56,475	58,134
1996-2000	35,095	54,346	58,551	77,541	84,874
	Total Outstanding Farm Debt				
1981-1982	153,112	152,670	152,670	152,209	152,209
1983-1984	170,233	168,010	168,010	165,625	165,625
1985-1986	190,890	185,013	185,013	178,589	178,589
1986-1990	220,438	206,079	206,079	189,907	189,907
1991-1995	280,333	236,176	234,505	195,013	195,013
1996-2000	335,312	242,238	237,492	195,013	195,013
	Farm Debt/Asset Ratio				
1981-1982	.176	.176	.176	.176	.176
1983-1984	.188	.188	.188	.181	.181
1985-1986	.194	.194	.194	.187	.187
1986-1990	.209	.197	.197	.184	.184
1991-1995	.230	.197	.197	.156	.156
1996-2000	.237	.170	.170	.132	.132
	Farm Debt/Net Income Ratio				
1981-1982	4.8	4.8	4.8	4.8	4.8
1983-1984	5.6	5.3	5.3	5.2	5.2
1985-1986	6.6	6.0	6.0	5.4	5.4
1986-1990	7.8	6.4	6.4	5.1	5.1
1991-1995	9.2	5.7	5.6	3.5	3.4
1996-2000	9.5	4.4	4.1	2.5	2.3

Table 42. Uses of U.S. farm capital flow for five alternatives to 2000

Year	BASE	MOD-T	MOD	HIGH-T	HIGH
	Alternatives				
	(million 1978 dollars)				
	Real Estate Capital Flow				
1981-1982	13603.2	13604.0	13604.0	13604.9	13604.9
1983-1984	14087.3	14094.2	14094.2	14102.6	14102.6
1985-1986	14518.2	14540.5	14540.5	14567.4	14567.4
1986-1990	15074.0	15142.4	15142.4	15223.0	15223.0
1991-1995	16274.5	16519.8	16538.1	16914.8	16933.1
1996-2000	17673.8	18299.6	18363.1	19018.9	19147.5
	Buildings and Improvements Capital Flow				
1981-1982	5507.3	5508.4	5508.4	550910	5509.9
1983-1984	5559.3	5568.5	5568.5	5579.8	5579.8
1985-1986	5589.4	5617.2	5617.2	5651.6	5651.6
1986-1990	5641.1	5712.5	5712.5	5808.5	5808.5
1991-1995	5844.0	6072.9	6089.2	6423.5	6452.4
1996-2000	6129.1	6607.5	6692.9	7185.8	7339.6
	Machinery Capital Flow				
1981-1982	7522.7	7332.0	7332.0	7141.6	7141.6
1993-1984	7778.9	7285.1	7285.1	6796.4	6796.4
1985-1986	7910.0	7132.7	7132.7	6373.3	6373.3
1986-1990	7942.2	6855.0	6855.0	5923.2	5923.2
1991-1995	8074.2	6639.3	6468.8	5919.6	5695.1
1996-2000	8375.3	6959.0	6623.6	6254.0	5741.6
	Net Change in Financial Assets				
1981-1982	-672.1	-679.9	-679.9	-688.0	-688.0
1983-1984	-371.9	-421.2	-421.2	-477.7	-477.7
1985-1986	-153.9	-267.7	-267.7	-402.4	-402.4
1986-1990	-959.3	-1642.1	-1642.1	-2468.9	-2468.9
1991-1995	-1267.7	-2676.0	-2684.9	-2721.4	-2721.4
1996-2000	-2612.6	-995.9	-986.9	-34.9	-34.9
	Net Change in Stored Crop Inventories				
1981-1982	-103.2	-117.1	-117.1	-134.7	-134.7
1983-1984	56.1	16.6	16.6	-34.0	-34.0
1985-1986	197.6	134.6	134.6	52.1	52.1
1986-1990	209.9	131.7	131.7	31.7	31.7
1991-1995	113.5	16.2	-94.5	-213.1	-233.1
1996-2000	59.9	-32.8	73.0	-345.3	-119.6

Table 42. (continued)

Year	Alternatives BASE	MOD-T	MOD	HIGH-T	HIGH
	- - - - - - - - - (million 1978 dollars) - - - - - - - - - -				
	Net Change in Livestock Inventories				
1981-1982	870.1	865.3	865,3	859.2	859.2
1983-1984	382.3	361.4	361.4	334.8	334.8
1985-1986	314.4	282.9	282.9	242.2	242.2
1986-1990	330.1	300.4	300.4	258.9	258.9
1991-1995	351.6	363.7	349.9	523.7	523.8
1996-2000	336.8	522.8	587.6	795.5	849.8
	Total Capital Flow				
1981-1982	26,728.07	26,512.83	26,512.83	26,292.98	26,292.98
1983-1984	27,491.97	26,904.51	26,904.51	26,301.91	26,301.91
1985-1986	28,375.59	27,440.37	27,440.37	26,484.32	26,484.32
1986-1990	29,081.83	27,816.79	27,816.79	26,655.57	26,655.57
1991-1995	30,267.97	29,927.83	28,767.32	29,297.17	29,100.02
1996-2000	32,007.85	31,356.05	31,340.17	31,909.01	31,958.93

(Table 41). The implication of Table 41 is that the farm sector will be better able to internally finance an ever increasing capital flow expense as petroleum prices rise.

Rising petroleum prices will also increase the farming sectors ability to manage increased debt as the D/I ratio (Table 41) reveals. The BASE alternative projected a doubling of the current D/I ratio by 2000. But, under the HIGH petroleum price alternative, the present D/I ratio is maintained to 1990 and actually reduced beyond 1990.

In a slightly paradoxical manner, petroleum price increases can actually benefit the farm sector. These increases may restrict some input usage, crop yields and evantually crop supplies. Declining crop supplies will raise crop prices which will be translated into higher feed costs for livestock producers. This will serve to limit output and raise the

the prices of livestock commodities as well. But, just as consumers will suffer under these higher prices, producers will gain as net incomes rise.

In the financial sector, total capital flow demands will be relatively unaffected by rising diesel prices as the fall in machinery capital flows is neutralized by the rise in the value of land and buildings capital flows. The significant effect of rising diesel prices will be to increase the ability of farmers to manage and internally finance their debt.

IX. LOW EXPORT SCENARIO

Because oil and energy are world market commodities, an increase in future petroleum prices may adversely affect real incomes in many other parts of the world including Eastern Europe, Western Europe, USSR, and Japan. Thus, U.S. agricultural export demand could decrease as the ability of the rest of the world to purchase U.S. commodities decreases. This situation is simulated in our study by using a Low-Export Scenario containing the same energy price alternatives as before (MOO-T, MOO, HIGH-T, HIGH) out with lower crop export trends. The original trends, shown in Chapter XI, are duplicated for the Low-Export Scenario to 1985. But, to simulate a decrease in foreign demand for U.S. crop commodities beyond 1985, the 1985 export levels are held constant through 2000 for the Low-Export Scenario.

The decreased export demand has little additional effect on the preinput and input results from the model as they coincide closely to the trended export results of Chapters IV and V. That is, higher energy prices cause a reduction (from BASE projections) of water, machinery, fertilizer, and chemical use in similar magnitudes as higher energy prices affected the higher trended export demand scenario. Thus, as energy prices rise, estimated total crop production is reduced from the BASE similarly under both export scenarios (Tables 28, 43). Conversely, crop inventories and crop prices are affected greatly by lower export demands. Inventories of U.S. crops under the Low-Export scenario are reduced as energy prices rise. But the reduction is much

Table 43. Estimated U.S. crop production for five alternatives to 2000, Low-Export Scenario

Year	Alternative				
	BASE	MOD T	MOD	HIGH T	HIGH
	Feed Grains (million tons)				
1981-1982	228.96	227.96	227.70	226.44	226.44
1983-1984	237.92	235.37	235.37	232.80	232.80
1985-1986	247.32	243.26	243.26	239.11	239.11
1986-1990	257.16	254.15	254.15	248.26	248.26
1991-1995	275.29	271.15	270.76	264.82	262.69
1996-2000	294.79	290.06	283.65	285.28	282.22
	Wheat (million bushels)				
1981-1982	2174.46	2166.76	2166.76	2159.05	2159.02
1983-1984	2270.59	2249.75	2249.75	2228.66	2228.66
1985-1986	2336.64	2303.44	2303.44	2268.83	2268.83
1986-1990	2387.93	2355.22	2355.22	2313.70	2313.70
1991-1995	2494.16	2400.34	2405.13	2379.20	2367.40
1996-2000	2617.10	2501.31	2439.77	2465.07	2450.18
	Soybeans (million bushels)				
1981-1982	1918.27	1913.11	1913.11	1907.95	1907.95
1983-1984	2014.29	2001.27	2001.27	1988.26	1988.26
1985-1986	2111.31	2090.50	2090.50	2069.65	2069.65
1986-1990	2243.91	2190.16	2190.16	2161.94	2161.94
1991-1995	2520.09	2401.30	2392.02	2388.46	2380.56
1996-2000	2804.79	2603.49	2621.24	2616.70	2590.08

smaller than the inventory reductions in the alternatives where exports are allowed to rise to 2000. Crop prices reflecting inventories, rise in this scenario as energy prices rise (Table 44) but the reduction of export demand serves to restrict prices from rising to the levels under trended exports (Table 29).

As crop commodities used for feed become more expensive with rising prices, livestock and poultry production is reduced. But, again, because the lower export demands in this scenario restrict the rise of crop prices to some extent, livestock and poultry production is not reduced as significantly as in Figure 21 under trended exports. In fact (Table 45) illustrates a relatively small reduction in poultry production as petroleum prices rise (although lamb production is still drastically reduced). It follows then, that livestock and poultry prices rise from the BASE as energy prices rise (Table 46) but rise less than in Figure 23, where the exports are not reduced. The end result can be captured in Table 47. Net income and internal funds are increased 32 percent from the BASE to the HIGH alternative in 2000. But this increase is 45 percent less than the increase under trended exports (Table 41).

In summary, when lower export demands are incorporated into this energy study, the severe impact of increased energy prices in agriculture decrease. Rising energy prices combined with the lower exports of crop commodities reduce the usage of energy-intensive inputs, lower production, and increase from commodity prices and net income. Since the lower export demands were found to counteract impacts of rising

Table 44. Estimated U.S. crop prices received by farmers for five alternatives to 2000, in 1978 prices, Low-Export Scenario.

Year	Alternative				
	BASE	MOD T	MOD	HIGH T	HIGH
			Feed grains ($/ton)		
1981-1982	83.74	84.58	84.58	85.42	85.42
1983-1984	81.03	83.57	83.57	86.13	86.13
1985-1986	75.84	80.76	80.76	85.92	85.92
1986-1990	69.64	73.86	73.86	83.57	83.57
1991-1995	63.34	59.73	60.68	80.82	86.03
1996-2000	63.00	47.48	53.23	79.19	90.36
			Wheat ($/bushel)		
1981-1982	2.56	2.58	2.58	2.60	2.60
1983-1984	2.53	2.62	2.62	2.70	2.70
1985-1986	2.32	2.50	2.50	2.69	2.69
1986-1990	2.10	2.20	2.20	2.53	2.53
1991-1995	1.88	1.69	1.71	2.21	2.27
1996-2000	1.85	1.24	1.40	1.89	2.06
			Soybeans ($/bushel)		
1981-1982	8.25	8.28	8.28	8.31	8.31
1983-1984	8.01	8.16	8.16	8.31	8.31
1985-1986	7.64	7.89	7.89	8.24	8.24
1986-1990	7.38	7.05	7.05	7.84	7.84
1991-1995	7.30	5.95	6.07	7.74	7.95
1996-2000	7.61	4.83	5.19	6.82	7.85

Table 45. Estimated U.S. livestock and poultry production, Low-Export Scenario

Year	BASE	Alternative MOD T	MOD	HIGH T	HIGH
		Beef (million pounds)			
1981-1982	27171.45	27171.45	27171.45	27171.45	27171.45
1983-1984	28776.64	28875.36	28775.36	28774.09	28774.09
1985-1986	30182.26	30162.97	30162.97	30143.96	30143.96
1986-1990	31877.10	31763.29	31649.91	31649.91	31649.81
1981-1995	35000.55	34770.64	34772.42	34770.76	34166.42
1996-2000	36626.57	36905.60	36824.95	35375.83	35255.45
		Pork (million pounds)			
1981-1982	13541.73	13541.73	13541.73	13541.73	13541.73
1983-1984	13334.06	133304.38	13274.66	13274.66	13274.66
1985-1986	13299.69	13190.21	13080.25	13080.25	13080.25
1986-1990	13564.46	13397.31	13397.31	13116.95	13116.95
1991-1995	14140.04	14449.68	14424.11	13632.07	13584.48
1996-2000	14495.16	15273.75	15174.71	14266.65	13936.75
		Lamb (million pounds)			
1981-1982	240.53	240.53	240.53	240.53	240.53
1983-1984	230.56	229.74	229.74	228.93	228.93
1985-1986	202.99	184.67	184.67	170.78	170.78
1991-1995	228.74	198.14	197.23	161.15	161.09
1996-2000	259.17	294.17	273.78	167.61	167.46
		Chicken (million pounds)			
1981-1982	11492.59	11489.78	11489.78	11486.98	11486.98
1983-1984	12138.72	12117.15	12117.15	12095.55	12095.55
1985-1986	12882.34	12826.34	12826.34	12770.07	12770.07
1986-1990	13811.17	13803.23	13803.23	13684.97	13684.97
1991-1995	15634.54	15804.55	15801.31	15493.50	15456.18
1996-2000	17391.71	17779.54	17689.52	17370.54	17254.60
		Turkey (million pounds)			
1981-1982	2309.49	2309.21	2309.21	2308.94	2308.94
1983-1984	2368.27	2365.36	2365.36	2362.50	2362.50
1985-1986	2459.81	2459.81	2452.63	2452.63	2452.63
1986-1990	2585.34	2584.00	2584.00	2569.53	2569.53
1991-1995	2807.08	2844.12	2841.71	2801.77	2796.92
1996-2000	3032.05	3093.04	3082.05	3054.04	3035.14

Table 46. Estimated U.S. price of livestock and poultry in 1978 dollars, Low-Export Scenario

Year	Alternative				
	BASE	MOD T	MOD	HIGH T	HIGH
			Beef (¢/pound)		
1981-1982	135.52	135.52	135.52	135.52	135.52
1983-1984	130.23	130.26	130.26	130.29	130.29
1985-1986	128.47	128.81	128.81	129.14	129.14
1986-1990	128.36	130.20	130.20	132.08	132.08
1991-1995	131.92	135.20	135.24	144.79	144.86
1996-2000	139.97	135.36	135.62	159.06	161.05
			Pork (¢/pound)		
1981-1982	88.34	88.34	88.34	88.34	88.34
1983-1984	87.89	88.26	88.26	88.64	88.64
1985-1986	86.80	88.25	88.24	89.68	89.68
1986-1990	83.32	85.95	85.95	90.00	90.00
1991-1995	80.13	77.53	77.88	90.81	91.41
1996-3000	80.56	69.63	71.22	90.17	94.84
			Lamb (¢/pound)		
1981-1982	138.49	138.49	138.49	138.49	138.49
1983-1984	137.46	137.59	157.59	137.71	137.71
1985-1986	138.09	138.71	138.71	139.32	139.32
1986-1990	138.38	139.84	139.84	141.57	151.57
1991-1995	140.42	139.40	139.53	145.34	145.53
1996-2000	145.64	139.09	140.21	149.46	151.43
			Chicken (¢/pound)		
1981-1982	34.50	34.55	34.55	34.60	34.60
1983-1984	34.09	34.54	34.54	34.99	34.99
1985-1986	32.40	33.58	33.68	34.95	34.95
1986-1990	31.18	31.88	31.88	34.83	34.83
1991-1995	34.46	30.79	30.94	39.29	40.07
1996-2000	37.83	28.31	30.30	40.20	43.45
			Turkey (¢/pound)		
1981-1982	54.05	54.06	54.06	54.07	54.07
1983-1984	51.14	51.28	51.28	51.42	51.42
1985-1986	48.30	48.83	49.35	49.35	49.35
1986-1990	45.52	46.54	46.54	48.10	48.10
1991-1995	43.88	43.91	44.05	49.78	50.00
1996-2000	45.42	40.17	41.56	52.51	54.01

Table 47. Internal funds and net income of U.S. farms in million 1978 dollars, Low-Export Scenario

Year	Alternative				
	BASE	MOD T	MOD	HIGH T	HIGH
			Internal Funds		
1981-1982	19141.16	19286.64	19286.64	19430.95	19430.95
1983-1984	18524.13	19113.02	19693.86	19693.86	19693.86
1985-1986	17640.66	18868.67	18869.67	20228.19	20228.19
1986-1990	17150.28	17671.90	17671.90	20694.18	20694.18
1991-1995	18637.97	16315.52	16315.52	23944.95	24914.16
1996-2000	21407.97	12171.65	14138.27	24667.16	28309.46
			U.S. Net Farm Income		
1981-1982	31378.95	31617.46	31617.46	31854.02	31854.02
1983-1984	30367.42	31332.82	31332.82	32285.02	32285.02
1985-1986	28919.13	3o832.25	30932.25	33160.97	33160.97
1991-1990	30554.07	26197.57	26736.77	39254.04	40842.91
1996-2000	35095.05	19953.52	23177.48	40438.00	46408.96

X. SUMMARY

It is estimated the United States reached its petroleum production peak in 1970. Predictions indicate world oil production likely will peak before 2000. Yet, demand for oil in the United States remains relatively high. The real price of gasoline decreased 40 percent from 1935 to 1970. U.S. demands increased steadily to 1978 since, even as domestic production declined, the nation was able to draw on imported petroleum. Imports now constitute slightly more than one-third of U.S. oil consumption.

As U.S. dependency on foreign oil climbed, so did the organization of its suppliers. Ultimately whenever the monopolistic muscles of our suppliers were flexed through embargoes or price hikes, the ripple was felt in every U.S. economic sector.

The real price of oil rose significantly (over 30 percent) during 1972-1974 for the first time since the late fifties. Although relatively constant from 1974-1978, the real price of petroleum again has leaped upward. And, most projections reveal little chance of relief from spiraling oil prices as far into the future as the year 2000. Even with a vigorous alternative fuels program, the United States cannot expect to replace any significant amount of petroleum with alternative sources of energy until at least 1990. Therefore, the U.S. may be facing increasing oil prices for some time into the future, (even though the United States currently is experiencing a short-term glut of oil).

What do these prospective prices mean for U.S. agriculture? Most inputs purchased in agricultural production are directly or indirectly dependent on petroleum products. Machinery operation is directly affected by petroleum prices through the use of fuel. Energy is a major input of irrigated agriculture. Large amounts of petroleum are used to produce the chemical inputs (fertilizer, pesticides, etc.) which characterize today's agriculture. Livestock production also is affected directly by petroleum prices. The most important results come indirectly through the previously mentioned crop production affects in the form of higher feed costs. Crop and livestock production is not the only segment of agriculture which depends on petroleum. Food processing and marketing costs also are greatly affected at the wholesale and retail level.

This econometric study projects the effects of five possible oil price environments on the U.S. agricultural sector and its important subsectors to the year 2000. In general, the effects of rising petroleum prices are widespread in all sectors of the agricultural economy. The initial results reflect higher prices of certain energy intensive agricultural inputs. Eventually, fertilizer, pesticide, and machinery purchases will decline from the BASE due to the relative expense of these inputs. Irrigation is also an energy intensive practice that will decrease significantly under higher energy prices. The historical decrease in farm and hired labor, on the other hand, and as predicted in the model, may slow in order to help counteract the effects of other input usage decreases.

As the growth in total input usage is ultimately decreased, increases in crop yields are predicted to eventually slow. Although this slowdown is not drastic, it does decrease total production enough annually to lessen crop inventories. This decrease in crop supply increases the prices received for crop commodities.

Crop price increases provide negative impacts for livestock producers as feed costs rise. With higher feeding costs, livestock production is reduced and livestock inventories depleted. As supplies fall, farm prices for livestock rise. Meat retailers are expected to face higher wholesale prices and higher marketing costs due to higher petroleum prices. This increases the farm-retail margin and raises retail meat prices. Consumers, in turn, react by reducing meat consumption slightly per person.

Because the price elasticity of demand for farm commodities is inelastic, a rise in commodity prices will have little effect on consumer demand. Therefore, farm operators are expected to realize an actual increase in net income nationally as petroleum prices rise. This increase in national net farm income leads to a similar increase in internal funds used to meet the costs of expanding capital demands. As the capital financing burden shifts from external to internal funds, the total outstanding farm debt load falls. And, as land prices rise to reflect higher returns, the debt/asset ratio decreases from the projected trend as petroleum prices rise.

A Low-Export Scenario is used to simulate possible decreased demands for U.S. crop commodities if petroleum prices rise worldwide, causing foreign real incomes to fall. This decreased demand will result in lowering the severity of effects caused by rising petroleum prices. Crop and livestock inventories will be reduced, commodity prices and national farm income increased, and the growth in farm debt slowed with lower export demands and rising petroleum prices. But, these changes will not be nearly so great in comparison to petroleum prices rising in an environment of high export demands.

The most significant policy implication which can be drawn from this study is that a lack of specific long-run policy to affect the increases in petroleum prices would most benefit farmers. That is, because increases in petroleum prices increase average national farm income in the long run, the policy which benefits farmers most is no policy. (Although it is probable that marginally operated farms and beginning farmers may not be able to pay for the initial costs of increasing petroleum in the short run and therefore may exit the industry.)

XI. LIMITATIONS OF THE STUDY

This study employs an econometric model which bases projections on historical data. Therefore, it may not predict with perfect accuracy the effects of future shocks to the agricultural economy currently absent from the economy. For example, as petroleum prices rise, technology may develop to reduce consumption through pure consumption decreases and/or by substitution of other energy forms. This will result in dampening the projected decrease in petroleum-based input usage which will in turn reduce effects of rising petroleum prices on production, prices, net income, and capital flow. To minimize the chances of structural change errors, more emphasis should be placed on results from the earlier years of the projected period. In other words, there is less chance of any structural changes within the agricultural sector in the short run. This is not to say long-run projections are useless. On the contrary, they serve to enlighten planners to possible policy needs. But, the longer the prediction period, the greater the chance of model misspecification in those larger periods.

It is probable that production cost increases from higher petroleum prices will be quite different between different regions of the United States. Even though the model predicts rising national farm income as petroleum prices rise, some regions may in fact suffer a loss of income. This would be especially true for regions dependent upon groundwater irrigation. But, because the model is national in scope, these regional differences are averaged out.

The model does not explicitly incorporate three areas which could have some effect on this study. First, no-till farming is an option which is not in the model but may be used rather than labor to substitute for energy-intensive inputs as energy prices rise. Secondly, marginal lands, which are not included in the model, may be brought into production in the future, requiring greater fertilizer. Thirdly, alternatives such as the conversion of corn to ethanol and soybeans to diesel fuel are not options in the model.

The export demand projections, described earlier, are based on historical trends with recent increases (in the 70s) taken into account. Because the export demand sector is an exogenous portion of the model, endogenous interaction between exports and the rest of the agriculture model cannot be analyzed (different predetermined levels of exports could be analyzed). Therefore, in the future, large unpredicted shifts in exports could sway some results. The Center for Agricultural and Rural Development hopes to endogenize the export sector shortly.

XII. BIBLIOGRAPHY

Alexander, Sidney S.
1975 "Paying for Energy." Report of the 2th Century Fund Task Force on the International Oil Crises. McGraw-Hill. New York.

Barton, Weldon
1979 "Energy Inputs." Presented at the Agricultural Outlook Conference, Washington, D.C., November 5-8.

Christensen, Douglas A., Andrew S. Morton, and Earl O. Heady
1980 National and Regional Surface and Groundwater Demand Function Estimates: A National Linear Programming Approach to Simulated Increases in Water Prices and Their Effect on U.S. Agriculture. CARD Report forthcoming 1981. Ames, Iowa: Center for Agricultural and Rural Development.

Committee on Nuclear and Alternative Energy Systems (CONAES), The National Research Council
1980 Energy in Transition 1985-2010. San Francisco: W.H. Freeman and Company.

Committee on Nuclear and Alternative Energy Systems (COANES).
1978 "U.S. Energy Demand: Some Low Energy Futures," Science, April 14.

Drabenstott, Mark
1981 "Capital and credit demands in U.S. agriculture: Projections for alternative economic and policy environments." Unpublished Ph.D. dissertation.

Dvoskin, Dan, Earl O. Heady, and Burton C. English
1978 "Energy Use in U.S. Agriculture: An Evaluation of National and Regional Impacts From Alternative Energy Policies." CARD Report 78, Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa.

Ecklund, Georgi
1980 "OPEC Crude: "Real" Prices Haven't Gone Up Since 1974." World Oil. January, pp. 119-122.

English, Burton C., Raymond Joe Schatzer, Roland K. Roberts, and Earl O. Heady
1981 Potential Long-Term Agricultural Impacts of the Russian Grain Embargo. CARD Report 97, Ames, Iowa. Center for Agricultural and Rural Development.

Exxon Company
1979 U.S.A.'s Energy Outlook 1980-2000. Exxon Company, Texas. December.

Farrell, Kenneth R.
1979 "Food Prices in 1980." Presented at the Agricultural Outlook Conference, Washington, D.C., November.

Gaddy, J. L.
1977 "Toward Establishing a National Energy Policy," Energy Communications, Vol. 3, No. 3.

Hammoudeh, Shawkat
1979 "The Future Oil Price Behavior of OPEC and Saudi Arabia." Energy Economics. July.

Hauschen, Larry D.
1979 "Impact of Energy on Interfiber Competition and the Outlook for Cotton Producers." Presented at the Agricultural Outlook Conference, Washington, D.C., November 5-8.

Heady, Earl O.
1979 "Economic and Social Conditions Relating to Agriculture and its structure to Year 2000." Paper presented at a meeting of research directors of developed countries, Organization for Economic and Cooperation, Paris, France, December 10.

Heady, Earl O. and Luther G. Tweeten
1963 Resource Demand and Structure of the Agricultural Industry. Iowa State University Press, Ames.

Heady, Earl O. and Martin H. Yeh
1959 "National and Regional Demand Functions for Fertilizer." Journal of Farm Economics, XL1, pp. 332-348.

Hjort, Howard W.
1979 "Food and Agriculture: Policy Issues for the 1980s." Presented at the Agricultural Outlook Conference, Washington, D.C., November 5-8.

Hoffman, George
1980 USDA, ESCS, Personnel Communication, August 1.

International Research and Technology Inc. The Transportation Energy
1978 Conservation Network, for the Data Analysis Branch, TEC, ERDA.

Johnston, J. "Econometric Methods"
1972 "Econometric Methods." New York, McGraw-Hall Book Company, 2nd Edition.

Lönnroth, Mins, Peter Steen, and Thomas Johnasson
1980 Energy in Transition. University of California Press, Berkeley, California.

Marshall, Eliot
1980 "Energy Forecasts: Sinking to New Lows." Science, Vol. 208, June 20.

Meekhof, Ronald, Gill Mohinder, and Wallace Tyner
1980 Gasohol: Prospects and Implications, Washington, D.C. Economics, Statistics, and Cooperatives Service, USDA.

Melichar, Emanuel
1972 "Financing Agriculture: Demand for and Supply of Farm Capital and Credit." American Journal of Agricultural Economics 55(2): 313-325.

Melichar, Emanuel and Martha Waldheger
1979 Agricultural Finance Databook: Annual Series. Washington, D.C.

Miller, Dwight L.
1979 "Energy From the Farm." Presented at the Agricultural Outlook Conference, Washington, D.C., November 5-8.

Penson, John B., Jr., David A. Lins, and George D. Irwin
1971 "Flow of Funds Social Accounts for the Farm Sector." American Journal of Agricultural Economics. Vol. 53(1).

Pimentel, D., W. R. Lynn, W. K. MacReynolds, M. T. Hewes, and S. Rush
1974 "Workshop on Research Methodologies for Studies of Energy, Food, Man and Environment, Phase I," Tech. Rep., Cornell University Center for Environmental Quality Management, Ithaca, New York, June.

Popcock, C. C.
1979 "Prospects for Oil and Gas: A Look Ahead to Year 2000." World Oil, October, p. 107-111.

Roberts, Roland K.
1980 "Fertilizer Demand Functions for Specific Nutrients Applied to Four Major U.S. Crops." Unpublished manuscript, Center for Agricultural and Rural Development.

Roberts, Roland K. and Earl O. Heady
1980 An Analysis of Selected Policy Impacts on the U.S. Livestock Sector by an Econometric Simulation Model, CARD Report No. 92. Ames, Iowa: Center for Agricultural and Rural Development.

Roberts, Roland K. and Earl O. Heady
1979 A Five-Commodity Econometric Simulation Model of the U.S. Livestock and Poultry Sector. Ames, Iowa, Center for Agricultural and Rural Development, CARD Report 83T.

Roberts, R. and E. O. Heady
1979 Fertilizer Demand Functions for Specific Nutrients Applied to Four Major U.S. Crops. Unpublished manuscript.

Schatzer, Raymond Joe, Roland K. Roberts, Earl O. Heady, and Kisan R. Gunjal
1981 An Econometric Simulation Model to Estimate Input Stocks and Expenses, Supply Response, and Resource Demand for Several U.S. Agricultural Commodities. CARD Report 102T. Ames, Iowa: Center for Agricultural and Rural Development.

Schun, Sam H., Joel Darmstadter, Harry Perry, William Lamsay, and Milton Russell
1979 Energy in America's Future. Published for Resources for the Future by The Johns Hopkins University Press, Baltimore, Maryland.

Shonka, D. B., A. S. Loebl, P. D. Patterson
1977 Transportation Energy Conservation Data Book. Edition 2. Oak Ridge National Laboratory, Oak Ridge, Tennessee. October.

Stanford Research Institute
1977 Transportation in America's Future: Potentials for the Next Half Century. Report No. DOT-TPI-20-77-21, June.

Stobaugh, Robert and Daniel Yugin
1979 "Energy Future: Report of the Energy Project at the Harvard Business School." Random House, New York.

Transportation Energy Conservation Division, ERDA
1977 TEC Data Book, Data Analysis Branch, September.

Tweeten, Luther
1979 "Agricultural Policy Issues for the 1980s: Discussion." Presented at the Agricultural Outlook Conference, Washington, D.C., November 5-8.

Tyner, Fred and Luther G. Tweeten
1965 "A Methodology for Estimating Production Parameters." Journal of Farm Economics 47:1462-1467.

Tyner, Wallace E.
1980 "Our Energy Transition: The Next Twenty Years." Paper presented at the ASEA annual meeting, Urbana-Champaign, Illinois. July 27-30.

U.S. Department of Agriculture, Economic Research Service
1977 Energy and Agriculture: 1974 Data Base Volume 1 and 2. Government Printing Office, Washington, D.C., April.

U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service
1979 Agricultural Prices. Annual Summary 1978, June.

U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service
1981 Agricultural Statistics.

U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service
1980 Energy and U.S. Agriculture: 1974-1978. Statistical Bulletin 632, April.

U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service
1978 Energy Policies: Price Impacts on the U.S. Food System. Report No. 407, July.

U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service
1980 Farm Income Statistics. No. 627, January.

U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service
1980 U.S. Farm Numbers, Sizes and Related Structural Dimensions. Technical Bulletin No. 1625, July.

U.S. Department of Energy
1976 "Market Oriented Program Planning Study," Final Report, Vol. 1, "Integrated Summary," Washington, D.C., December.

U.S. Department of Energy
1980 Quarterly Report: Energy Information, Government Printing Office, Washington, D.C., April.

U.S. Energy Administration
1981 Executive Summary Circular. March.

World Oil Editorial Staff
1980 "Imports Should Fall in Response to Lower Demand," World Oil. February 15, pp. 69-70.

World Oil Editorial Staff
1980 "U.S. Oil Demand Falls as Prices Rise." World Oil. February 15, pp. 64-65.

APPENDIX A

Model Adjustments and Modifications

Adjustments and modifications of the estimated equations are made to account for assumed changes in consumer tastes and preferences, technological improvements, and other trend forces. These adjustments and modifications are important in providing a meaningful base run for an intermediate or distant future period of analysis, where tastes and preferences and technological growth rates are likely to change from the historical sample period.

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

Trend variables in five equations of the input section are adjusted. The trends for the livestock labor and fuel, oil, and repairs equations are assumed constant at 1976 values. The feed grain, wheat, and cotton fertilizer expense equations include time trends which are assumed to increase by 0.75 percent per year after 1976.

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

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

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

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

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

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

Projected Levels of Exogenous Variables

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

Exports and imports for both livestock and crop commodities are projected using trend variables or they are assumed constant. Ordinary least squares (OLS) or autoregressive least squares (ALS) are used to estimate the trend coefficients.

The following equations are used to project livestock imports and exports and poultry net exports. The figure in the parentheses are t values for the respective variables. The value of R^2, the mean square error (MSE), Dubin Watson coefficient, (DW), ($\hat{\rho}$) also are shown.

$$\text{B-IMP}_t = \underset{}{123.8902} + \underset{(5.837)}{76.5643\ \text{TIME}}, \qquad \hat{\rho} = \underset{(2.348)}{.4671}, \tag{6}$$

ALS, R^2 = .8670, MSE = 49142.4550, DW = 1.5608

$$\text{B-EXP}_t = 28.6993 + \underset{(9.241)}{4.217\ \text{TIME}}, \tag{7}$$

OLS, R^2 = .7952, MSE = 239.5221, DW = 1.449.

$$\text{B-IMP}_t = 123.8902 + 76.5643\ \text{TIME}, \qquad \hat{\rho} = .4671, \qquad (8)$$
$$\qquad\qquad (5.837) \qquad\qquad\qquad (2.348)$$

ALS, R^2 = .8670, MSE = 49142.4550, DW = 1.5608

$$\text{B-EXP}_t = 28.6993 + 4.217\ \text{TIME}, \qquad (9)$$
$$\qquad (9.241)$$

OLS, R^2 = .7952, MSE = 239.5221, DW = 1.449.

$$\text{P-IMP}_t = 13.7807 + 15.2609\ \text{TIME}, \qquad \hat{\rho} = .8554, \qquad (10)$$
$$\qquad (2.136) \qquad\qquad\qquad (5.929)$$

ALS, R^2 = .9527, MSE = 874.6217, DW = 1.1795.

$$\text{P-EXP}_t = 35.0471 + 7.7096\ \text{TIME}, \qquad (11)$$
$$\qquad (5.521)$$

OLS, R^2 = .5808, MSE = 2242.4922, DW = 1.0958.

L-IMP_t = 35.25 which is the 1973-76 average. (12)

$$\text{L-EXP}_t = .1023 + .3531\ \text{TIME}, \qquad \hat{\rho} = .4885, \qquad (13)$$
$$\qquad *5.413) \qquad\qquad\qquad (4.622)$$

ALS, R^2 = .8494, MSE = 1.0972, DW = 1.9666.

$$\text{C-NEXP}_t = -118.9969 + 229.3105\ \text{LOGTIME}, \qquad \hat{\rho} = .7068, \qquad (14)$$
$$\qquad\qquad\qquad\qquad\qquad (5.358)$$

ALS, R^2 = .7510, MSE = 2231.9151, DW = 1.080.

$$\text{T-NEXP}_t = -25.7649 + 34.8693\ \text{LOGTIME}, \qquad \hat{\rho} = .5071, \qquad (15)$$
$$\qquad (3.900) \qquad\qquad\qquad (3.180)$$

ALS, R^2 = .8494, MSE = 71.8139, DW - 1.8087.

The definitions of most of the above variables and symbols are found in Appendix B. These equations are estimated from annual time series data for 1953-76 found in Roberts and Heady, 1980.

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

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

Commodity	1972-76[a]	1980	1990	2000
Beef (million pounds)	1,879.0	2,372.2	3,131.9	3,907.6
Pork (million pounds)	493.4	499.5	668.6	824.3
Lamb and mutton (million pounds)	35.3[b]	35.3	35.3	35.3

[a]SOURCE: [45]

[b]A four-year average for 1973-76.

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

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

Commodity	1972-76[a]	1980	1990	2000
	------(million pounds)------			
Beef	128.2	146.8	189.0	231.1
Pork	291.4	250.9	328.0	405.1
Lamb and mutton	7.2	9.7	13.2	16.7
Chicken	273.6	390.3	429.3	481.9
Turkey	52.6	64.7	74.6	82.7

[a]SOURCE: [USDA, 1978].

Crop imports are assumed to be constant over the 1979-2000 period. Imports of 0.4 million tons, 2.0 million bushels, and 0.05 million bales are assumed for feed grains, wheat, and cotton lint, respectively. Soybean and cottonseed imports are assumed to be zero. The above assumptions are based upon 1972-76 averages for feed grain and cotton lint imports and a 1963-76 average for wheat imports.

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

$$FG\text{-}Y_t = .6690 + \underset{(17.575)}{.0498}\ TIME, \qquad (16)$$

OLS, $R^2 = .9224$, MSE = .0147, DW = 1.4314

$$WT\text{-}Y_t = 15.6801 + \underset{(12.981)}{6255}\ TIME, \qquad (17)$$

OLS, $R^2 = .8647$, MSE = 4.3016, DW = 1.3877.

$$SB\text{-}Y_t = 20.0293 + \underset{(7.693)}{.2746}\ TIME, \tag{18}$$

$$OLS,\ R^2 = .6948,\ MSE = 2.3271,\ DW = 1.5888.$$

$$CT\text{-}Y_t = 2230 + \underset{(4.457)}{.1989}\ LOGTIME, \qquad \hat{\rho} = \underset{(2.454)}{.4311} \tag{19}$$

$$ALS,\ R^2 = .7768,\ MSE = .0060,\ DW = 1.7475.$$

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

Military consumption of livestock commodities is the last group of exogenous variables which are projected by estimated econometric equations. The following equations are used to project livestock and poultry military consumption.

$$B\text{-}MILCONS_t = 33.7430 + \underset{(2.728)}{.2037}\ MILPOP_t, \qquad \hat{\rho} = \underset{(3.610)}{.7647} \tag{20}$$

$$ALS,\ R^2 = .8754,\ MSE = 2467.5413,\ DW = 1.4620.$$

$$P\text{-}MILCONS_t = -6.3338 + \underset{(3.702)}{.0798}\ MILPOP_t, \qquad \hat{\rho} = \underset{(6.139)}{.9006}, \tag{21}$$

$$ALS,\ R^2 = .9128,\ MSE = 337.1776,\ DW = 2.2077.$$

$$L\text{-}MILCONS_t = 1.0 \text{ which is the value of the variable for 1974, 1975,1976.} \tag{22}$$

$$C\text{-}MILCONS_t = \underset{}{-1.4465} + \underset{(2.880)}{.0300}\ MILPOP_t, \qquad = \underset{(4.818)}{.8540} \tag{23}$$

$$ALS,\ R^2 = .8672,\ MSE = 64.1501,\ DW = 2.1077.$$

$$T\text{-}MILCONS_t = 52.2126 + \underset{(4.234)}{7.4795}\ LOGTIME + \underset{(7.829)}{.0257}\ MILPOP_t, \tag{24}$$

$$OLS,\ R^2 = .7471,\ MSE = 39.7913,\ DW = 1.4905.$$

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

Table A-3 shows that military consumption of all livestock and poultry commodities increases except for lamb and mutton. These increases are due to the high levels of the estimated autoregressive parameters ($\hat{\rho}$s) even though military population is held constant. Turkey military consumption increases because it has a positive log time trend.

Another exogenous set of variables includes government policy variables, which are set at anticipated levels. These variables are difficult to project because their levels are determined by the government which offers, modifies, adds to, or eliminates national agricultural policy legislation without much warning. For the BASE and Alternative Runs, only government policies which have influenced the agricultural sector in the past are used. These policy variables are set at levels anticipated for the 1979-2000 period.

Table A-3. Projected levels of military consumption for beef, pork, lamb and mutton, chicken, and turkey for 1980, 1990, and 2000, with actual 1974-76 averages for comparison

Commodity	1974-76[a]	1980	1990	2000
	- - - -(million pounds) - - - - -			
Beef	247.2	274.4	288.1	289.0
Pork	109.6	88.8	99.7	103.6
Lamb and mutton	2.0	1.0	1.0	1.0
Chicken	114.4	42.7	51.4	53.2
Turkey	24.8	27.3	29.6	31.3

[a]SOURCE:

Crop loan rates are assumed to remain constant in real terms at levels which have prevailed over the most recent past. Loan rates are set at \$2.08 per bushel for corn, \$2.46 per bushel for wheat, \$4.50 per bushel for soybeans, and \$.48 per pound for cotton lint. The above loan rates are expressed in 1978 dollars and represent a 1977-78 average for corn, a 1976-78 average for wheat, and the 1978 value for soybeans, and the 1978 value for cotton lint. The cottonseed loan rate is assumed to be zero as it has been since 1971.

Most other government program variables except feed grain, wheat, and cotton government payments are set equal to zero over the analysis period. Government payments are assumed to be constant at \$224.55, \$324.06, and \$110.67 million for feed grains, wheat, and cotton (Stobaugh, Yugin, 1979), respectively. These figures are 1974-77 averages in 1978 dollars. Also, the free market dummy variables (FREE1 and FREE2) are included at a level of 0.5 instead of one in most cases. The exceptions occur in the wheat food demand, commercial demand and government inventory equations and the soybean harvested acreage equation where the value of one is retained throughout the analysis period. The free market dummy variables generally are included at values less than one because it is felt the forces which caused shifts in some of the crop market variables during the mid-1970s will be dissipated somewhat. However, they are not reduced to zero because some of the shifts which occurred are expected to persist into the future. The wheat low loan rate dummy (LLRDUM) is continued at a level of one to the year 2000 allowing the quantity of wheat supplies to have an added effect upon the price of wheat.

Other important exogenous variables are either assumed to be constant or to increase at assumed rates. Those remaining variables which are assumed to be constant are RFC (range feed conditions in 17 western states) which takes on a value of 76.67 (1953-76 variable mean), and the by-product allowances for beef, pork, and lamb which are set at their 1953-76 variables means in 1978 dollars of 9.91, 7.12, and 14.44 cents per pound, respectively. The polyester price is assumed to be constant at its 1972-76 average of 57.77 cents per pound in 1978 dollars.

Table A-4 gives projected levels of certain other important exogenous variables. The Consumer Price Index 1967 = 100 (CPI) is assumed to grow at former President Carter's original guideline rate of 5.75 percent per year and the index of prices paid by farmers 1967 = 100 (IPPBF) is assumed to increase at a rate of 6 percent because it traditionally has increased faster than CPI.

Table A-4. Assumed levels of other important exogenous variables for 1980, 1990, and 2000 with 1976 actual values for comparison

Variable	1976	1980	1990	2000
CPI (1967 = 100)[a]	170.50	218.60	382.50	668.80
IPPBF (1967 = 100)[b]	201.00	259.60	464.80	832.40
INC (bil. $)[a, d]	693.10	791.70	1,124.20	1,596.30
PINC ($)[a, d]	3,222.00	3,573.80	4,714.40	6,311.20
POP (mil.)[b]	213.00	220.00	224.50	262.30
W(MA4)[c, d]	2.95	3.05	4.40	3.58

[a]SOURCE: [Bureau of Economic Analysis, 1977]

[b]SOURCE: [United States Department of Agriculture, 1976]

[c]SOURCE: [Bureau of Census, 1976].

[d]These variables are deflated by CPI (1967 = 100)

Growth rates for personal disposable income in 1967 dollars (INC), personal disposable income per capita in 1967 dollars (PINC), and civilian population (POP) are taken from the OBERS projections [U.S. Water Resources Council, 1974]. Disposable income and disposable income per capita are assumed to grow at the same rate as personal income and personal income per capita. Military population is subtracted from the OBERS population projections to arrive at civilian population, which is used in this study. The annual time series for INC, PINC, and POP are derived from the OBERS projections by calculating annual growth rates. For example, growth rates in population between 1980 and 1985 were calculated by the following formula:

$$1 = r = \text{antilog}\left(\frac{\text{Ln } POP_{85} - \text{Ln } POP_{80}}{5}\right) \tag{25}$$

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

$$= 1.009645$$

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

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

APPENDIX B

Definitions of Variable Code Names

AC	Harvested acreage (million acres).
ACALL	Tobacco acreage allotment (million acres).
ACATDUMY	Acreage allotment dummy with 1.0's in years allotments were in effect.
ACDIV	Acres diverted from production under crop commodity programs (million acres).
BLCT-PROD	The sum of the production of beef, lamb and mutton, chicken, and turkey in millions of pounds.
BLIGHT	Dummy variable for corn blight in 1970.
BPCT-PROD	The sum of the production of beef, pork, chicken, and turkey in millions of pounds.
BMKQUOTA	Market quota of burley tobacco production (in millions of pounds) 1971-1976.
BYPROD	Amount paid to farmers in cents per pound for by-products not sold as meat at the retail level deflated by the Consumer Price Index 1967 = 100.
CCONS	Civilian consumption in millions of pounds of carcass weight or ready-to-cook weight meat.
CDEM	Total domestic crop year demand for all uses, except wheat which excludes food demand (same units as production)
CINV	Privately owned ending crop year inventory (same units as production).
CNPR	Average crop year price received by farmers for corn (dollars per bushel).
CPI	The Consumer Price Index with 1967 = 100.
CR	Cash receipts in thousands of dollars from the sale of a livestock commodity deflated by the Consumer Price Index 1967 = 100.
CRPTS	Cash receipts from the sale of crops (million dollars).
CSPR	Price of cotton seed deflated by index of prices paid by farmers.
Ct-CDEMP	Domestic demand for cotton per capita multiplied by 100 (bales).
D6170	Feed grain base dummy with 1961-1970 = 1 and 0 otherwise.
D6771	Dummy variable = 1.0 for Vietnam War years 1967-1971.
D6871	Dummy variable = 1.0 for Vietnam War years 1968-1971.
D6872	Dummy variable = 1.0 for Vietnam War years 1968-1972.
DALLOT	Dummy variable for wheat allotment program with 1.0's for 1971-1973.
DMSPI	Change in index of motor supplies price.
EXP	Exports in millions of pounds of carcass weight meat.
EXPTS	Crop year exports (same units as production).
FC	A weighted average feed grain and soybean price per hundred pounds of feed for the commodity deflated by the index of prices paid by farmers with 1967 = 100. These variables are taken as proxies for feed costs.
FEED	Purchased livestock feed (million 1967 dollars).
FERT	Fertilizer and lime expense (million 1967 dollars).
FOOD	Crop year demand for wheat as food (million bushels).
FOR	Machinery fuel, oil and repairs expense (million 1967 dollars).

FP	Gross farm value for beef (choice), pork and lamb (choice), and farm value for chicken and turkey deflated by the index of prices paid by farmers with 1967 = 100. Gross farm value and farm value are prices paid to farmers for a quantity of live animal or bird equivalent to one pound of retail cuts or ready-to-cook bird.
FREE1	Free market dummy variable with 1.0's for 1973-76.
FREE2	Free market dummy variable with 1.0's for 1974-76.
FRM	The farm-retail margin in cents per pound of meat sold at the retail level for the ith commodity deflated by the Consumer Price Index 1967 = 100.
FSIZE	Average number of acres per farm.
FSPI	Index of farm supplies price deflated by GNP deflator (1967 = 100).
FTPI	Index of fertilizer price deflated by GNP deflator (1967 = 100).
GINC	Cash receipts plus government payments (million dollars).
GINV	Government owned ending crop year inventory (same units as production).
GPAY	Government payments to farmers under crop programs (million dollars).
GNP	Gross National Product deflator index (1967 = 100).
IMP	Imports in millions of pounds of carcass weight meat.
IMPTS	Crop year imports (same units as production).
INV	End-of-year stocks in millions of pounds of carcass weight for beef, pork, and lamb and mutton and ready-to-cook weight for chicken and turkey.
INTRT	Interest rate paid by farmers on new farm loans.
IPPBF	The index of prices paid by farmers with 1967 = 100.
LABR	Man=hour requirements (million man-hours).
LLRDUM	Dummy accounting for low wheat loan rates with 1964-76 = 1 and 0 otherwise.
LOGTIME	Natural log of TIME variable.
LPRDUM	Soybean low price dummy with 1975 = 1 and 0 otherwise.
LPUR	Livestock purchased by farmers (million 1967 dollars).
LR	Crop government program loan rate (same units as price except FG which is the corn loan rate in dollars per bushel).
LV-PR	Weighted average livestock and poultry farm price (formed by weighing the farm prices for beef, pork, lamb, chicken, and turkey by their respective productions in millions of pounds).
(MA2)	A two-year equally-weighted moving average of the accompanying variable.
(MA3)	A three-year equally-weighted moving average of the accompanying variable.
(MA4)	A three-year, weighted, moving average of the accompanying variable where the weights are 1/4, 1/2, and 1/4.
MACH	Machinery interest and depreciation (million 1967 dollars).
MC	Payment by wheat processors for marketing certificates (dollars per bushel).
MHPI	Index of machinery price deflated by GNP deflator (1967 = 100).

MILCONS	Military consumption in millions of pounds of carcass weight or ready-to-cook weight meat.
MISC	Miscellaneous expenses including pesticides, small hand tools, binding materials, electricity, telephone, etc. (million 1967 dollars).
MPUR	Machinery purchased (million 1967 dollars).
MSPI	Index of motor supplies price deflated by GNP deflator (1967 = 100).
MSTK	Ending calendar year stock of machinery on farms (million 1967 dollars).
MSTKAVE	Average of beginning and ending calendar year stock of machinery on farms (million 1967 dollars).
NEXP	Net exports in millions of pounds of ready-to-cook meat.
PFDUM	A dummy variable with 1973 = 1 and 0 otherwise to account for the effects of the 1973 price freeze.
PINC	Per capita disposable income (dollars).
PLCT-PROD	The sum of the production of pork, lamb and mutton, chicken, and turkey in millions of pounds.
POLYPR	Polyester price (cents per pound).
POP	U.S. civilian population (million).
PR	Average crop year price received by farmers deflated by the implicit GNP deflator (LV, dollars per hundred weight; FG, dollars per ton; WT and SB, dollars per bushel; GT and TB, cents per pound). All prices and incomes are deflated by the Consumer Price Index 1967 = 100 when used in the output sector.
PR2	PR variable deflated by index of prices paid by farmers instead of GNP.
PRDUM	Dummy with 1973 = 1 and 0 otherwise.
PRLA	Index of price of land and buildings per acre (index 1967 = 1.0).
PRO	Crop production (FG, million short tons; W and SB, million bushels; CT, million bales; and CS, million short tons).
PROD	Production in millions of pounds of carcass or ready-to-cook weight meat.
RECTIME	Reciprocal of TIME variable.
REEX	Real estate expense including interest on land and farm buildings and depreciation repairs and maintenance on farm buildings (million 1967 dollars).
RETX	Real estate taxes (million 1967 dollars).
RFC	An index of range feed conditions in 17 western states. RFC ranges from 49 or below indicating very bad to 100 and over indicating excellent range feed conditions.
RP	The retail price in cents per pound of the commodity deflated by the Consumer Price Index 1967 = 100.
SBAR	Acreage withheld from production under the Soil Bank Acreage Reserve program (million acres).
SEED	Purchased plus home-grown seed for individual crops (million 1967 dollars).

SDPI	Index of seed prices deflated by the implicit GNP deflator (1967 = 100).
SQRTIME	Square root of the TIME variable.
SPA	Stock of physical assets defined as the sum of STKAVE, MSTKAVE, and VAAL (million 1967 dollars).
SPPR	Average support price levels deflated by the implicit GNP deflator (same units as price).
STK	End of year commodity stock on farms (million 1967 dollars).
STKAVE	Average of beginning and end of year commodity stock on farms (million 1967 dollars).
SUPPLY	Beginning crop year supply defined as the sum of production, carry-in stocks, and imports (same units as production).
t	Current year.
TDEM	Total domestic crop year demand for all uses plus exports (same units as production).
TIME	Time trend with 1949 = 1, 1950 = 2, 1951 = 3 ..., 1976 = 28.
TINV	Ending crop year inventory (same units as production).
TXRT	Tax rate per dollar value of land and buildings.
VALA	Value of farmland and buildings (million 1967 dollars).
VOLPG	Dummy variable for voluntary wheat programs with 1.0's for 1965-1970.
W	The wage rate in dollars per hour for meat manufacturing employees deflated by the Consumer Price Index 1967 = 100.
WAR1	Post war dummy variable for World War II with 1.0's for 1949-1951.
WAR2	Post war dummy variable for World War II with 1.0's for 1949-1952.
WPRD1	Wheat price dummy, PR, with price equal to zero for 1953-1963.
WPRD2	Wheat price dummy, PR, with price equal to zero for 1949-1972.
WPRD3	Wheat price dummy, PR2, with price equal to zero for 1949, 1953-1962.
Y	Crop yield per harvested acre (FG and CS, short tons W and SB, bushels; and CT, bales).

List of Prefixs

B	Beef
C	Chicken
CS	Cottonseed
CT	Cotton lint or cotton total
FG	Feed grain
L	Lamb and mutton
LV	Livestock Total
P	Pork
SB	Soybean
T	Turkey
TB	Tobacco
WT	Wheat
US	United States Total

ADDITIONAL COPIES of this publication can be obtained by writing the Center for Agricultural and Rural Development, 578 East Hall, Iowa State University, Ames, IA 50011. Price is $3 each.