December 1982 A.E. Res. 82-47

STRUCTURAL CHANGE IN ACREAGE SUPPLY RESPONSE: AN ECONOMETRIC ANALYSIS OF U.S. FEED GRAIN PROGRAMS, 1948-1980

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PREFACE

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The research reported herein was supported by the College of Agricultural and Life Sciences, University of Wisconsin, Madison, under North Central Regional Project NC-152 ("Economic Consequences of Selected Provisions of the Food and Agricultural Act of 1977"), and by the College of Agriculture and Life Sciences, Cornell University.

The authors wish to thank Jean-Paul Chavas and Bill Tomek for helpful comments on earlier drafts, John Geweke for suggesting the parameter stability test used here, Joe Baldwin for preparing the figures, and Carol Searles for typing assistance.

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CHAPTER I

INTRODUCTION

The study of agricultural commodity supply and crop acreage response has traditionally occupied an important role in agricultural economics analysis. From the research perspective, supply response analysis has had applications to areas ranging from the study of farmers' response to risk and uncertainty to the development of spatial equilibrium models and the specification and estimation of large-scale econometric forecasting models. From the point of view of policy analysis, the results of supply analysis have proved important in helping determine the international trade impacts of changes in commodity policy and in estimating the effects on U.S. producers of changes in domestic farm programs.

This last area, the investigation of impacts of government agricultural commodity programs, has received particular attention in recent years for a variety of reasons. First, the programs themselves have been directed at some of the major agricultural commodities produced in the U.S. (corn, wheat, cotton, etc.) with far-reaching implications for international commodity markets, U.S. foreign economic policy, and other areas. Second, most of the commodity programs have been voluntary rather than mandatory in nature, with producers electing to participate or not participate with programs operative in any specific year. Thus, in some years, these programs have had relatively minor impacts on aggregate commodity supplies, while in other years, these effects have been substantial; in either case, these effects have been uncertain, a priori. Third, because the provisions of farm programs have continually changed over time, it has been difficult to construct meaningful economic models which have applicability over the long run. Finally, like many other government programs, farm commodity programs have important political implications with associated welfare considerations, differential geographic effects, and major impacts on the basic structure of agriculture.

This paper examines the impacts of government feed grain programs on corn and soybean acreage response in the post-World War II period. The aggregate acreage supply decisions of producers in four Corn Belt states (Illinois, Indiana, Iowa, and Ohio) are analyzed under two regimes: a "free market" regime composed of years in which producers responded to primarily market-based factors in formulating their acreage allocation decisions, and a "farm program" regime in which participating producers received various program benefits but had to idle land and abide by planting restrictions to receive those benefits. This disaggregated approach permits explicit attention to be given to the role that farm programs have played in causing structural change in crop response functions in the post-War era.

In addition, the approach taken here extends previous research in a number of ways. First, a simple theoretic framework based on expected profit maximization is developed which focuses attention on the often-overlooked but fundamental decision faced by grain producers in many years, whether or not to participate in voluntary feed grain programs. The discussion emphasizes the extent to which the degree of aggregate program participation has important implications for the construction and interpretation of supply response models.

Second, the disaggregated nature of the econometric model estimated permits attention to be given to statistical testing of the hypothesis of supply elasticity stability over time and regime changes. Accounting for the likelihood of structural change in supply relationships enables the piecing together of some apparently disparate results in the previous literature.

Third, inclusion of both corn and soybean crops in the model developed and estimated permits recognition of the importance of the multiple crop (and often unintended) effects of farm programs. This phenomenon is particularly important in the Corn Belt states given the dominance of corn and soybean crops. Multiple crop approaches to the crop acreage response question have only infrequently been developed (see Walker and Penn and, more recently, McKinzie, Binkley, and Gardiner's discussion of a "systemic" approach).

Finally, both autocorrelation in individual supply equations and contemporaneous correlation across error terms in sets of supply equations are often encountered in empirical analysis. However, previous models have only infrequently corrected for either of these econometric problems. This analysis uses Parks' three-stage Aitken procedure to correct for both types of error term correlation in a multiple equation system. Use of the Parks' procedure yields coefficient (elasticity) estimates which are more efficient than would otherwise be obtainable.

The organization of the paper is as follows: Chapter II outlines historical developments in U.S. and Corn Belt crop acreage and production, post-War government feed grain programs, and the previous literature on acreage supply response. The third Chapter develops the microeconomic foundations and aggregative theoretic model underlying the estimated econometric model. Chapter Four describes the econometric model, the Parks estimation procedure, and the data used in the analysis. Particular attention is given to an alternative method of incorporating program-related provisions in an econometric model of supply response. Chapter Five discusses the parameter stability tests performed and presents the econometric results. The discussion emphasizes the importance of temporal and regime changes in supply elasticities and the multiple crop effects of feed grain programs. The final chapter summarizes the results and suggests extensions for further work. The emphasis throughout the paper is on the analysis of structural changes in acreage response relationships that have been caused by farm programs over the post-War era.

CHAPTER II

PRODUCTION TRENDS, FARM PROGRAMS, AND PREVIOUS APPROACHES TO COMMODITY SUPPLY RESPONSE ANALYSIS

This chapter provides the background for the development of the acreage response model presented later in this study. Three areas are reviewed here: (i) trends in U.S. and Midwestern crop production and acreage allocation over the period 1948-1980; (ii) major post-War government feed grain programs and their implications for acreage supply; and (iii) the previous economic literature which has investigated the effects of farm programs on acreage supply response.

Trends in Crop Production and Planted Acreage

The post-World War II era has witnessed a number of major transformations in U.S. agriculture (Cochrane, Schertz). Among these changes have been enormous production increases in feed and food grain crops as the U.S. has assumed an increasingly dominant position in the world grain trade. As can be seen in Table 1, these production increases have been most impressive for corn, soybeans, and wheat. U.S. corn production increased from 3.31 billion bushels in 1948 to 7.76 billion bushels in 1979, an increase of 134 percent. Production increases for soybeans were even more spectacular, increasing tenfold from 227 million bushels in 1948 to 2.27 billion bushels in 1979. Except for wheat, which has also recorded large production increases in the past three decades, the production of most other grains has increased to a lesser extent or, in some cases (oats, in particular), even diminished.

Examination of Table 1 also reveals the fact that the expansion in production has been the result of different factors for different crops. Yield increases between 1948 and 1979 of over 154 percent for corn more than offset a decrease in harvested acreage of 7.6 percent. For wheat the story was somewhat similar, with a large 90 percent yield increase offsetting a substantial 14.3 percent decrease in harvested acreage. For soybeans, the situation was considerably different with a sevenfold increase in harvested acreage reinforcing a 50 percent increase in average yields. Overall, total crop acreage increased by a modest 6.4 percent between 1948 and 1979, nationally, although this national figure masks considerable regional variation in planted acreage trends. In sum, the large post-War expansion in grain production has been largely a story of: (i) substantial increases in yield for corn, wheat, and to a lesser extent, soybeans; (ii) a massive movement out of alternative crops into soybeans; and (iii) relative stability in the overall amount of land resources devoted to crop production. The forces underlying these developments have been many, including increased specialization of production on individual farms, rapid technological change, and large increases in farm usage of non-labor capital-intensive inputs (Rosine and Helmberger).

In the area of prime interest in this study, the U.S. Corn Belt, and specifically the states of Illinois, Indiana, Iowa, and Ohio, the above trends have proven especially important. Because of a favorable climate, a

TABLE 1

U.S. PRODUCTION, YIELDS, AND HARVESTED ACREAGES OF MAJOR GRAINS IN SELECTED YEARS

Year		Crop				
		Corn	Soybeans	Wheat	Other Grains[1]	Total Grains
1948:	Production (mill. bu.)	3,307	227	1,314	2,057	6,901
	Ave. Yield (bu./acre)	43.0	21.4	18.0	--	--
	Acres Harvested (1,000)	76,840	10,430	73,017	63,694	223,981
1960:	Production	3,908	555	1,357	2,360	8,180
	Ave. Yield	54.5	23.5	26.2	--	--
	Acres Harvested	71,649	23,655	51,896	60,502	207,702
1970:	Production	4,152	1,124	1,370	2,238	8,884
	Ave. Yield	72.4	26.7	31.0	--	--
	Acres Harvested	57,358	42,056	44,141	45,194	188,479
1979:	Production[2]	7,764	2,268	2,142	2,052	14,226
	Ave. Yield	109.4	32.2	34.2	--	--
	Acres Harvested	70,984	70,530	62,600	34,176	238,290

[1]Includes three other feed grains (oats, barley, sorghum), and three food grains (rye, rice, and buckwheat).

[2]Record production year in 1948-1980 period.

SOURCE: U.S.D.A. Agricultural Statistics, 1948-1980.

well-developed transportation system, and a flat, relatively homogeneous topography, the Corn Belt area has maintained a comparative advantage in grain production, particularly in corn and soybeans. Table 2 demonstrates the extent to which the four-state area has developed and maintained a significant share of total U.S. production of these two crops. Although individual state shares of national production have shifted over time, the region as a whole has accounted for over 50 percent of national corn and soybean production for at least the past two decades. Table 2 does not reveal a closely related development: the production of oats in the four state area decreased from 514.5 million bushels in 1950 to 101.3 million bushels in 1980. In terms of the region's national share of production, the decline was from 36.5 percent to 22.1 percent.

While yield increases have proved as important in the Corn Belt as nationally in causing grain production increases, the increases in land resources devoted to corn and soybean production have been, to an even greater extent than nationally, the result of shifts from other crops into corn and soybeans rather than the opening up of new crop acreage. As demonstrated in Figure 1 and in Appendix Table A.1, the expansion in total crop acreage in the four-state region was relatively modest over the post-War period, increasing from 62.1 million acres in 1948 to 73.8 million acres in 1979, or approximately .5 percent annually. At the same time, however, the proportion of this slowly growing land base devoted to the production of corn and soybeans (or idled under feed grain programs) has steadily increased to a 1980 figure of 82.4 percent. Accompanying this trend have been offsetting decreases in acreages planted to oats, rye, barley, and sorghum grain (except in Illinois). Increasingly, then, the Midwestern grain producer's decision has become one of the allocation of a relatively fixed acreage base among competing crops, in particular corn versus soybeans.

One of the short-run trends revealed in Figure 1 is the highly variable proportion of cropland idled under government feed grain programs. In many years, idled acreage represented an alternative "crop", with returns to idled, diverted, or set-aside acreage coming from the series of feed grain programs which have existed over the post-War era. Though discontinuous in nature and possessing continually changing incentives and constraints, in many years, feed grain programs provided a dominant influence in determining aggregate planted acreage and production levels. To understand the role that these programs have had in influencing acreage allocation among competing crops (including idled land), it is necessary to review briefly the evolution of post-War government feed grain programs.

Government Farm Programs: 1948-1980

The evolution of U.S. farm programs in the post-War era has been detailed elsewhere (Brandow; Cochrane and Ryan) and thus a lengthy review of these programs is unnecessary here. It is important, however, to outline the major changes in post-War feed grain programs which have had such a strong impact on trends in corn and, indirectly, soybean production. Underlying these trends, of course, is the changing environment these programs have created for producer decision-making.

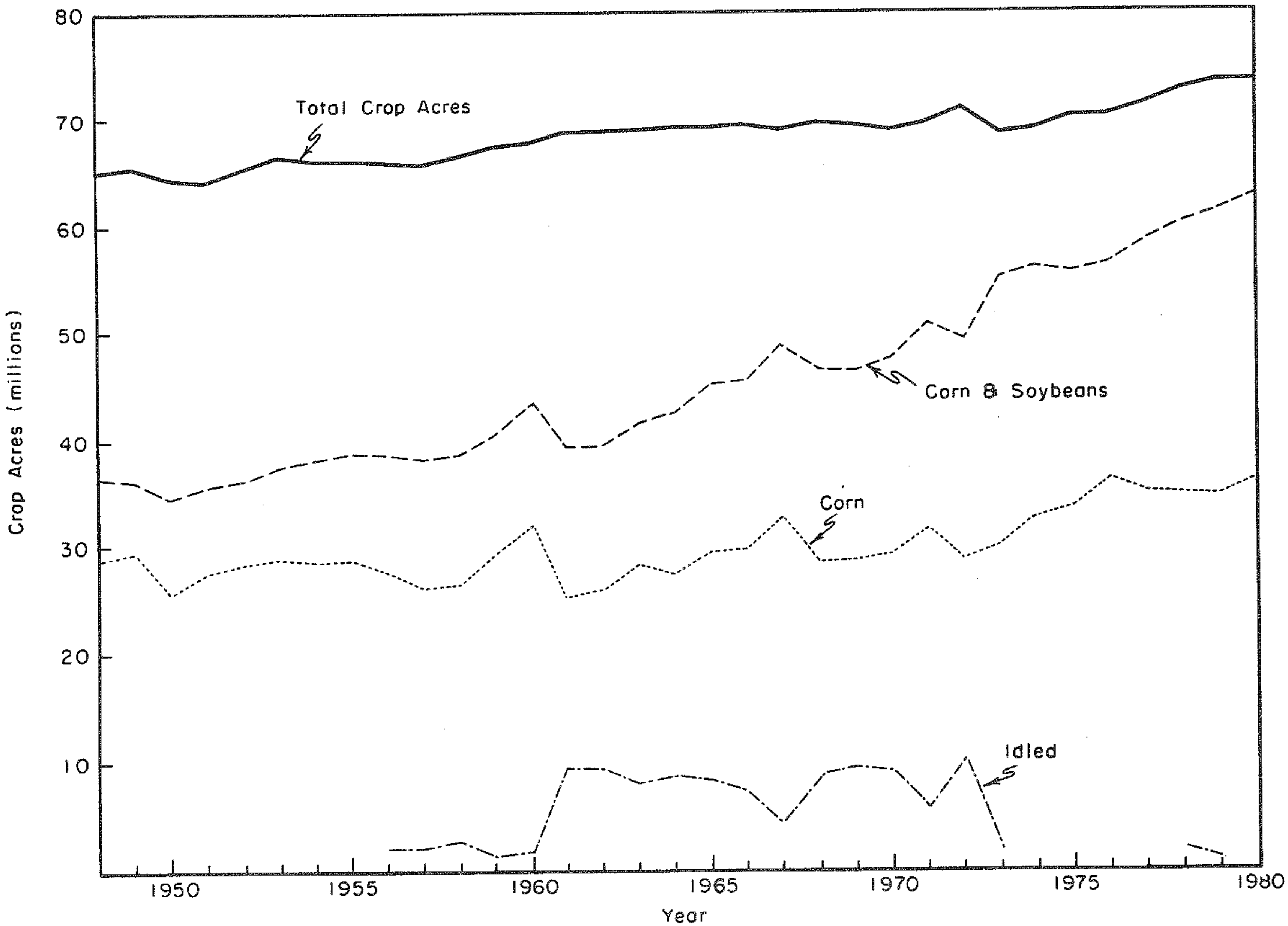
TABLE 2

PRODUCTION AND PERCENTAGE OF TOTAL U.S. PRODUCTION OF FOUR MIDWESTERN STATES FOR SELECTED CROPS AND YEARS

Year, Crops	State (percent of U.S. production)					
	Illinois	Indiana	Iowa	Ohio	Total Four States	U.S.
1950: Corn, all (1,000 bu.)	422,331 (13.8%)	212,430 (6.9%)	475,203 (15.5%)	174,928 (5.7%)	1,284,892 (42.0%)	3,057,803 (100%)
Soybeans (1,000 bu.)	95,736 (32.0%)	37,170 (12.4%)	42,460 (14.2%)	24,525 (8.2%)	199,891 (66.8%)	299,279 (100%)
1960: Corn	678,980 (17.4%)	350,336 (9.0%)	772,541 (19.8%)	230,044 (5.9%)	2,031,901 (52.0%)	3,908,070 (100%)
Soybeans	129,298 (23.3%)	65,205 (11.7%)	66,274 (11.9%)	36,726 (6.6%)	297,503 (53.6%)	555,307 (100%)
1970: Corn	735,560 (17.9%)	371,998 (9.1%)	859,140 (21.0%)	232,078 (5.7%)	2,198,776 (53.6%)	4,099,493 (100%)
Soybeans	210,800 (18.8%)	101,618 (9.0%)	184,600 (16.4%)	68,799 (6.1%)	565,817 (50.4%)	1,123,740 (100%)
1980: Corn	1,065,780 (16.0%)	602,880 (9.1%)	1,463,000 (22.0%)	440,700 (6.6%)	3,572,360 (53.7%)	6,647,534 (100%)
Soybeans	309,875 (17.1%)	157,680 (8.7%)	322,530 (17.7%)	135,360 (7.4%)	925,445 (50.9%)	1,817,097 (100%)

SOURCE: U.S.D.A. Agricultural Statistics 1950-1981.

FIGURE I. ACREAGE TRENDS IN CORN BELT REGION, 1948 - 1980



The Free Market Regime

Examination of government feed grain programs over the post-War period reveals the existence of two major types of programs, each discontinuous in nature. On the one hand are programs that offered producers various types of benefits, principally price support loans on production, but which required no concomitant limitations on feed grain production. On the other hand are the programs which offered participating producers added benefits (diversion payments, set-aside payments, deficiency payments, etc.), but which also required production cutbacks in the form of acreage allotments, diversion and set-aside requirements, etc.

The first set of years in which no production controls were required of producers we refer to as the "free market" regime in this study. These years were 1948-49, 1951-53, 1959-60, 1974-77, and 1980. Although price support loans were available to producers in these years, in many cases, loan rates were less than or only slightly greater than market prices. Some additional farm program benefits (Soil Bank payments, disaster payments, etc.) were available to producers in several of these years, but not on a consistent basis nor on the scale provided by the feed grain programs in other years. During this period, then, Midwestern feed grain and soybean producers generally reacted to competitive market-oriented factors in formulating their resource allocation decisions.

The Farm Program Regime

The majority of years in the 1948-1980 period, were characterized by government feed grain programs which provided producers with sets of incentives and constraints in attempting to control grain production and simultaneously enhance producers' incomes. These programs and the years in which they were relevant were: the acreage allotment and Soil Bank programs, 1950 and 1954-58; the acreage diversion programs, 1961-70; and the set-aside programs, 1971-73 and 1978-79. The main provisions of these programs and the crops to which they applied are outlined in Table 3.

Acreage Allotment and Soil Bank Programs: 1950, 1954-58

The acreage allotment program of the 1950's offered participating corn producers guaranteed price support loans on production in return for their abiding by allotments or limitations on corn plantings, generally defined by specified proportions of previously planted acreage. Unlike later programs which were national in scope, the acreage allotment programs applied only to the major corn producing areas of the U.S., the boundaries of which were revised annually: the Corn Belt states, eastern Plains states, southern Lake states, and coastal regions of the mid-Atlantic states.

The corn allotment program was initially moderately successful in cutting back corn supplies, but a number of developments limited the program's success in its later years. Participation rates were generally low, reaching a maximum of 41 percent of eligible acreage in 1955, and declining substantially after that, due partially to the introduction in 1956 of a second tier price support loan for those who did not comply with acreage allotments. In addition, allotments "chased" acreage from corn and wheat

TABLE 3

SUMMARY OF PROVISIONS OF FEED GRAIN PROGRAMS, 1948-1980

PROGRAM, YEAR	CROPS ELIGIBLE[1]	PAYMENTS[2]	CONSTRAINTS	OTHER PROVISIONS
Acreage Allotment/Soil Bank Programs				
1950	C	PSL	Acr. Allotment	-
1954	C	PSL	Acr. Allotment	-
1955	C	PSL	Acr. Allotment	-
1956	C	PSL, ARP (SB)	Acr. Allotment, SB Diversions	-
1957	C	PSL, ARP (SB)	Acr. Act. Allotment, SB Diversions	-
1958	C	PSL, ARP (SB)	Acr. Act. Allotment, SB Diversions	-
Acreage Diversion Programs				
1961	C,S	PSL,DP_r,DP_v	Acr. Diversion: Min. & Max.	-
1962	C,S,B	PSL,DP_r,DP_v	Acr. Diversion: Min. & Max.	-
1963	C,S,B	PSL,DP_r,DP_v,PSP	Acr. Diversion: Min. & Max.	-
1964	C,S,B	PSL,DP_r,DP_v,PSP	Acr. Diversion: Min. & Max.	-
1965	C,S,B,O	PSL,DP_r,DP_v,PSP	Acr. Diversion: Min. & Max.	FG/Wheat Subst.
1966	C,S,B,O	PSL,DP_v,PSP	Acr. Diversion: Min. & Max.	FG/Wheat Subst.
1967	C,S	PSL,PSP	Acr. Diversion: Min.	FG/Wheat Subst.
1968	C,S	PSL,PSP,DP_v	Acr. Diversion: Min. & Max.	FG/Wheat Subst.
1969	C,S,B	PSL,PSP,DP_v	Acr. Diversion: Min. & Max.	FG/Wheat Subst.
1970	C,S,B	PSL,PSP,DP_v	Acr. Diversion: Min. & Max.	FG/Wheat Subst.
Acreage Set-Asides				
1971	C,S	PSL,SAP	Acr. Set-aside: Min.	FG/Wheat Subst.
1972	C,S,B	PSL,SAP,DP_v	Acr. Set-aside: Min. & Max.	FG/Wheat/Soybeans Subst.
1973	C,S,B	PSL,SAP	Acr. Set-aside: Min.	FG/Wheat/Soybeans Subst.
1978	C,S,B	PSL,DFP,DP_v	Acr. Set-aside: Min. & Max. NCA Limit	FG/Wheat/Soybeans Subst.
1979	C,S	PSL,DFP,DP_v	Acr. Set-aside: Min. & Max. NCA Limit	FG/Wheat/Soybeans Subst.

[1]C = Corn, O = Oats, B = Barley, S = Sorghum (grain)

[2]PSL = Price Support Loan, ARP (SB) = Soil Bank Acreage Reserve Payments, DP_r = Payments for Required Diversion, DP_v = Payments for Voluntary Diversion, PSP = Price Support Payments, SAP = Set-aside Payment, DFP = Deficiency Payment

into the production of other crops, partially diminishing their intended effects. For these and other reasons, the corn allotment program was discontinued after 1958.

The Soil Bank program was introduced in 1956 and exerted a modest temporary impact on planted crop acreage in the U.S. in the late 1950's and, to a lesser extent, the early 1960's. Intended as an additional method of lowering the then rapidly expanding output of crop producers, the Soil Bank program had two main features, an Acreage Reserve program which existed on an annual basis only through 1958, and a long-term Conservation Reserve program, which extended (due to the existence of long-term contracts signed in the 1950's) through 1973. The Acreage Reserve program was designed to limit the acreage planted to allotment crops (corn, wheat, cotton, etc.) by offering income-compensating payments to producers of these crops for their planting reductions. The Conservation Reserve program offered payments for foregone production to producers as a means to divert marginal land from crop production to conservation uses on a longer-term basis. The Soil Bank program was discontinued in 1959, although the last Conservation Reserve contracts did not expire until the early 1970's.

The acreage allotment and Soil Bank programs were considerably different from the programs which followed in the 1960's and 1970's. The allotment program offered more limited benefits, imposed stricter constraints, was more limited geographically in scope, and in general represented a fundamentally different approach to acreage control than did succeeding programs. For these reasons, the six years in which the acreage allotment program was in effect are excluded from the present analysis.

Acreage Diversion Programs: 1961-1970

The acreage diversion programs of the 1960's marked the first step in increasing flexibility in government feed grain programs from the restrictive allotment programs. Like the allotment programs, they were voluntary in nature, but offered feed grain producers greater financial incentives for idling land previously devoted to grain production.

As can be seen in Table 3, four types of incentives were offered participating producers under the acreage diversion programs in various years: (i) price support loans (1961-1970); (ii) payments for required acreage diversion (1961-1965); (iii) payments for voluntary diversion (1961-70 except for 1967); and (iv) price support payments (1963-70). Price support loans were offered in each year to participants on "normal production",[1] subject to the required idled acreage constraint of 20 percent of historic base acreage. During the first five years of the diversion programs, 1961-65, additional payments for these minimum diversion requirements were also made to producers, to further induce their compliance by partially compensating them for their income foregone by their idling land. In all years but 1967, participating producers could divert additional cropland, up to a maximum proportion of base acreage, and

[1]"Normal production" from crop "base acreage," in turn defined by the previous years' plantings, minus acres devoted to conserving uses, minus land idled under the feed grain programs.

receive "voluntary diversion payments". Finally, beginning in 1963, price support loan rates were lowered substantially, and a "price support payment" became available to producers, paid on normal production on acreage actually grown. In 1966 and thereafter, payments for required diversion were terminated, and the price support payment was paid on the smaller of planted acreage or 50 percent of base acreage.

The principal constraints on participating producers were the required diversion level of 20 percent of base acreage, the maximum diversion level of 40 percent (1961-63) or 50 percent (1964-66, 1968-70) of base acreage, and after 1966, the limitations on price support payments. An additional constraint was eliminated in 1965 when the "substitution" provisions were introduced, enabling producers of feed grains or wheat to substitute the production of one crop for another without losing program eligibility or benefits. Though important in some areas (e.g. the Plains states), the substitution provisions did not prove particularly important in Corn Belt states where winter wheat has been a crop of generally only minor importance.

The average diversion programs of the 1960's represented a partial step from the constraining allotment programs of the 1950's to the even more flexible set-aside programs of the 1970's. Not surprisingly then, feed grain program participation rates (defined by the ratio of participating to eligible crop base acreage) were considerably higher than during the 1950's, generally running between 55 and 65 percent nationwide. The set-aside programs, though, proved even more popular.

Acreage Set-Aside Programs: 1971-73, 1978-79

The acreage set-aside programs of the 1970's represented the final step in the trend toward allowing for greater decision-making flexibility by participating feed grain producers under the general constraints imposed by government commodity programs. The major constraint imposed by these programs was that to receive program benefits, feed grain (and wheat) producers were required to set-aside a specified proportion of their total crop acreage to conserving uses. Unlike previous programs which required limitations on acreage planted to specific crops, once the initial set-aside acreage was idled, producers were then free to plant any combination of feed grains, wheat, soybeans, or other crops they desired.

The set-aside programs changed substantially over the 1970's, but the program may be broken down into two phases, one existing in 1971-73 and the second operative in 1978-79. The 1971-73 program required minimum set-asides of overall crop acreage (20 percent in 1971; 25 percent in 1972; 10 percent (under one option) in 1973), but allowed for substantial flexibility in planting decisions once this constraint had been met. Two primary types of benefits accrued to cooperating producers: price support loans (though at low levels), and set-aside payments, based on 50 percent of base acreage of program crops. Set-aside payments were calculated by the product of 50 percent of crop base acreage, times historic (or later, "program") crop yield, times a per bushel payment rate determined by the difference between a guaranteed payment rate and the October-February average market price. A preliminary set-aside payment was made to producers early in the planting season based on an estimate of the final price differential. Only in 1972 were additional voluntary diversion payments (for diversion up to an additional 20 percent of corn base acreage) available to participating producers.

As a result primarily of the increased flexibility in planting decisions allowed under the set-aside programs, feed grain program participation rates increased markedly over previous levels. The proportion of feed grain base acreage on participating farms to total eligible base acreage in the U.S. increased from 66 percent in 1970, the final acreage diversion program year, to 88 percent in 1973, the highest historical level of feed grain program participation.

A number of changes characterized the 1978-79 set-aside programs following passage of the Food and Agriculture Act of 1977. First, required set-asides were made proportionate to current rather than historic planting levels. Second, a "normal crop acreage" (NCA) was defined for each farm, based on total 1977 plantings of designated crops, and program benefits were only available to producers whose planted plus required idled acreage was no larger than their NCA. Third, paid voluntary diversion was again made optional for program participants, if the total of their planted acreage, required set-asides, and voluntary diversions did not exceed their NCA. Finally, while price support loans were available to producers as before, the principal program benefit was redefined in the form of "deficiency payments" based on target prices guaranteed to producers. Deficiency payments (DP) for corn were calculated as follows:

$$DP = [P_c^t - \max(P_c^m, P_c^s)][Y_c][a_{cp}][\alpha]$$

where: P_c^t = corn target price,

P_c^m = corn market price,

P_c^s = corn loan rate,

Y_c = corn program yield,

a_{cp} = planted corn acreage,

and α = "allocation factor", where $.8 \leq \alpha \leq 1.0$.

The maximum benefit ($\alpha = 1.0$) was available only if the producer reduced his corn acreage to a specific proportion below the previous year's plantings.[2] Generally, then, returns to producers under the program were greater the higher the target price, the lower the market price or loan rate, and the greater the product of corn plantings relative to the size of the allocation factor. Other program benefits were made available in the form of disaster payments, participation in the grain reserve, etc. High market prices relative to program benefits held participation rates and

[2]These planted acreage limitations for corn were 95 percent of 1977 plantings in 1978, and 90 percent of 1978 "considered" plantings in 1979.

total acreage diversions in the 1978-79 feed grain programs to rather low levels (see Figure 1).

The foregoing review of post-War government feed grain programs sets the stage for the subsequent incorporation of specific program provisions into an econometric supply response model (see Chapter IV). In addition, it permits several important conclusions regarding the historic direction of those programs. These trends included: a gradual lessening of specific crop planting constraints in favor of greater flexibility in planting choices; an increasing integration of commodity program pricing policies into the larger world market; a gradual increase in rates of program participation accompanying the increased program flexibility; and an increasing reliance on providing participation incentives rather than imposing constraints in attempting to control feed grain supplies.

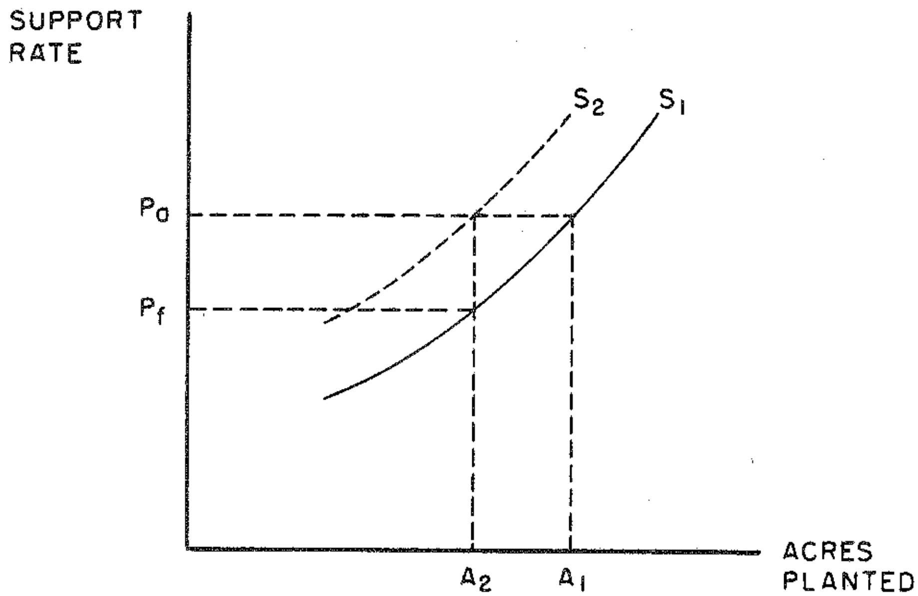
Literature Review

The problems involved in modeling the response of crop acreage and agricultural supply to changes in output prices and other variables have concerned researchers for decades. Several different avenues of research have been pursued. First, following the seminal work of Nerlove (1956, 1958) and his development of the adaptive expectations model, a considerable body of literature has been concerned with empirical verification, modification, and critiques of the Nerlovian model (Askari and Cummings). In the area of acreage response analysis, studies using adaptive expectations approaches have included analyses of U.S. (Lidman and Bawden) and Canadian (Schmitz) wheat supply, and Robinson and Hoover's study of corn supply response in the Southern U.S. Second, programming models have formed the basis for development of the "representative farm" approach to supply estimation (Sharples; Tomek and Robinson), the recursive programming models developed by Henderson and Day, and, more recently, multiple product approaches based on constant elasticity of transformation (CET) production functions (Green; Shumway and Chang). A third body of work has, in recent years, begun to address the important role played by risk-related variables in agricultural supply response (Just; Traill; Burnstein).

The supply analysis literature which is particularly relevant to this study is that which has focused on the incorporation and analysis of the impacts of government farm programs on agricultural commodity supply. Because these programs have been highly variable and discontinuous in nature, but at the same time have had important short-run impacts on crop acreage, the problems posed for economic analysis have been substantial. Yet the dynamic policy environment surrounding farm programs has continued to stimulate research in this area.

Without doubt, the most common approach to the integration of government program parameters in acreage response models has been the use of "effective" price support and diversion payment variables as explanatory variables in econometric time-series supply models. First used by Houck and Subotnik in their 1969 analysis of soybean acreage supply, and later by Houck and Ryan in an analysis of corn acreage response under government

FIGURE 2. EFFECTIVE SUPPORT PRICE



Source: Houck, et al. (1976)

farm programs, the construction of "effective" price and payment variables is based on the argument that the constraints imposed by production control programs on planted crop acreage make program benefits available to the producer on only a portion of total acreage.

In Figure 2, for example, an announced support rate of P_a, with no accompanying acreage restrictions, would be assumed to induce the planting of A_1 acres. However, imposition of a planting constraint, A_2, drives the "effective" level of P_a to P_f, where $P_f = r \cdot P_a$, $0 \leq r \leq 1.0$. The result is an effective shift in the supply curve from S_1 to S_2. Parameter r is an "adjustment factor" where:

$$r = 1/2\left[\frac{A_{min}}{A_{base}} + \frac{A_{max}}{A_{base}}\right]$$

that is, r equals the average of the minimum and maximum proportions of base acreage that could be planted under the program. Clearly, if no voluntary acreage diversion is permitted, as in 1967, $r = 1.0$, and $P_f = P_a$. The suggested method (Houck, et al.) for determining "effective diversion payment" levels (DP_f), where $DP_f = w \cdot DP_a$, DP_a equals the announced diversion payment, and $0 \leq w \leq 1.0$, is analogous. Given estimates of r and w and exogenous announced support price and diversion payment levels, the major program parameters can be integrated fairly simply as independent variables in econometric models which attempt to explain endogenous acreage response.

Since its introduction, the "effective" price and payment concept has been used extensively in the specification of crop supply response under government farm programs. Houck and Subotnik and, later, Kenyon and Evans, applied the concept to soybean supply response. Houck and Ryan, and Ryan and Abel (1973a, 1973b) analyzed feed grain supply response to effective support prices and diversion payments. Applications to several crops were made by Houck, et al., Walker and Penn, and, most recently, McKinzie, Binkley, and Gardiner. Moe and Whittaker, and Wilson, Arthur, and Whittaker utilized the concept in studying the role of risk in the production of wheat in the Northwest. This widespread use of the effective price concept has been due to, first, the ability to include a number of program parameters in a single explanatory variable in a regression equation, and, second, the commonly desirable statistical properties (high R^2, significant coefficient estimates) of models subsequently estimated.

Despite these apparent advantages, however, a number of serious problems characterize the construction and use of "effective" price and payment variables. First, though amenable for use in aggregate economic analysis, the meaning of these variables for actual farmer decision-making is uncertain. The effective price and payment variables are constructed on the basis of average participation rates, while individual farmers either do or do not participate based on market price expectations, announced program benefits and constraints, and other factors.

A second problem is that it is difficult to form *a priori* expectations regarding the direction of changes in acreage response due to changes in expected price and payment variables. For example, an increase in the effective support rate is generally assumed to have a positive effect on planted crop acreage. However, from an alternative perspective, an increase in effective support prices would be expected to make program participation more profitable, thereby increasing the participation rate and *decreasing* aggregate crop acreage. Thus, there is considerable uncertainty regarding the expected effects of changes in effective price and payment variables, *a priori*.

Third, use of effective price and payment variables obscures the fact that it is not the absolute levels of these variables, but rather their magnitudes *relative to* market prices that induces participation in feed grain programs and thus influences aggregate crop acreage. Unfortunately this problem is not solved if market price variables are included as separate regressors in regression equations because, as pointed out by Burnstein, their simultaneous use creates confusion as to which is the relevant price variable determining crop acreage.

Despite these and other problems, the effective price approach has dominated the literature in recent years. Other approaches have been taken however. Penn and Irwin used simple price supports along with lagged market prices in a simultaneous equation model of crop production in the Delta states. Lidman and Bawden, and later Garst and Miller, in studies examining U.S. wheat acreage response, used variables explicitly measuring program benefits and constraints (acreage allotments, set-asides, etc.). Other studies have included lagged endogenous acreage variables under the partial adjustment hypothesis (Penn and Irwin; Gardner; etc.). Finally, a number of the above (and other) studies have included current year acreages planted to other crops as explanatory variables in single equation supply models. If one accepts the proposition, however, that acreage allocation decisions for spring-planted crops are made simultaneously rather than recursively, then the inclusion of such variables as regressors in econometric supply models is inappropriate, since the resulting ordinary least squares coefficient estimates are inconsistent.

A recent approach to acreage supply response analysis has been the disaggregated approach initially taken by Morzuch, Weaver, and Helmberger, in a study of wheat acreage response. This approach uses data that is disaggregated geographically by state and temporally by the existence or nonexistence of government farm programs in specific years. The advantages of this approach are, (i) that years in which market forces dominated crop production are not combined with years in which government farm programs exerted strong influences on acreage allocation decisions, and (ii) that estimated supply elasticities are not constrained to being equal across different regions and years. The primary disadvantage of this approach is the resulting lack of time series observations in econometric models which begin with disaggregated temporal data. This, however, is the basic approach that is followed in this analysis.

The abovementioned and other acreage response studies have yielded widely varying estimates of acreage supply response elasticities for corn and soybeans, the two crops of prime interest in this study. Table 4 summarizes some of these results. The use of three different proxies for farmers' expected prices renders these estimates, in a strict sense, incomparable. However, the high degree of correlation among the different measures (Houck and Ryan; Kenyon and Evans) means that some generalizations are possible.

With regard to corn acreage response, short-run own-price elasticities of supply range from a puzzling -.20 (Reed and Riggins) to a high of .44 (Weaver and Krainick). For those studies which have used the effective price approach, supply elasticity estimates are much closer in magnitude, generally in the .13 to .23 range. While the different price measures, geographic areas, and time periods used no doubt account for much of this variation, the range of estimates is uncomfortably wide. Given this degree of variation, the results of highly aggregative studies would appear to be of questionable relevance to specific geographic areas or for specific time periods.

For soybeans, the short-run supply elasticity estimates are even more variable. Depending on the area, time period, and price measure used, estimates range from a low of .16 (Heady and Rao) to a high of .84 (Houck and Subotnik). As for corn, the high degree of variation in these estimates makes generalizations from aggregative studies to specific regions and time periods problematical. Nevertheless, soybean own-price elasticities do appear uniformly higher than those for corn over the post-War period.

Table 4 also provides some estimates of long run and cross-price elasticities for the two crops. As expected under the Nerlovian adaptive

Table 4

SUMMARY OF ACREAGE RESPONSE ESTIMATES FOR CORN AND SOYBEANS

STUDY	AREAS AND YEARS ANALYZED		ESTIMATION METHOD	EXPECTED PRICE PROXY*	ESTIMATED ELASTICITIES: CORN SR	ESTIMATED ELASTICITIES: CORN LR	ESTIMATED ELASTICITIES: SOYBEANS SR	ESTIMATED ELASTICITIES: SOYBEANS LR
Nerlove (1956)	U.S.	1909-32	OLS	$P_{c,t-1}$	.09, .18			
Heady & Rao (1967)	U.S.	1929-63	OLS	$P_{s,t-1}/P_{c,t-1}$			.34	
	Corn Belt	1929-63	OLS	$P_{s,t-1}/P_{c,t-1}$			.27	
	Four States**	1929-63	OLS	$P_{s,t-1}/P_{c,t-1}$			.16, .28, .23, .51	
Houck & Subotnik (1967)	U.S.	1946-66	OLS	$P_{s,t-1};P^e_{s,t}$			.84, .43	
	U.S.	1946-66	OLS	$P_{c,t-1};P^e_{c,t}$			(-.65, -.17)	
	Corn Belt	1946-66	OLS	$P_{s,t-1};P^e_{s,t}$			.50, .17	
	Corn Belt	1946-66	OLS	$P_{c,t-1};P^e_{c,t}$			(-.50, -.13)	
Penn (1973)	U.S.	1954-70	ZEF	$P^e_{c,t};P^e_{s,t}$	.23		.31	
				$P_s;P^e_{c,t}$	(-.16)		(-.21)	
	U.S.	1966-70	ZEF	$P^e_{c,t};P^e_{s,t}$	.19		.24	
				$P_s;P^e_{c,t}$	(-.18)		(-.12)	
	No. Central	1950-70	ZEF	$P^e_{c,t};P^e_{s,t}$	.17		.39	
				$P_s;P^e_{c,t}$	(-.08)		(-.44)	
	No. Central	1965-70	ZEF	$P^e_{c,t};P^e_{s,t}$	.16		.30	
				$P_s;P^e_{c,t}$	(-.08)		(-.22)	

Table 4 (Continued)

STUDY	AREAS AND YEARS ANALYZED		ESTIMATION METHOD	EXPECTED PRICE PROXY*	ESTIMATED ELASTICITIES			
					CORN		SOYBEANS	
					SR	LR	SR	LR
Kenyon-Evans (1975)	U.S.	1948-74	OLS	$P^e_{FG,t}; P^e_{s,t}$	.30	.59	.68	3.78
				$P^e_{s,t}; P^e_{c,t}$	(-.03)	(-.05)	(-.24)	(-1.31)
	Corn Belt	1948-74	OLS	$P^e_{s,t}$			.55	4.21
				$P^e_{c,t}$			(-.50)	(-3.75)
Gardner (1976)	U.S.	1950-74	OLS	$P_{s,t-1}$			.56	1.04
				$P^f_{s,t}$			.45,.61	1.36
Houck, et. al. (1976)	U.S.	1949-70	OLS	$P^e_{c,t}$	.13			
	U.S.	1950-74	OLS	$P^e_{c,t}$	.13			
	U.S.	1950-72	OLS	$P_{s,t-1}$			.39	
Whittaker & Bancroft (1979)	Corn	1963-74	OLS	$P^e_{c,t}$	.22			
Weaver & Krainick (1979)	Four States**	"Price Support Years."	OLS	$P^f_{c,t}$	.10,.03,.13,.03			
	Four States**	"Set-Aside Years."	OLS	$P^f_{c,t}$	.36,.30,.14,.28			
	Four States**	"Acr. Diver. Years."	OLS	$P^f_{c,t}$	.31,.44,.08,.44			
Reed & Riggins (1981)	Kentucky	1960-79	SUR	$P_{c,t-1}$ $P_{s,t-1}$	-.20 to .56 0 to -1.00			

$*P^e_t$ = "effective support prices"; P_{t-1} = lagged market prices; P^f_t = future prices

** "Four States" are (in order): Illinois, Indiana, Iowa, Ohio.

expectations framework, long-run estimates are uniformly greater than short-run estimates for both crops. Examination of cross-price elasticity estimates reveals that soybean acreage appears much more sensitive to changes in corn prices than vice versa. This result is confirmed in this analysis as well. A hypothesis that might explain these findings is that variations in corn acreage appeared highly dependent on the existence and changing provisions of feed grain programs relative to variations in soybean prices. Conversely, for soybeans, variations in corn prices as well as the cross-commodity effects of the feed grain programs appear to have been important determinants of acreage response. These questions are dealt with in depth in following chapters.

CHAPTER III

THE THEORY OF FARM PROGRAM PARTICIPATION

Although the rate at which farmers participate in voluntary farm programs has important implications for aggregate supply responsiveness for the relevant crops, the producer's participation decision has received little attention in previous research. In this chapter, the basic feed grain program participation decision for a representative farmer is discussed and, using some simple results from duality theory, a model of the participation decision is proposed. The decision of whether or not to participate in a representative corn program is considered first. Implications for aggregate corn acreage supply response are then presented. Finally, attention is directed to the implications of feed grain program participation for soybean production in a production system where corn and soybeans are the major crop alternatives.

Feed Grain Program Participation

Consider a voluntary feed grain (corn) program in which participating producers are required to limit corn acreage to no greater than a specified proportion of historic base acreage in return for a guaranteed payment from the government. The remaining idled or set-aside acreage is assumed to equal a specified percentage of the overall base acreage, and the sum of the set-aside acreage and planted acreage limitation (allotment) equals total base acreage. The guaranteed program payment is assumed to equal the product of an announced per bushel payment rate, established yield, and a designated proportion of feed grain base acreage. These features approximate those which have characterized actual feed grain programs since 1961, and could be reformulated to reflect specific program changes (price support payments, deficiency payments, etc.) since that time. For the present purposes, though, these general features will suffice.

Consider next a crop producer who must allocate his land among competing crops and must decide whether or not to participate in the voluntary program. Given the dominant role of corn and soybean crops in the Corn Belt region, the region of specific interest here, it is assumed that the producer must plant either corn or soybeans, or if he elects to participate in an acreage reduction program, he may idle crop acreage.

It is useful to consider the producer's objective function under the above alternatives as one of maximizing expected profit given both exogenously determined factors (both market and program-related) and his expectations of other random variables (e.g. output prices). In fact, the expected profit function for the individual producer expresses maximized expected profit as a function of all exogenous parameters and constraints in the system (Silberberg). In those "free market" years when acreage reduction programs are not optional or in "farm program" years in which the producer elects nonparticipation, the producer's expected profit function may be represented as a function of only market-related parameters and constraints. In this case, the producer's expected profit (π^*) is defined as:

$$(1) \quad \pi^* = P_c q_c^* + P_s q_s^* - \underline{w} \cdot \underline{x} - TFC$$

or, in general functional form,

$$(2) \quad \pi^* = \pi^*(P_c, P_s, \underline{w}, \underline{Z})$$

where P_c is the expected price of corn; P_s is the expected price of soybeans; q_c^* and q_s^* are, respectively, the expected quantities of corn and soybean produced (where each is the product of planted acreage and expected yield); $\underline{w}$ is a vector of variable input prices (labor, fuel, fertilizer, etc.); $\underline{x}$ is the associated vector of variable inputs employed; and $\underline{Z}$ is a vector of fixed inputs (total land available ($\overline{a}$), machinery, etc.) with an associated total fixed cost, TFC. Note that the form of equation (1) assumes statistical independence between crop prices and yields, a reasonable assumption at the level of the individual producer (Dillon).

If, in years in which a voluntary feed grain program is in effect, the producer elects to participate, his maximized expected profit can be represented by an alternative expected profit function, π':

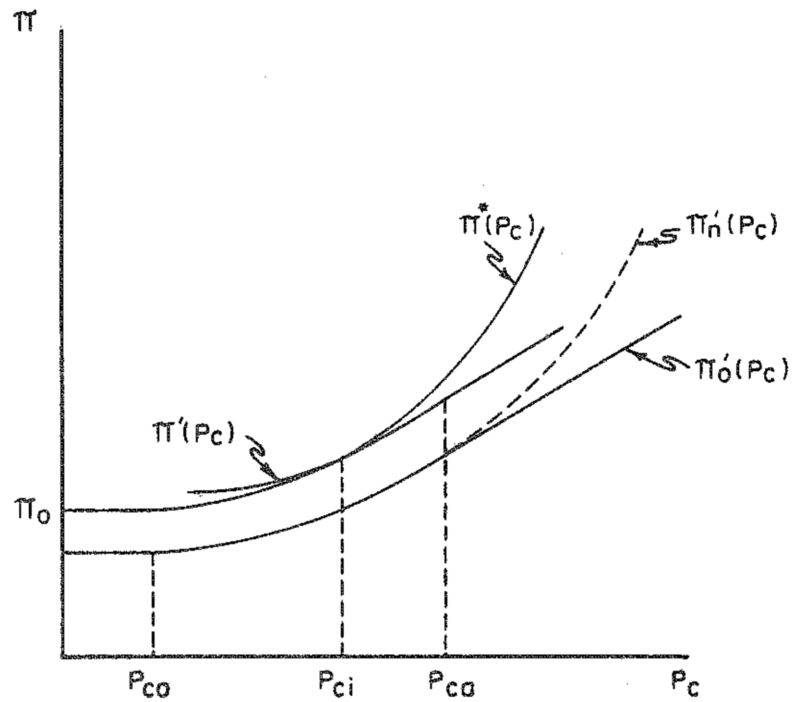
$$(3) \quad \pi' = \pi'(P_c, P_s, \underline{w}, \underline{Z}, B, a_{cb}, \alpha)$$

where B is the per acre direct payment (diversion, set-aside, or deficiency payment; a_{cb} is the established feed grain base; α equals the proportion of base acres that a program participant must idle; and all other variables are defined as before. The participating producer is assumed to maximize expected profit, π', given the incentives and constraints defined by the provisions of the program.

Figure 3 gives a graphical representation of the relevant expected profit functions for the nonparticipation and participation options under the voluntary program, assuming all variables except for P_c remain constant. Consider first the nonparticipant's expected profit function $\pi^*(P_c)$. If $P_c \leq P_{co}$, the producer plants only soybeans, and expected profit is constant at π_o for different P_c. However, for $P_c > P_{co}$ with all choice variables held constant, maximized expected profit would increase linearly with increases in P_c. If choice variables were allowed to assume their optimal values, the level of expected profit for any P_c would be even greater (Silberberg, p. 266). Under these circumstances, the usual properties of $\pi^*(P_c)$ hold; e.g., π^* is convex, nondecreasing, continuous, and homogeneous of degree one in P_c (Varian, p. 30).

Furthermore, using Hotelling's lemma, the supply function for corn, q_c^*, can be derived from the expected profit function, π^*:

FIGURE 3. EXPECTED PROFIT FUNCTIONS WITH AND WITHOUT PARTICIPATION IN THE FEED GRAIN PROGRAM



(4) $\frac{\partial \pi^*}{\partial P_c^*} = q_c^*(P_c, P_s, \underline{w}, \underline{Z})$

At any given level of production, q_c^* is assumed to be the product of harvested acreage and expected yield, Y_c^*. Since Y_c^* is, by definition, stochastic and price insensitive, the mapping of the corn acreage supply function, $a_c(P_c, P_s, \underline{w}, \underline{Z})$ with respect to P_c will be identical to the $q_c^*(P_c)$ function, differentiated only by a constant representing expected yield. This then establishes the relationship between the producer's expected profit function and the corn acreage supply function.

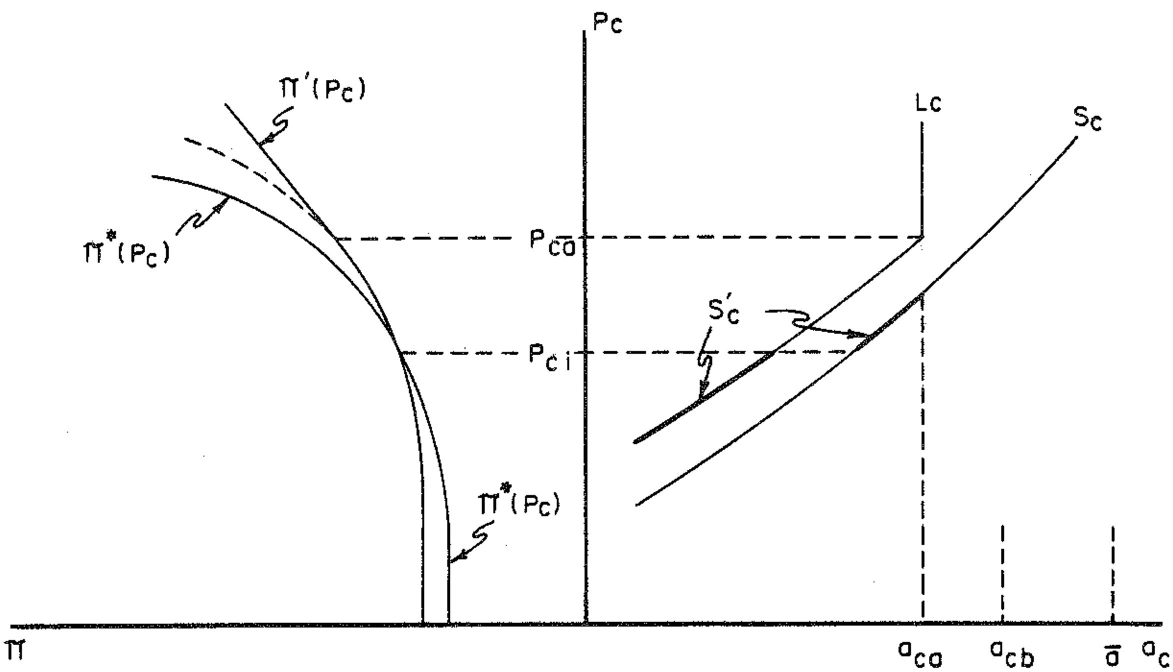
Now consider the nature of the expected profit function for a producer participating in the feed grain program who is required to set-aside a proportion of his cropland base. For the moment, abstract away from program benefits received. Due to the decreased cropland resources at his disposal, the producer's expected profit function shifts down to $\pi_n'(P_c)$. From the envelope theorem, π_n' must be less steeply inclined than π^* for any level of P_c, and may never rise above π^*. Assume that π_n' is, in fact, everywhere below π^*, given the viability of soybeans as a cropping alternative. As P_c rises above P_{co} and approaches P_{ca}, the profit-maximizing participating producer plants more acreage to corn, with a specified level of crop acreage set aside. Ultimately, however, at $P_c = P_{ca}$, the producer plants as much corn as is allowed under the feed grain program. For $P_c > P_{ca}$, the producer may not increase corn acreage, thus expected profit increases linearly along $\pi'_o(P_c)$ with further increases in P_c. Again, given the envelope theorem, π'_o will lie everywhere below π_n' beyond the point of tangency at $P_c = P_{ca}$.

The participating producer has thusfar been assumed to have set aside cropland, but no offsetting program benefits have yet been specified. Clearly, under the scenario described above, no incentive to participate in a voluntary feed grain program would exist, given that the expected profit function for the participant lies everywhere below that for the nonparticipation option. However, if a per acre set-aside payment is paid to participating producers, the participant's expected profit function is shifted up from $\pi_o'(P_c)$ to $\pi'(P_c)$. Given the set-aside and payment provisions, the decision to participate becomes a function of the level of P_c. At $P_c < P_{ci}$, corn market prices are relatively low, and the expected profit maximizing producer elects program participation ($\pi'(P_c)$). However, for higher corn price levels, $P_c > P_{ci}$, expected profit is maximized through nonparticipation. Price levels P_{ci} and P_{ca}, we will subsequently refer to as the indifference price and the allotment price, respectively. Whether or not the eligible producer voluntary elects to participate in the feed grain program will depend on the value of P_c relative to P_{ci}, as well as the magnitudes of the program parameters (B, a_{cb}, and α).

Given the above formulation, the corn acreage supply function for the representative producer depends fundamentally on the relationship between P_{ca} and P_{ci}. Figure 4 demonstrates the corn supply function for the case described above, where $P_{ca} > P_{ci}$. The second quadrant of Figure 4 gives the expected profit functions for the participating and non-participating options, as expressed above in Figure 3. In the first quadrant, $\bar{a}$ equals total farm acreage, a_{cb} equals corn base acreage, a_{ca} is the corn acreage allotment, S_c is the corn acreage supply curve assuming program non-participation, and L_c is the supply function assuming participation and an acreage allotment at a_{ca}. Supply curves S_c and L_c are derived, in the manner described above, from the first derivatives of π^* and π' with respect to P_c. The second partial derivatives give the curvature properties of S_c and L_c. Note that the perfectly inelastic portion of L_c above $P_c = P_{ca}$ is due to the linearity of $\pi'(P_c)$ above P_{ca}.

The participant's supply curve L_c lies to the left of S_c because of the set-aside acreage requirement and, above P_{ca}, because of the acreage allotment as well. The profit-maximizing producer elects to participate in the feed grain program at low corn prices, $P_c < P_{ci}$, yielding the lower darkened segment of S_c'. For $P_c > P_{ci}$, the producer does not participate and produces along the positively inclined segment of S_c' above P_{ci}. In the case depicted in Figure 4, the allotment price, P_{ca}, at which the producer would encounter the planted acreage restriction, is sufficiently above P_{ci} that the allotment is non-binding. The result is a discontinuous corn acreage supply curve, S_c', the discontinuity technically being a result of the different slopes of π^* and π', from which the underlying supply curves are derived.

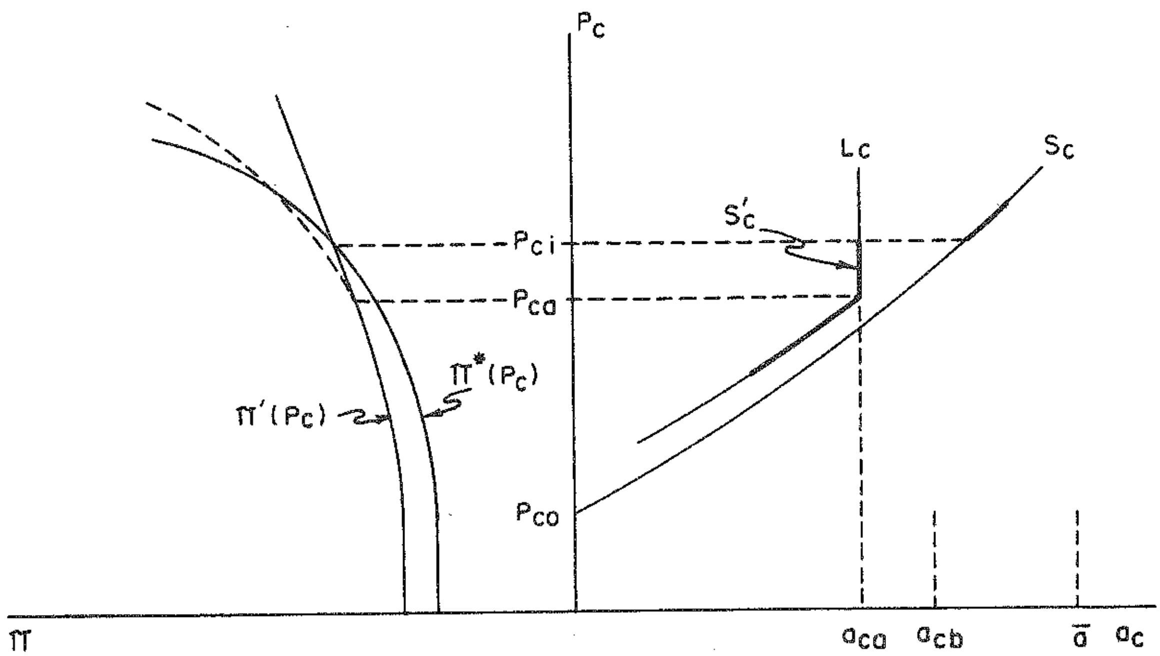
FIGURE 4. EXPECTED PROFIT FUNCTIONS AND CORN ACREAGE WITH NON-BINDING ALLOTMENT



In Figure 5, the alternative case, $P_{ci} > P_{ca}$, is considered. Expected profit functions, acreage supply functions, price and acreage variables are defined as above. For low corn price levels, the producer again participates but eventually encounters the allotment price, at which point the acreage allotment is binding, and planted corn acreage can rise no further. As the corn price rises above indifference price, P_{ci}, the producer elects not to participate and planted corn acreage increases along the darkened segment of S_c. Again, the resulting corn acreage response curve is discontinuous, reflecting the profit-maximizing producer's shift from participation to nonparticipation at indifference price P_{ci}. Although this case differs from Figure 4 in that an inelastic portion of the acreage supply function results, in both cases, the corn supply function is discontinuous and noticably different from the normal supply function applicable under a free market setting. In addition, for any $P_c < P_{ci}$, corn acreage under the feed grain program is, in both cases, less than in its absence.

In Figure 6, aggregate corn acreage supply is depicted under the circumstances outlined above. We assume that the corn price at which the producer is indifferent between participation and nonparticipation is

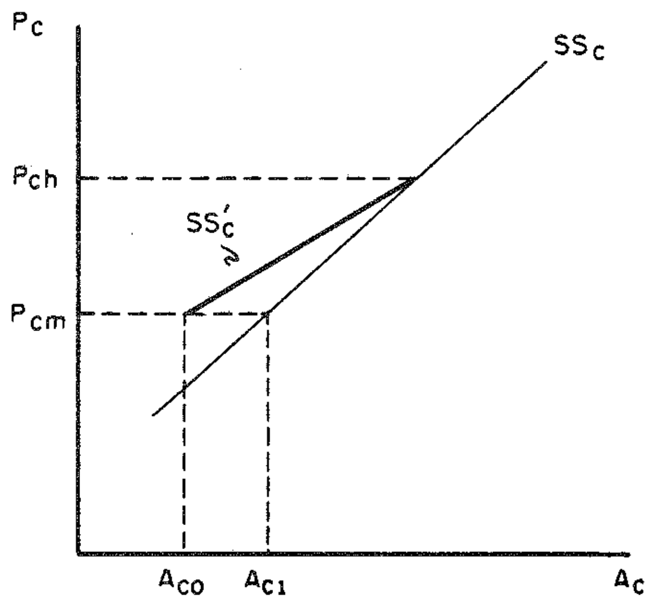
FIGURE 5. EXPECTED PROFIT FUNCTIONS AND CORN ACREAGE WITH BINDING ALLOTMENT



different for producers in any geographic region. Thus a range of indifference prices, from P_{cm} to P_{ch}, is assumed to exist. Above the highest indifference price, P_{ch}, all farmers elect nonparticipation and the aggregate acreage supply function would be simply the competitive market supply function, SS_c. At $P_c \leq P_{cm}$, all producers participate and aggregate corn acreage is less than under free market conditions, given both idled land and binding acreage allotments for many producers.

In fact, however, experience with voluntary feed grain programs over the 1960's and 1970's demonstrated varying rates of program participation, though never at the extremes of zero and 100 percent participation. This common case is represented in Figure 6 by the darkened curve, SS_c', lying to the left and less steeply inclined than the free market supply function, SS_c. A linear form of SS_c' is assumed here for simplicity, although the form that SS_c' would actually assume would depend on the actual distribution of indifference prices among farmers in a given geographic region. As can be seen in Figure 6, the position of SS_c' is important in considering aggregate corn acreage response under feed grain programs, in that its lower slope compared to SS_c implies a higher own-price elasticity of corn acreage response under the acreage reduction program compared to competitive market conditions. The specific magnitude of the producers' aggregate price responsiveness will depend on the relative values of the market and program variables.

FIGURE 6. AGGREGATE CORN ACREAGE SUPPLY CURVE



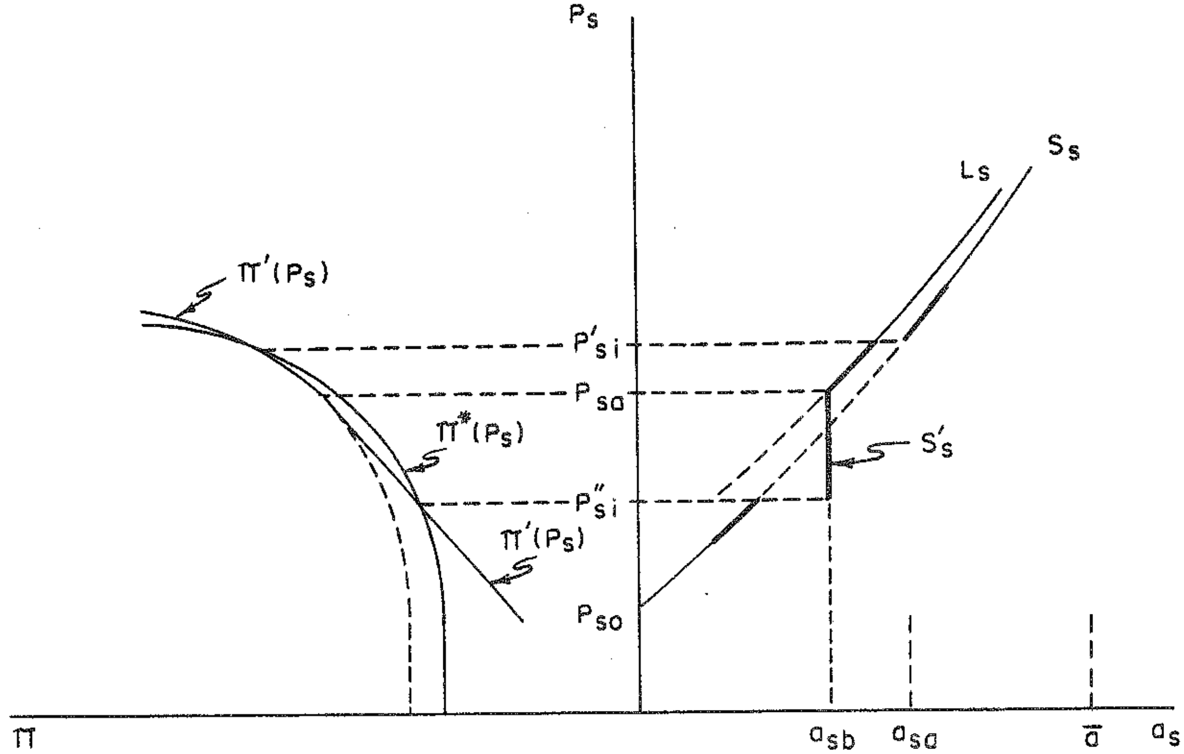
<u>Cross-Commodity Effects and Soybean Acreage Supply</u>

The introduction of an acreage restriction program has implications not only for the specific crop to be controlled but for the entire production system. In Corn Belt states where corn and soybeans are the dominant crops, the implications of the abovementioned corn program provisions in determining soybean supply responsiveness are important, though often unpredictable.

Assume the existence of a feed grain program such as that described above, with the price of corn held constant. Consider, in Figure 7, the shape of expected profit functions for a corn-soybean producer with respect to changes in soybean prices, P_s. Define the expected profit function for the nonparticipator by $\pi^*(P_s)$ and for the participator by $\pi'(P_s)$. As P_s declines from a high level and approaches P_{sa}, the producer plants less soybeans and more corn (see quadrant one). At these high expected soybean prices, the opportunity cost of participating in the corn program (e.g., the acreage required to be set aside) is sufficiently high that the producer elects not to participate. Thus the soybean acreage supply curve is similar to that existing under competitive market conditions.

As soybean prices decline further to P_{si}', however, the opportunity cost of the set-aside is finally exceeded by the payments available to the producer from participating in the program and setting aside acreage equal to $(a_{sa} - a_{sb})$. Above $P_s = P_{sa}$, though, the corn acreage allotment is not

FIGURE 7. EXPECTED PROFIT FUNCTIONS AND SOYBEAN ACREAGE WITH BINDING AND NON-BINDING ALLOTMENTS



binding and the producer continues to substitute corn acreage for soybean acreage as the relative price of soybeans declines. With a further decline in the price of soybeans to "allotment price" level P_{sa}, however, the supply-inducing price for corn is now high enough that the participating producer encounters the corn acreage constraint imposed by the program. Assuming that $(\bar{a} - a_{sb})$ equals feed grain base acreage and that $(a_{sa} - a_{sb})$ is the required set-aside, soybean acreage may not expand beyond the planting level a_{sb}, as prices decline from $P_s = P_{sa}$. With voluntary acreage idling provisions in effect, the producer might elect to set-aside additional land, with the result that soybean acreage would decline further along the dashed section of curve L_s. Without this option, however, the soybean acreage supply curve would retain an inelastic portion below P_{sa}.

Finally, as soybean prices decline to an extremely low level (P_{si}"), the opportunity cost of the corn allotment becomes high enough that the producer leaves the program. The relative price of soybeans is now sufficiently low that removal of the corn acreage constraint induces the producer to plant fewer and fewer acres to soybeans as prices decline below $P_s = P''_{si}$. The set-aside payment to the program participant could be high enough to outweigh the increasing opportunity cost of the corn allotment as soybean prices decline below P_{sa}. If this were the case, the producer would elect participation for most levels of P_s, thus eliminating the darkened portion of S'_s lying below P''_{si}. The above analysis can also be easily modified to explain soybean acreage supply in other unique situations (specialized soybean production, etc.).

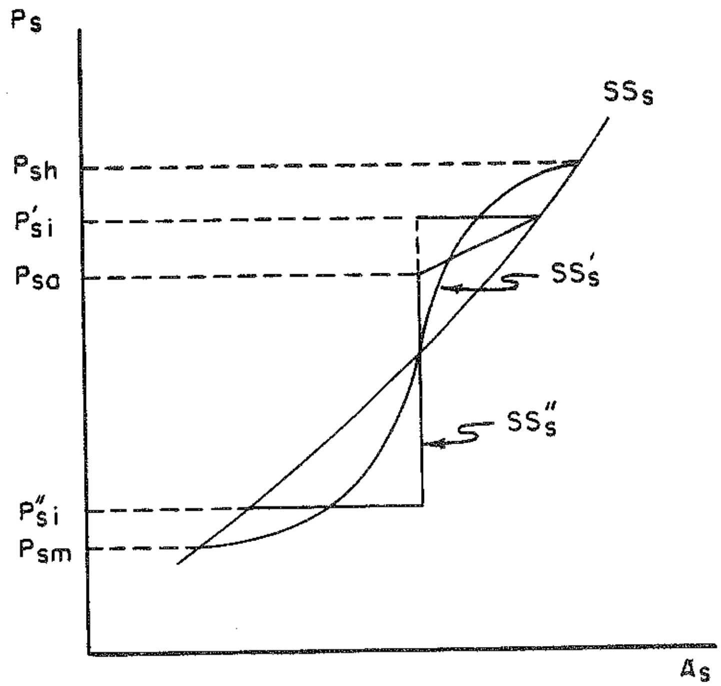
The importance of the preceding analysis lies in the theoretical existence of two indifference prices in the case of soybean acreage supply. This stems from the fact that the set-aside payment must be large enough to compensate the participating producer for both foregoing production on the required set-aside and abiding by the corn acreage allotment. At high expected soybean price levels, the opportunity cost created by the first constraint is high enough to encourage nonparticipation. At low soybean price levels, the cost of the second (allotment) constraint becomes high enough to also lead to nonparticipation. At intermediate price levels, however, the profit-maximizing producer will elect to participate if the opportunity costs of the two constraints decline sufficiently such that they are more than compensated for by deficiency payments and other program benefits.

Finally, what may be said regarding the aggregate acreage supply responsiveness for soybeans? Figure 8 depicts two alternative cases, the implications of which depend on assumptions made regarding producers' indifference prices. If all producers had identical indifference price levels of P'_{si} and P''_{si}, then the aggregate soybean acreage supply curve would be SS''_s. Instantaneous program entry and exit at price levels P'_{si} and P''_{si} makes SS''_s perfectly elastic at these two prices, and, due to 100 percent participation between prices P_{sa} and P''_{si}, soybean supply is perfectly inelastic in this portion of the curve. The assumption of identical indifference price levels for all producers makes this alternative extremely unrealistic, however.

If, though, indifference prices vary among producers, a different aggregate supply curve (SS'_s) results. Consider indifference prices corresponding to P'_{si} which range upward to P_{sh}, and those corresponding to P''_{si} which range downward to P_{sm}. In the upward range, as prices decline below P_{sh}, producers increasingly elect to participate, setting aside acreage but with the corn allotment not yet binding. Within this range, soybean acreage is necessarily less than under competitive conditions (curve SS_s). Within the lower range, as prices rise to P_{sm} and above, producers also join the program, setting aside acreage but also increasing soybean acreage as a result of the corn allotment provisions. In this case, soybean acreage exceeds that planted under a free market regime. As prices rise between P''_{si} and P'_{si}, additional producers join the program while other producers elect to drop their participation. The resulting acreage supply curve, SS'_s, is essentially a smoothed version of SS''_s and approximates actual soybean acreage supply under the feed grain program.

Little can be concluded definitively about soybean supply responsiveness under partial program participation compared with competitive conditions. Depending on the range of soybean prices, SS'_s might have a greater,

FIGURE 8. AGGREGRATE ACREAGE SUPPLY CURVES FOR SOYBEANS WITH AND WITHOUT A FEED GRAIN PROGRAM



smaller, or equal elasticity than that obtained under a competitive market. The magnitude of aggregate soybean supply responsiveness under an acreage limiting feed grain program is essentially an empirical question, then, depending on the relative magnitudes of soybean prices, corn prices, and feed grain program incentives and constraints.

CHAPTER IV

THE EMPIRICAL MODEL

This chapter describes a multiple equation econometric model which is used to estimate corn and soybean acreage supply response in the four-state Corn Belt region. Attention is first given to an alternative method of incorporating feed grain program provisions in an empirical supply model. The estimation model and data used in the analysis are then described. Next, Parks' generalized regression procedure, used in the estimation of the empirical model, is reviewed. Finally, a test for structural stability of coefficient estimates is discussed.

Government Program Variables in Acreage Response Models

As mentioned in Chapter II, three major types of benefits accrued to producers participating in feed grain programs over the post-War period. They were: (i) price support loans, (ii) payments for required diversion, and (iii) a sequence of price support payments, set-aside payments, and deficiency payments. The approach taken here estimates the magnitudes of each of these benefits in the relevant years, sums the total benefits available to producers in any given year, and incorporates the resulting payment estimate as an explanatory variable in the econometric model finally estimated.

Price Support Loan Incentives

Price support loans have been available to corn and soybean producers in all years and on total production except for 1961-62 for corn, when price support loans were available only on "normal" production. The levels that these loan rates assumed relative to expected market prices are important in contributing to total program participation incentives and, ultimately, in determining participation rates. For soybeans, loan rates exceeded average market prices in only five of the 33 years between 1948 and 1980: 1957-58, 1961, and 1967-68 (see Appendix Table A.4). Moreover, the largest difference between the two prices was only $.09 (in 1958), and in three of the five years, the differential was $.02 or less. In only three years, 1958, 1961 and 1968, did loan rates exceed market prices lagged one year (an approximation to farmers' expected prices the following year). Thus, it seems reasonable to argue that the soybean loan rate was of negligible importance compared to soybean market prices in the formation of producers' production and planting decisions.

For corn, though, the story is different. Although after 1962 corn loan rates exceeded average market prices on only one occasion (1967), in 1962 and before, loan rates were greater than market prices in all but two years, 1950 and 1951. The reason for this change is that beginning in 1963, in order to stimulate exports and hold down domestic prices, corn loan rates were reduced to world price levels, while the price support payment feature (see below) was added to the feed grain program to enhance producers' returns. Thus in the "program" years treated in this study, 1961-73 and 1978-79, the price support loan rate was an important participation incentive only in 1961 and 1962.

During both of these years, the price support loan incentive (PSLI) was available on normal production on corn acreage planted in a manner estimated as follows:

$$(4.1) \quad PSLI_j = (P_c^* - E_j(P_c))(Y_{cj})(a_{cp}, j)$$

where P_c^* = price support loan,

$E_j(P_c)$ = expected corn market price in state j,

Y_{cj} = historic corn yield in state j,

and a_{cpj} = planted corn acreage in state j.

Given announced corn loan rates equal to $1.20 per bushel in both 1961-62, lagged market prices as proxies for expected market prices, exogenously determined historic corn yields, and maximum corn plantings for program participants of 80 percent of corn base, the PSLI variable can be calculated for each of the four states in years 1961-62. This is done in Table 5. The values are expressed in terms of dollars per required idled acre where required idled acres, by definition, equal 20 percent of corn base or 25 percent of maximum corn plantings.

TABLE 5

PRICE SUPPORT LOAN INCENTIVE (PSLI)
PAYMENTS FOR SELECTED STATES: 1961-62

State	1961	1962
Illinois	$28.35	$32.40
Indiana	31.35	37.23
Iowa	34.72	34.71
Ohio	31.35	37.23

Payments for Required Diversion

The second category of payments offered to feed grain producers as incentives for participation in the feed grain programs were payments for acreage mandatorily idled under the acreage diversion program. These payments were offered in five years only, 1961-65, after which higher price support payments were offered, in part to reflect the discontinuance of required diversion payments. These payments were calculated by:

$$(4.2) \quad DP_{rj} = (.5)(P_c^*)(Y_{cj})(\bar{a}_r^I) = (.5)(P_c^*)(Y_{cj})(.2\bar{a}_c)$$

where $\bar{a}_r^I$ = required idled acreage,

$\bar{a}_c$ = corn base acreage,

and all other variables are defined as previously. In 1963 and for the two succeeding years, the payment calculation method was changed slightly to:

$$(4.3) \quad DP_{rj} = (.2)(P_c^* + b_c)(Y'_{cj})(\bar{a}_r^I),$$

reflecting a decrease in the payment rate coefficient from .5 to .2, and the addition of a new per bushel "price support payment" (b_c) to the (now much lower) price support loan rate. Since all components of (4.1) and (4.2) were exogenously determined under the acreage diversion program, these payments for required diversion (per required idled acre) are easily calculated. The estimated payments are summarized in Table 6.

TABLE 6

PAYMENTS FOR REQUIRED DIVERSION (DP_r) FOR SELECTED STATES: 1961-65

Year	Illinois	Indiana	Iowa	Ohio
1961	40.50	39.20	38.60	39.20
1962	40.50	39.20	38.60	39.20
1963	16.90	16.35	16.10	16.35
1964	18.70	17.90	17.60	17.55
1965	19.30	18.70	18.05	17.95

Price Support Payments, Set-Aside Payments, and Deficiency Payments

Beginning in 1963 and continuing through the set-aside programs of the 1970's, payments were made to producers to induce their participation in government feed grain programs and to enhance producer incomes in surplus years. These payments were called "price support payments" under the acreage diversion programs (1963-70), while under the set-aside programs, they were referred to as "set-aside payments" (1971-73) and "deficiency payments" (1978-79). The methods of calculating these payments changed over time as the programs evolved. Each is considered in turn here.

Variable price support payments (PSP's) were first offered to program participants in 1963-1965, according to the formula:

$$(4.4) \quad PSP_j = (b_c)(Y_{cj})(a_{cp}),$$

or the product of the announced per bushel support payment b_c (equal to \$.18 in 1963, \$.15 in 1964, and \$.20 in 1965), times historic yield, times total planted corn acreage. Because total price support payments received by farmers varied positively with planted acreage, their net effects on aggregate planted acreage were, to some extent, offsetting. While increases in b_c made program compliance more attractive and thus tended to decrease planted acreage, these same increases represented a price premium to participants, making increased corn planting within the program guidelines more attractive relative to voluntary land diversion. The net effect of these two countervailing incentives is difficult to ascertain _a priori_.

In 1966-1970, the method of calculating price support payments was altered, decreasing the positive planting incentive existing under the 1963-63 programs. The new payment formula was:

$$(4.5) \qquad PSP_j = (b_c)(Y_c'')(.5\bar{a}_c)$$

or the product of the announced per bushel payment (\$.30 in each year), times projected yield (five-year average yield, adjusted for trend), times the _smaller_ of planted acreage or 50 percent of corn base acreage ($\bar{a}_c$). Since maximum acreage diversion levels ranged from 20 percent of base (in 1967) to 50 percent of base (in 1966, 1968-70), planted acreage had to at least equal 50 percent of base; thus the last term of (4.5) was fixed or historically determined as were b_c and Y_c''. Price support payments in 1966-70, then, represented essentially fixed payments to participating producers.

Although the inception of the acreage set-aside program in 1971 is often considered to have represented a considerable change in program philosophy, the continuation of payments to producers in the form of "set-aside payments" rather than price support payments represented only a small real change in program operation. Set-aside payments (SAP) were calculated by:

$$(4.6) \qquad SAP_j = (P_c^t - P_c)(Y_c')(.5\bar{a}_c),$$

or the product of a differential between a guaranteed return (\$1.35 per bushel in 1971-72; \$1.64 per bushel in 1973) and the marketing year average price, times adjusted historic yield, times 50 percent of base acreage. A preliminary payment based on an estimate of $(P_c^t - P_c)$ was announced prior to planting and paid to producers before harvest. Since (i) the preliminary payment (\$.32 per bushel in 1971 and 1973; \$.40 per bushel in 1972) did not have to be returned even if the actual differential was less than the estimate, and (ii) the producer received additional payments if the actual differential exceeded the estimate, the preliminary payment represented an essentially fixed guarantee to the producer, as under the earlier diversion program.

During the final two years of production control programs considered here, 1978-79, the method of calculating program benefits, now called "deficiency payments", was changed considerably. Deficiency payments were variable in nature, and calculated according to the formula:

$$(4.7) \qquad DFP_j = (P_c{}^i - \max(P_c{}^*, P_c))(Y_c{}')(\alpha)(a_{cp}),$$

where $P_c{}^t$ equals the target price for corn ($2.10 per bushel in 1978; $2.20 per bushel in 1979), $P_c{}^*$ is the corn loan rate, P_c is the corn market price, $Y_c{}'$ is historic yield, a_{cp} is planted corn acreage, and α is the "allocation factor" (see explanation in Chapter II). The deficiency payment rate was a maximum $.10 per bushel in 1978 and $.20 per bushel in 1979. For producers who exceeded the most stringent planting requirements, α was reduced proportionately, thus decreasing the effective deficiency payments received. In estimating program benefits, an allocation factor equal to one is assumed here.

Based on announced program provisions, an allocation factor equal to one, and maximum permitted corn plantings under the series of programs, it is possible to estimate the relevant price support, set-aside, and deficiency payments payable to participating producers in the four states. This is done in Table 7. Again, payments are expressed in terms of dollars per required idled acre under the program.

Total Program Participation Incentives

As reviewed above, three broad categories of payments were made to grain producers participating in feed grain programs over the period 1961-1979. Ideally, estimates of each of these payments in each sample state would be available for every year in the sample period, permitting their inclusion as independent variables in an econometric model of acreage supply. In fact, however, each of the types of payments was available in only a small subsample of years: price support incentives in 1961-62, payments for required diversion in 1961-65, price support payments in 1963-70, set-aside payments in 1971-73, and deficiency payments in 1978-79. On the other hand, all of these types of payments had the same main objective, *viz.*, encouraging a basic level of participation in feed grain programs. This fact, along with the discontinuities of the payment variables themselves, suggests the necessity of aggregating the various participation incentive payments into a "total incentive payment" measure to be included in the econometric analysis which follows.

The TIP variable, then, measures the sum of all participation incentives relevant in each sample year. Table 8 illustrates the values taken by TIP for the four sample states over the program regime years. Since the values of TIP are expressed in terms of payments per required idled acre, these values measure the estimated gross returns to an acre of idled cropland under program participation. If idled or diverted acreage is thought of as an alternative "crop", then increases in TIP would be expected to lead to increased program participation, higher levels of idled acreage, and lower levels of corn acreage, *ceteris paribus*.

In addition to the incentives provided by feed grain programs to encourage a basic level of program participation, in most years, further

TABLE 7

PRICE SUPPORT, SET-ASIDE, AND DEFICIENCY PAYMENTS
FOR SELECTED STATES: 1961-1973, 1978-1979
(PAYMENT PER IDLED ACRE)

PAYMENTS AND YEARS	ILLINOIS	INDIANA	IOWA	OHIO
PRICE SUPPORT PAYMENTS				
1963	$30.40	$29.40	$34.70	$29.40
1964	28.05	26.85	26.35	26.30
1965	38.60	37.35	36.10	35.85
1966	61.80	58.90	57.90	54.55
1967	67.65	65.25	61.60	55.95
1968	64.05	62.55	62.85	58.05
1969	68.40	63.83	64.30	59.93
1970	66.75	65.70	66.45	61.80
SET-ASIDE PAYMENTS				
1971	76.65	73.44	68.80	67.85
1972	67.36	63.20	81.60	65.60
1973	139.20	139.20	139.20	139.20
DEFICIENCY PAYMENTS				
1978	89.30	89.30	89.30	89.30
1979	172.80	172.80	172.80	172.80

TABLE 8

TOTAL INCENTIVE PAYMENTS* FOR SELECTED STATES: 1961-1973, 1978-1979
(PAYMENT PER IDLED ACRE)

YEAR	ILLINOIS	INDIANA	IOWA	OHIO
1961	$68.85	$70.55	$73.32	$70.55
1962	72.90	76.43	73.31	76.43
1963	47.30	45.75	50.80	45.75
1964	46.75	44.75	43.95	43.85
1965	57.90	56.05	54.15	53.80
1966	61.80	58.90	57.90	54.55
1967	67.65	65.25	61.60	55.95
1968	64.05	62.55	62.85	58.05
1969	68.40	63.83	64.30	59.93
1970	66.75	65.70	66.45	61.80
1971	76.65	73.44	68.80	67.85
1972	67.36	63.20	81.60	65.60
1973	139.20	139.20	139.20	139.20
1978	89.30	89.30	89.30	89.30
1979	172.80	172.80	172.80	172.80

*Sum of: Price support loan incentive payments, price support payments, set-aside payments, deficiency payments, and payments for required diversion.

payments were offered to those producers who voluntarily idled additional acreage. As can be seen in Table 3, these provisions were incorporated into feed grain programs in all years between 1961 and 1979, except for 1967, 1971, and 1973. While payments for voluntary diversion were in most cases formulated differently than payments for required diversion, their main impact was in their being paid on higher levels of acreage diversion. These varying diversion levels are incorporated in the variable described next.

Acreage Diversion Limits

The feed grain program benefits reviewed above were not available to producers on an unlimited basis. Acreage planting constraints and diversion requirements accompanied program payment incentives and these constraints were important in determining aggregate crop acreage levels.

In all years except for 1978-79, minimum acreage diversion levels required of producers were expressed as a percent of historic crop base acreages. In 1961-70, these minimum diversion levels were 20 percent of historically defined feed grain base acreage. As noted previously, after 1965, if a producer was eligible for and elected to take advantage of the feed grain-wheat substitution provisions, he also had to idle 20 percent of his wheat allotment. The 20 percent level of required diversion continued through the set-aside program of 1971, after which the level was raised to 25 percent of base in 1972 and then lowered to 10 percent in 1973. Throughout the 1961-73 period, adjustments of base acreage and wheat allotments were made on individual farms to reflect local conditions. However, at the state level of aggregation, year-to-year changes in required diversion levels were minor, as revealed in Table 9.

Ceilings on additional voluntary acreage diversions were less stable over the 1960's and 1970's. In 1961-63 and during the set-aside program of 1972, ceilings were set at 20 percent of feed grain base, while in the years 1964-1970 (excluding 1967) maximum voluntary paid diversion levels were increased to 30 percent of base acreage. In 1967, 1971, and 1973, no paid voluntary diversion was permitted. Statewide voluntary diversion levels assuming full program compliance are given in Table 9.

In 1978-79, unlike previous years, both required set-asides and voluntary diversion levels were expressed as proportions (10 percent in each case) of current feed grain planting level rather than in terms of historic base acreage. However, since maximum deficiency payment rates were only made available to producers limiting their corn plantings to specified proportions of the previous year's planted acreage, it is possible to specify effective diversion limits assuming full program compliance. Since these planting limitations were specified as 95 percent of 1977 acreage in 1978 and 90 percent of 1978 "considered" planted acreage in 1979, the effective required and voluntary diversion limits were 10 percent of each figure, or 9.5 percent and 9.0 percent of the previous year's corn plantings in 1978 and 1979, respectively. These figures are also given in Table 9.

As reviewed in Chapter 2, the 1961-79 feed grain programs also stipulated planted acreage limitations or allotments in most years. In 1961-

TABLE 9

REQUIRED (R) AND VOLUNTARY (V) IDLED ACREAGE LIMITATIONS*: 1961-73, 1978-79
ACRES (MILLIONS)

YEAR	ILLINOIS		INDIANA		IOWA		OHIO	
	R	V	R	V	R	V	R	V
1961	2165	2165	1096	1096	2624	2624	823	823
1962	2153	2153	1111	1111	2645	2645	765	765
1963	2176	2176	1133	1133	2681	2681	783	783
1964	2181	3272	1135	1702	2689	4033	784	1176
1965	2181	3272	1136	1704	2696	4044	785	1177
1966	2183	3275	1138	1707	2699	4048	786	1179
1967	2183	--	1137	--	2706	--	785	--
1968	2184	3276	1136	1705	2698	4047	784	1176
1969	2183	3274	1136	1704	2698	4047	783	1175
1970	2181	3272	1135	1702	2698	4047	782	1173
1971	2175	--	1117	--	2699	--	766	--
1972	2266	1813	1164	931	3188	2551	755	604
1973	1104	--	569	--	1398	--	377	--
1978	1053	1053	590	590	1228	1228	343	343
1979	1005	1005	558	558	1165	1165	325	325

*Limitations based on maximum statewide compliance with feed grain program provisions.

1970, given the lack of major changes in program formulation, these acreage limitations were highly stable. Even under the less restrictive set-aside programs of the 1970's, producers were offered higher payment rates for abiding by planted acreage restrictions in 1972, 1978, and 1979. Only in 1971 and 1973, were there no limitations (explicit or implicit) on planted corn acreage. Given the high degree of stability of aggregate planted acreage limitations, explicit measures of these limitations were not included in the analysis below.

Econometric Model

The discussion in Chapters 2 and 3 provides the basis for the estimation of an econometric model of corn and soybean acreage supply for the four-state area, the specification of which is primarily dependent on the existence or absence of acreage-controlling government feed grain programs. In the absence of these programs, acreage supply functions for corn and soybeans under a "free market regime" may be specified for the four states as follows:

$$(4.8) \quad AC_{it} = f_i(PC_{it-1}, PS_{it-1}, T) \quad i=1, \ldots, 4$$

$$(4.9) \quad AS_{it} = g_i(PC_{it-1}, PS_{it-1}, T) \quad i=1, \ldots, 4$$

where AC_{it} and AS_{it} are the acreages planted to corn and soybeans in state i in year t, PC_{it-1} and PS_{it-1} are the relative prices of corn and soybeans in state i in year t-1, and T is a trend variable representing systematic excluded variables which influence planted acreage (e.g., technological change). Price variables PC_{it-1} and PS_{it-1} are average state market prices in year t-1 divided by an index of prices of variable inputs used in crop production (see below). The four states included in the analysis are all in the geographically homogeneous Corn Belt area: Illinois, Indiana, Iowa, and Ohio. Sets of equations (4.8) and (4.9) were estimated using a multiple equation generalized least squares regression procedure applicable to pooled cross-section time-series data (see discussion below).

The free market regime includes the twelve years from 1948 through 1980 in which no acreage control programs were applied to feed grain crops: 1948-49, 1951-53, 1959-60, 1974-77, and 1980. Some farm program benefits were available to producers during those years (price support loans, etc.), however, relatively high market prices and a lack of acreage controls meant that cash grain producers responded to largely competitive market forces in formulating their acreage allocation decisions.

In other years, as has been described previously, the existence of feed grain programs and the alternatives they created for grain producers fundamentally altered production decisions. For these "farm program regime" years, 1961-73 and 1978-79, the important role played by program payments and constraints in determining feed grain acreage necessitates an alternative specification of state corn acreage supply functions:

$$(4.10) \quad AC'_{it} = h_i(PC_{it-1}, PS_{it-1}, TIP_{it}, ADV_{it}, T) \quad i=1, \ldots, 4$$

where TIP_{it} represents the total incentive payments available to producers (expressed in dollars per required idled acre), ADV_{it} is the maximum state acreage diversion level (expressed in numbers of acres), and all other variables are defined as before. Increases in TIP_{it} represent increased expected returns from idling acreage as required under feed grain programs, and thus, *ceteris paribus*, are expected to lead to greater rates of program participation, higher levels of aggregate acreage diversions or set-asides, and consequently, lower levels of planted corn acreage. Increases in ADV_{it}, as reviewed above, are due largely to increases in voluntary diversion limits since these increases represent (i) greater incentives to participate in the feed grain program and (ii) increased competition for corn acreage on a relatively fixed cropland base. Given these factors, the expected sign on the regression coefficient on ADV_{it} is also expected to be negative.

Sets of supply response equations are also estimated for state soybean acreage under the farm program regime. Two formulations were used due to the *a priori* uncertainty regarding the effects of corn program variables on soybean acreage:

$$(4.11) \quad AS'_{it} = m_i(PC_{it-1}, PS_{it-1}, T) \quad i=1, \ldots, 4$$

$$(4.12) \quad AS'_{it} = n_i(PC_{it-1}, PS_{it-1}, TIP_{it}, ADV_{it}, T) \quad i=1, \ldots, 4$$

All variables are defined as previously.

In equations (4.11), the corn program variables were excluded since initial empirical results did not conclusively indicate significant structural change in coefficient (elasticity) estimates over the two regimes. The model was also estimated with the corn program variables included, given the arguments presented in Chapter 3 as well as the historical importance of the "safety valve" effect of feedgrain programs in soybean acreage. Given these reasons, a different supply responsiveness of state soybean acreage might be expected under the farm program regime compared to the free market regime. However, it is not possible to state *a priori* the expected signs of the coefficients of the program variables TIP_{it} and ADV_{it} in equation (4.12).

Data

The dependent variables in equations (4.8) through (4.12) represent the acreages planted to corn and soybeans in the four-state area. Because planted corn grain acreage data is not available on a consistent basis over the entire 1948-80 sample period, corn and soybean harvested acreage data from U.S.D.A's. *Agricultural Statistics* is used as a proxy for planted acreage. Planted acreage data for corn and soybeans is listed in Appendix Tables A.2 and A.3.

Relative price variables PC_{it-1} and PS_{it-1} are the ratios of one year lagged average state market prices for corn and soybeans, respectively, to an index of prices for variable inputs used in crop production. Lagged market prices are one of several proxies that have been used to measure producer price expectations. Alternative measures have included distributed lags of past prices and indexes of futures price (Gardner; Morzuch, Weaver, and Helmberger). Lagged market prices are generally highly correlated with other price expectation proxies, which has led to their frequent use in supply analysis (recent examples include Whittaker and Bancroft, Reed and Riggins).

An input price index is used in this study to adjust output prices for changes in the prices paid by farmers for the variable inputs used in crop production: seed, fertilizer, motor vehicles and supplies, farm machinery, and farm supplies. Given the lack of sufficient input utilization data, it is not possible to construct "true" price indexes for variable inputs (e.g., Laspeyres, Paasche, or Divisia Indexes). Instead, weights are assigned to each category of input prices in proportion to weights developed by the U.S.D.A. for use through 1964, and revised in 1965 (Stauber, Hale, and Peterson; U.S.D.A. Crop Reporting Board). These weights are given in Table 10. Individual input price indexes were obtained from the U.S.D.A.'s Agricultural Prices publication. The resulting variable input price index is given in Appendix Table A.5. Adjustment of output price variables by the input price index restricts equations (4.8)-(4.12) to be homogeneous of degree zero in prices, as suggested by economic theory.

The government program variables, TIP and ADV included in equations (4.10) and (4.12) for the farm program regime have been explained in detail above and require no further treatment here. A trend variable is included in each acreage equation as a proxy for technological change, an important factor in producer decision-making, but one which is exceedingly difficult to quantify. All variables are expressed in logarithms, so that equations (4.8)-(4.12) are in log-linear functional form.

Estimation Procedure

Each of the sets of equations (4.8)-(4.12) includes acreage supply equations for the four states considered in this study. Given their continguous location, relatively high degree of geographic homogeneity, and similar cropping systems, it is reasonable to assume that weather and other exogenous forces have generally similar impacts on planting decisions throughout the region. This implies that error terms in each set of crop acreage response equations across the four states will be contemporaneously correlated, which in turn suggests the use of multiple equation generalized least squares regression procedures to arrive at efficient coefficient estimates. Few previous acreage response studies have used multiple equation procedures in estimating supply relationships, though notable exceptions include Whittaker and Bancroft's use of a pooled time-series cross-section model and Reed and Riggins' use of a seemingly unrelated regression model.

A common procedure in such cases is the two-stage Zellner-Aitken or Zellner efficient (ZEF) method of estimation in which: (1) OLS is applied to each equation in the system yielding residuals which are then used in

TABLE 10

VARIABLE INPUT GROUPS AND WEIGHTS: 1948-1964; 1965-1980

YEARS AND INPUT GROUPS	WEIGHTS*
1948-64:	
Seed	.090
Fertilizer	.145
Motor Supplies	.155
Motor Vehicles	.184
Farm Machinery	.296
Farm Supplies	.130
	1.000
1965-80:	
Seed	.078
Fertilizer	.182
Agricultural Chemicals	.108
Fuels, Energy	.195
Farm Supplies	.117
Autos, Trucks	.152
Tractors, Self-Propelled Machines	.095
Other Machinery	.074
	1.000

*Weights are proportions of total variable input price index in each group. Sources: Stauber, Hale, and Peterson. Ag. Econ. Res. 1959. USDA Crop Reporting Board, "Index numbers of prices received and prices paid by farmers." May 1976.

computing the estimated variance and covariance elements of $\hat{\Sigma}$; and (2) the "true" coefficient vector $\underline{\beta}$ is then estimated by the ZEF estimator $\hat{\underline{\beta}}$:

$$(4.13) \quad \hat{\underline{\beta}} = [X'(\hat{\Sigma}^{-1} \times I)X]^{-1} [X^1(\hat{\Sigma}^{-1} \times I)\underline{y}]$$

where: $\underline{y}$ = the vector of observations on all state acreage variables

X = the block diagonal matrix of observations on K explanatory variables for each state,

and $\hat{\Sigma}$ is the estimated covariance matrix which takes the form

$$(4.14) \quad \hat{\Sigma} = \begin{bmatrix} S_{11}I_T & S_{12}I_T & S_{13}I_T & S_{14}I_T \\ S_{21}I_T & S_{22}I_T & S_{23}I_T & S_{24}I_T \\ S_{31}I_T & S_{32}I_T & S_{33}I_T & S_{34}I_T \\ S_{41}I_T & S_{42}I_T & S_{42}I_T & S_{44}I_T \end{bmatrix} = S \times I_T,$$

The ZEF estimator has been shown to be unbiased if the mean of $\underline{b}$ exists and if $\underline{b}$ is symmetrically distributed around $\underline{\beta}$ (Kakwani), and to be asymptotically efficient.

An additional complication arises here in the ZEF estimation of equations (4.8)-(4.12), however. Though rarely corrected for in acreage response studies, autocorrelation frequently characterizes estimated acreage supply equations. In the preliminary supply equations estimated over the entire time series in this analysis, high degrees of autocorrelation of error terms were found to characterize all state equations for both corn and soybeans. In order to correct for both this autocorrelation and the contemporaneous correlation across equations, Parks' "three-stage Aitken method" was employed to correct for both problems. Parks' procedure involves: (i) OLS regression and the estimation of an autocorrelation coefficient $\hat{p}$ (using the Cochrane-Orcutt procedure) for each equation separately, (ii) adjustment of variables in each equation based on $\hat{p}$, and (iii) estimation of the entire set of equations using the ZEF estimator (4.13). Given the high autocorrelation coefficients encountered in the preliminary analysis, and the likelihood of contemporaneous correlation across individual equations in a multiple equation system, the Parks procedure provides a method for obtaining more efficient regression coefficient estimates than would otherwise be obtainable.

Because of the low number of observations (years) in each of the two regimes analyzed, a restricted version of the generalized regression model was estimated in each case. In the final step of each regression procedure, cross-equation equality restrictions were imposed on all coefficients, except intercept terms which were allowed to vary across states. Since all equations were estimated in log-linear form, these equality restrictions meant that supply elasticities were restricted to being equal across all four states under each regime. Given the geographic homogeneity and similarities of grain cropping patterns of these four states, these restrictions appear justifiable.

Testing for Structural Change

The issue of structural change in corn and soybean acreage supply response over the free market and farm program regimes may be examined statistically. A number of tests have been used in testing for structural stability (Wald, LaGrange, likelihood ratio), though it must be noted that in the multiple equation case, the same estimated covariance matrix must be used in arriving at unconstrained and constrained coefficient estimates. The LaGrange test was used here to test for coefficient stability. The relevant test statistic is:

$$(4.15) \qquad \frac{Tr(\hat{\Sigma}_R) - Tr(\hat{\Sigma}_U)/KL}{Tr(\hat{\Sigma}_U)/T - KL} \sim F_{(KL,\ T-KL)}$$

where: $Tr(\hat{\Sigma}_R)$ = trace of the variance matrix of restricted coefficient estimates,

$Tr(\hat{\Sigma}_U)$ = trace of the variance matrix of unrestricted coefficient estimates,

K = number of independent variables,

L = number of equations, and

T = number of observations.

Estimated F-statistics in the critical F region would lead to rejection of the null hypothesis of coefficient stability across regimes, providing some confirmation of the arguments presented in Chapter III and of the usefulness of the dual regime estimation model.

CHAPTER V

ESTIMATION RESULTS

This chapter presents the empirical results from estimation of the econometric models developed in Chapter Four, and discusses these results in light of the theoretical discussion of Chapter Three and previous research. After presenting the results from the structural change tests, attention is devoted first to the results of the estimation of the corn acreage response equations and then to the empirical results for the soybean acreage equations.

Tests for Structural Change

The hypothesis of crop supply response stability over the free market and farm program regimes was tested using the LaGrange test, as outlined in Chapter Four. Specifically, the hypothesis tested was the null hypothesis that the coefficient vector estimated for each crop under the free market regime (equations (4.8) and (4.9)) was equal to the coefficient vector estimated under an expanded farm program regime (equations (4.10) and (4.11)). For the purposes of this test only, all non-free market regime years in the 1948-1980 period were included in the farm program regime. Imposition of the required cross equation restrictions in a generalized least squares regression amounts to a regression using data from the total sample years, 1948-1980, with K (the number of independent variables in each state acreage equation) equal to four (representing an intercept term, PC_{it-1}, PS_{it-1}, and T), L (the number of state acreage equations in each estimated model) equal to four, and T (the number of total time series observations) equal to 132 (33 years times four).

The restricted GLS regression using the Parks' procedure described previously yields an estimated covariance matrix of restricted transformed residuals, $\hat{\Sigma}_r$, the trace of which, $Tr(\hat{\Sigma}_r)$ is used in calculating the test statistic. Allowing the estimated coefficient vectors to vary over the two regimes amounts to estimating equations (4.8) - (4.11) in an unrestricted form, which yields the trace of the covariance matrix of unrestricted transformed residuals, $Tr(\hat{\Sigma}_u)$. In this case, the LaGrange test statistic given by equation (4.15) becomes:

$$(5.1) \qquad \frac{Tr(\hat{\Sigma}_r) - Tr(\hat{\Sigma}_u)/16}{Tr(\hat{\Sigma}_u)/116} \sim F(16,116)$$

where the critical F(16,116) value equals 1.75. The F-statistic (5.1) was calculated for both corn and soybean crops over the 1948-1980 sample period, with the results given in Table 11.

The results indicate that the hypothesis of supply response stability over the free market and farm program regimes is rejected for corn. This is not surprising given the results of the theoretical model of Chapter Three, which pointed to a fundamentally different acreage allocation

TABLE 11: TESTING STABILITY IN CROP SUPPLY RESPONSE

Crop	$Tr(\hat{\Sigma}_u)$	$Tr(\hat{\Sigma}_r)$	$F_{(16,116)}$	$F_{(.05)}$	$H_0: \beta_{FMR} = \beta_{FPR}$
Corn	2.9025	3.9194	2.544	1.75	reject
Soybeans	3.2520	3.7778	1.175	1.75	do not reject

allocation problem for the cash grain producer in the presence of an acreage limiting feed grain program compared to the situation existing in a freely competitive market. The result provides support for the disaggregated approach taken here with regard to corn acreage response.

In the case of the soybean acreage equations, the hypothesis of equal supply responsiveness over the two regimes is not rejected. This result is not entirely surprising given the problems described in Chapter Three in modeling soybean acreage response to changes in corn programs, in particular, the offsetting effects that those programs had in influencing planted soybean acreage. However, given the uncertainty surrounding the nature of those effects, it is interesting that their net effect in influencing soybean acreage does not appear to result in a statistically significant change from soybean acreage response under a free market. Since the discussion of Chapter Three suggests that corn program variables are nonetheless important in determining non-program crop acreage (e.g. soybean acreage) in some years, the conservative research approach is to estimate soybean supply equation separately for each regime, leaving open the likelihood of similar supply responsiveness under both regimes. This is the procedure followed below.

Corn Acreage Supply Response

Generalized least squares estimates of the sets of corn acreage supply equations (4.8) and (4.9) yield the results in Table 12. Following Parks' procedure, ordinary least squares was first applied to each state acreage equation to test for autocorrelation in the individual equations. Estimated autocorrelation coefficients ranged from .42 to .48, and indicated a statistically significant presence of autocorrelation in the residuals of each equation. The Cochrane-Orcutt procedure was employed to adjust for autocorrelation in each case.

The resulting GLS coefficient estimates for the corn acreage equations under the free market regime are statistically significant[1] and the signs on the own and cross-price variables have the expected positive and negative signs, respectively. For the four-state region overall, a relatively low own price elasticity of supply equal to .118 is estimated, with a

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[1]Use of the GLS procedure outlined above means that the ratios of coefficient estimates to their standard errors indicate only approximate statistical significance.

TABLE 12: CORN ACREAGE RESPONSE ESTIMATES

REGIME	STATE	$\hat{p}$	INTERCEPT[a]	CORNIDX	SOYBIDX	TREND	TIP	ADV
Free Mkt. Regime[b]	Illinois:	.470	9.447 (.364)	.118 (.067)	-.166 (.060)	.058 (.021)	–	–
	Indiana:	.422	8.800 (.363)					
	Iowa:	.445	9.614 (.362)					
	Ohio:	.478	8.429 (.363)					
Farm Program Regime[c]	Illinois:	.470	7.339 (1.243)	.239 (.108)	.050 (.121)	.470 (.093)	-.103 (.046)	-.070 (.029)
	Indiana:	.422	6.644 (1.222)					
	Iowa:	.445	7.468 (1.245)					
	Ohio:	.478	6.099 (1.213)					

[a]Estimated standard errors in parentheses.
[b]Years: 1948-49, 1951-53, 1959-60, 1974-77, 1980.
[c]Years: 1961-73, 1978-79.

cross-price elasticity with respect to soybean price of -.166. The trend variable is positively signed and statistically significant.

For the farm program regime, coefficient estimates are also statistically significant, excepting the coefficient on relative soybean price. The results provide substantial support for the argument of variable price responsiveness developed previously. An own-price elasticity of supply of .239 is estimated over the program years, over twice the magnitude of the estimated supply elasticity in free market years. Though the estimated soybean price coefficient has an unexpected positive sign, it is not statistically significant, confirming the relative weakness of cross-price responsiveness of corn acreage supply under acreage controlling feed grain programs. The estimated coefficients on the farm program variables are also statistically significant with the expected negative signs, indicating that program payments and acreage limitations were in fact significant determinants of corn acreage supply under this regime. The negative signs on the coefficients suggest that increases in payment incentives led, through increased program participation, to lower planting levels, while increases in idled acreage limitations competed with planted corn acreage in the Corn Belt region.

These results corroborate earlier findings by Weaver and Krainick which also pointed toward an increasing corn supply responsiveness under feed grain programs. They also provide some explanation for Whittaker and Bancroft's estimates of a higher corn acreage supply elasticity in the 1963-1974 period than had been estimated for a period including earlier years. Based on the preceding arguments and these empirical results, there seems to be substantial support for the argument that the introduction of government feed grain programs has led to an increasing supply responsiveness of corn in relevant periods of the past two decades. Thus, it would appear that use of the constant elasticity estimates which are given by models which do not adequately incorporate the effects of program-induced structural change in corn acreage supply may lead to biased estimates of corn supply responsiveness.

Soybean Acreage Supply Response

The coefficient estimates for the soybean supply equations given in Table 13 are less conclusive than those estimated for corn. This outcome was not entirely unexpected, given the parameter stability results obtained previously and the theoretical discussion in Chapter Three. As in the case of the corn acreage equations, estimated autocorrelation coefficients for the individual state equations are high, ranging from .315 to .505. After correction for autocorrelation, GLS estimation of the soybean acreage equations for the free market years yielded a restricted supply elasticity estimate of .345, within the range of previous estimates (see Chapter 2). The expected negative sign on the relative corn price coefficient and positive signs on the soybean price and trend coefficients were confirmed.

For the farm program regime, two different acreage supply models were estimated, one excluding and one including the feed grain program variables as regressors, models A and B, respectively. Non-rejection of the hypothesis of parameter stability for soybean supply response (see Table 11)

TABLE 13: SOYBEAN ACREAGE RESPONSE ESTIMATES

REGIME	STATE	$\hat{P}$	INTERCEPT (A)	INTERCEPT (B)		CORNIDX	SOYBIDX	TREND	TIP	ADV
Free Mkt. Regime	Illinois:	.505	7.458 (.278)			−.226 (.051)	.345 (.050)	.127 (.016)	–	–
	Indiana:	.315	6.685 (.275							
	Iowa:	.405	6.927 (.298)							
	Ohio:	.468	6.311 (.285)							
Farm Program Regime	Illinois:	.505	7.009 (.579)	9.442 (.782)	(A)	−.340 (.097)	.291 (.085)	.588 (.067)		
	Indiana:	.315	6.270 (.575)	8.642 (.764)	(B)	−.458 (.073)	.020 (.081)	.542 (.053)	.105 (.032)	−.082 (.022)
	Iowa:	.405	6.764 (.575)	9.206 (.780)						
	Ohio:	.468	6.004 (.577)	8.346 (.759)						

implies that the free market model (with program variables excluded) effectively explains variation in soybean acreage supply in feed grain program years as well as in non-program years. Based on this result, model A was estimated, yielding a restricted soybean supply elasticity estimate of .291. Although this estimate is less than the elasticity estimate for the free market regime, the difference is small, as would be expected given non-rejection of the parameter stability hypothesis.

Model B was estimated with the feed grain program variables included. Inclusion of these variables as regressors lowered the estimate of the soybean acreage supply elasticity to a statistically non-significant .02. However, in this formulation, the program variables themselves proved to be significant determinants of planted soybean acreage levels. The positive sign on the coefficient of the TIP variable measuring feed grain payment incentives indicates that increases in program participation incentives have in fact had an effect in inducing the substitution of soybean plantings with corn acreage limitations in effect. This "safety valve" effect (Walker and Penn) is one reason why acreage limitation programs have often not had their intended effects in controlling crop acreage.

Feed grain acreage diversion limits (ADV) also have a significant effect on soybean acreage, though the sign of the estimated coefficient is negative. This implies that the potential positive influences of diversion ceiling increases on soybean acreage (through increased participation incentives) are dominated by the competitive relationship between diverted land and soybean acreage, both being substitutes for corn acreage. The positive response of soybean acreage to decreases in corn prices under feed grain programs is further confirmed by the highly negative cross-price elasticity of soybean acreage with respect to corn price (-.458). In sum, these results provide considerable support for Walker and Penn's statement that "soybean acreage was more responsive to feed grain program changes than own-price changes over much of the post-War period (p. 56). Despite the parameter stability tests discussed above, the empirical results presented here in large measure confirm the importance of considering changes in feed grain program provisions in accounting for soybean acreage trends when those programs are in effect.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The theoretical discussion, econometric model and empirical results presented in this paper have been concerned with analyzing the effects of government feed grain programs on corn and soybean acreage supply response in a four-state region of the U.S. Midwest. In recent years, more than 50 percent of total U.S. production of these two crops has originated in the region comprised of the states of Illinois, Indiana, Iowa and Ohio. At the same time, the high degree of substitutability between corn and soybeans for cash grain producers in this region suggests that the effects of production-controlling feed grain programs on forthcoming crop acreage supplies would be particularly evident in this region. Thus, the Corn Belt area serves as a prime case study for the analysis of the effects of government feed grain programs.

While the analysis of commodity supply response has been a frequent focus of agricultural economics research, relatively little attention has been given to modeling the feed grain producer's program participation decision and the implications of this decision for aggregate supply response. Using an expected profit function approach and the concept of indifference prices, the discussion in Chapter Three presented a method through which the individual producer's participation decision may be analyzed. Through this analysis, it was concluded that the aggregate corn acreage supply curve under an optional acreage curtailment program was likely to be more elastic than that existing in the absence of such a program. On the other hand, the theoretical model also provided a basis for arguing that corn acreage limitation programs often have had offsetting effects on soybean acreage, such that the net effect on forthcoming soybean acreage supplies is inconclusive. These results were subsequently confirmed by the empirical analysis.

The usefulness of the "effective price" concept in explaining the effects of government farm programs on crop acreage has been questioned in past research. An alternative method of incorporating program incentives and constraints was presented in which the primary program variables included in the estimated supply models measured participation incentives to producers and maximum acreage diversion limits under feed grain programs. In incorporating these variables into the empirical models, a dual "free market" and "farm program" regime formulation was developed which explicitly permits varying price responsiveness across two markedly different production environments. To a large extent, use of this empirical framework avoids the considerable conceptual problems arising from the inclusion, in a single model, of years in which competitive market force exerted dominant influences on farmers' decisions, and years in which farm programs were of major importance.

In estimating acreage supply equations, commonly encountered econometric problems such as autocorrelation of error terms have often been overlooked. However, adequately dealing with empirical problems such as autocorrelation often results in estimation results which differ substantially from those which do not make the necessary corrections and adjustments. Given the empirical problem of simultaneously estimating acreage response functions for states in a contiguous, homogeneous area, a multiple equation generalized least squares regression procedure was used. Given the extent to which autocorrelation proved to be a problem in individual state supply equations, Parks' three-stage Aitken procedure was used to simultaneously correct for autocorrelation and contemporaneous correlation of equation error terms in arriving at efficient coefficient estimates. Tests for structural change in crop supply responsiveness under free market and farm program regimes using the LaGrange test were also performed to confirm the theoretical and empirical modeling approaches presented.

The empirical results obtained from estimation of the multiple equation acreage response models largely confirmed the dual regime approach to corn acreage supply response. Corn acreage was estimated to have a supply elasticity in the presence of feed grain programs over twice the magnitude of that estimated in their absence. Variables measuring feed grain program incentives and constraints were demonstrated to be significant determinants of corn acreage supply in the relevant years. These results imply not only that corn acreage is responsive to the existence and nature of feed grain program provisions when they are in effect, but that empirical models which fail to adequately differentiate between years in which acreage constraining programs are or are not in effect may be of questionable relevance in any given year.

In the case of the soybean supply equations, the results are less definitive, as expected given the preceding theoretical discussion. While the "slippage" of corn base acreage into soybean production may be predicted given the provisions of feed grain programs, the competitive relationships existing between soybean and set-aside acreage suggests that soybean acreage may decline under acreage control programs. It is uncertain a priori which situation will prevail on balance. The empirical results show that the soybean acreage supply elasticity declines in the presence of feed grain programs though the magnitude of the decline is inconclusive. Importantly, feed grain program payment and acreage constraint variables were found to be significant determinants of soybean acreage when those programs were in effect. In fact, under the farm program regime, soybean acreage appeared to be insensitive to corn price changes and highly sensitive to program variables. The empirical results also confirmed the competitive relationship existing between soybean acreage and idled acreage, both being competitors for corn base acreage.

In sum, the dual regime model presented in this paper proves quite useful in analyzing the impacts of government feed grain programs over much of the post-War period. A variety of effects of those programs are consistently explained by the theoretical approach and empirical results presented here. The main conclusion that derives from the above analysis is that empirical supply studies of crops subject to government farm programs must give adequate attention to the effects of those programs on crop supply response.

The results of this analysis suggest several promising areas for future research. In particular, greater attention needs to be devoted to the farm program participation decision. This decision is fundamental to the analysis of aggregate supply response, yet has received relatively little attention. Additional research is required in examining the implications and tradeoffs involved in multiple product production systems. McKinzie, Binkley, and Gardiner have recently addressed this problem. Finally, further research on the aggregate analysis of crop acreage responsiveness under changing farm programs is required. A forthcoming paper examines the implications of the disaggregated model presented here for forecasting purposes (see Lee and Helmberger), but additional research on other crops and programs is needed.

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A P P E N D I X   T A B L E S

TABLE A.1

TOTAL CROPLAND BASES FOR FOUR STATES*: 1947-1980

YEAR	ILLINOIS	INDIANA	IOWA	OHIO	TOTAL FOUR STATES
1947	19,797	10,678	21,448	10,156	62,079
1948	20,802	11,226	22,332	10,821	65,181
1949	20,800	11,274	22,827	10,851	65,752
1950	20,611	11,034	22,582	10,534	64,761
1951	20,650	11,092	21,766	10,587	64,095
1952	20,955	11,215	22,463	10,739	65,372
1953	21,373	11,297	22,791	10,897	66,358
1954	21,273	11,406	22,820	10,688	66,187
1955	21,206	11,409	23,113	10,436	66,164
1956	21,475	11,373	22,888	10,308	66,044
1957	20,733	11,143	23,454	10,430	65,760
1958	21,120	11,266	23,592	10,492	66,470
1959	21,583	11,645	23,639	10,580	67,447
1960	21,686	11,844	23,780	10,238	67,548
1961	22,127	12,262	24,027	10,376	68,792
1962	22,175	12,347	23,930	10,423	68,875
1963	22,068	12,322	24,027	10,425	68,842
1964	22,211	12,379	24,094	10,306	68,990
1965	22,450	12,039	24,030	10,455	68,974
1966	22,517	12,128	24,141	10,508	69,294
1967	22,369	12,035	23,810	10,389	68,603
1968	22,655	12,270	24,205	10,299	69,429
1969	22,548	12,395	24,004	10,124	69,071
1970	22,285	12,182	24,237	10,238	68,942
1971	22,522	12,209	24,310	10,377	69,418
1972	23,061	12,496	25,027	10,494	71,078
1973	22,278	11,996	24,551	10,000	68,825
1974	22,270	12,192	24,057	10,661	69,180
1975	22,906	12,259	24,334	10,731	70,230
1976	23,030	12,476	24,316	10,698	70,520
1977	23,441	12,664	24,559	10,837	71,501
1978	23,793	12,776	25,783	10,934	73,286
1979	24,127	12,743	25,818	11,150	73,838
1980	24,002	12,878	25,646	11,040	73,566

*Totals for each state in each year equal sum of harvested acres of 59 major crops, and acres idled under feedgrain, wheat, and Soil Bank programs.

TABLE A.2

CORN ACREAGE HARVESTED, FOUR STATES: 1948-1980

YEAR	ILLINOIS	INDIANA	IOWA	OHIO	TOTAL FOUR STATES
1948	8,965	4,665	10,732	3,506	27,868
1949	9,021	4,703	11,104	3,454	28,282
1950	8,008	4,227	9,396	3,155	24,786
1951	8,483	4,396	9,680	3,334	25,893
1952	8,728	4,458	10,449	3,382	27,017
1953	9,049	4,562	10,811	3,358	27,780
1954	8,699	4,665	10,014	3,530	26,908
1955	8,885	4,798	10,293	3,592	27,568
1956	8,477	4,592	9,413	3,415	25,897
1957	7,894	4,222	9,860	3,146	25,122
1958	8,244	4,291	9,733	3,167	25,435
1959	9,789	5,095	12,077	3,740	30,701
1960	9,985	5,152	12,166	3,383	30,686
1961	8,188	4,173	9,976	2,537	24,874
1962	8,270	4,298	9,776	2,663	25,007
1963	8,849	4,599	10,656	2,903	27,007
1964	9,182	4,737	9,804	2,961	26,684
1965	9,777	4,701	9,933	3,054	27,465
1966	10,342	5,077	10,132	3,115	28,666
1967	10,788	5,382	11,145	3,240	30,555
1968	10,088	4,790	9,808	2,884	27,570
1969	9,698	4,742	9,514	2,740	26,694
1970	9,940	4,923	10,077	3,040	27,980
1971	10,070	5,509	11,550	3,545	30,674
1972	9,225	4,884	10,600	3,090	27,799
1973	9,530	5,240	11,280	3,040	29,090
1974	9,900	5,460	12,000	3,650	31,010
1975	10,810	5,630	12,300	3,490	32,230
1976	11,590	6,300	12,900	3,820	34,610
1977	11,080	6,210	12,700	3,620	33,610
1978	11,170	6,200	12,850	3,610	33,830
1979	11,050	6,030	13,100	3,630	33,810
1980	11,460	6,280	13,300	3,900	34,940

SOURCE: U.S.D.A. Agricultural Statistics. 1948-1980.

TABLE A.3

SOYBEAN ACREAGE HARVESTED, FOUR STATES: 1948-1980

YEAR	ILLINOIS	INDIANA	IOWA	OHIO	TOTAL FOUR STATES
1948	3,354	1,459	1,564	908	7,285
1949	3,287	1,442	1,340	858	6,927
1950	3,989	1,652	1,930	1,090	8,661
1951	3,731	1,706	1,583	1,124	8,144
1952	3,716	1,683	1,526	940	7,865
1953	3,846	1,808	1,657	1,036	8,347
1954	4,143	1,939	2,129	1,122	9,333
1955	4,328	2,039	2,261	1,193	9,821
1956	4,649	2,142	2,500	1,301	10,592
1957	4,914	2,174	2,857	1,421	11,366
1958	5,066	2,269	3,116	1,441	11,892
1959	4,796	2,312	2,369	1,472	10,949
1960	4,973	2,415	2,599	1,499	11,486
1961	5,520	2,681	3,405	1,722	13,328
1962	5,575	2,708	3,405	1,791	13,479
1963	5,575	2,735	3,575	1,755	13,640
1964	5,734	2,817	4,254	1,860	14,665
1965	6,021	2,871	4,850	2,044	15,786
1966	5,941	2,814	4,996	2,105	15,856
1967	6,009	2,898	5,246	2,231	16,384
1968	6,663	3,246	5,561	2,276	17,746
1969	6,730	3,311	5,450	2,344	17,835
1970	6,800	3,278	5,680	2,550	18,308
1971	7,150	3,377	5,500	2,634	18,661
1972	7,520	3,688	6,000	3,010	20,218
1973	8,930	4,290	7,750	3,590	24,560
1974	8,440	3,890	7,110	3,190	22,630
1975	8,220	3,630	6,970	3,100	21,920
1976	7,560	3,280	6,450	2,880	20,170
1977	8,850	3,900	7,080	3,380	23,210
1978	9,240	4,180	7,550	3,750	24,720
1979	9,720	4,420	8,170	4,080	26,390
1980	9,250	4,380	8,270	3,760	25,660

SOURCE: U.S.D.A. Agricultural Statistics. 1948-1980.

TABLE A.4: NATIONAL AVERAGE LOAN RATES AND PRICES RECEIVED BY FARMERS FOR CORN AND SOYBEANS: 1948-1980

CROP YEAR (OCT. - SEPT.)	CORN		SOYBEANS	
	LOAN RATE	AVERAGE PRICE RECEIVED BY FARMERS	LOAN RATE	AVERAGE PRICE RECEIVED BY FARMERS
1948	1.44	1.28	2.18	2.27
1949	1.40	1.24	2.11	2.16
1950	1.47[1]	1.52	2.06	2.47
1951	1.57	1.66	2.45	2.73
1952	1.60	1.52	2.56	2.72
1953	1.60	1.48	2.56	2.72
1954	1.62[1]	1.43	2.22	2.46
1955	1.58[1]	1.35	2.04	2.22
1956	1.50[1] (1.25)[2]	1.29	2.15	2.18
1957	1.40[1] (1.10)[2]	1.11	2.09	2.07
1958	1.36[1] (1.06)[2]	1.12	2.09	2.00
1959	1.12	1.05	1.85	1.96
1960	1.06	1.00	1.85	2.13
1961	1.20	1.10	2.30	2.28
1962	1.20	1.12	2.25	2.34
1963	1.07	1.11	2.25	2.51
1964	1.10	1.17	2.25	2.62
1965	1.05	1.16	2.25	2.54
1966	1.00	1.24	2.50	2.75
1967	1.05	1.03	2.50	2.49
1968	1.05	1.08	2.50	2.43
1969	1.05	1.16	2.25	2.35
1970	1.05	1.33	2.25	2.85
1971	1.05	1.08	2.25	3.03
1972	1.05	1.57	2.25	4.37
1973	1.05	2.55	2.25	5.68
1974	1.10	3.02	2.25	6.64
1975	1.10	2.54	--[3]	4.92
1976	1.50	2.15	2.50	6.81
1977	2.00	2.02	3.50	5.88
1978	2.00	2.25	4.50	6.66
1979	2.00	2.25	4.50	6.28
1980	2.25	3.15	4.50	7.61

[1]Rate for allotment program participators in commercial area. Rates in non-commercial area were $1.10 in 1950; $1.22 in 1954; $1.18 in 1955; $1.24 in 1956; $1.27 in 1957; $1.02 in 1958.
[2]Rate for non-compliers in commercial area.
[3]No price support program for soybeans announced in 1975.

TABLE A.5

TOTAL VARIABLE INPUT PRICE INDEX: 1948-80

YEAR	INDEX OF VARIABLE PRICES (1967=100)
1948	73.46
1949	76.56
1950	76.37
1951	81.10
1952	84.70
1953	83.70
1954	83.20
1955	83.50
1956	83.60
1957	86.60
1958	87.90
1959	89.20
1960	89.99
1961	91.00
1962	91.80
1963	93.50
1964	94.20
1965	97.58
1966	98.40
1967	100.00
1968	101.60
1969	102.70
1970	106.10
1971	111.40
1972	115.80
1973	124.90
1974	159.80
1975	192.20
1976	196.40
1977	205.30
1978	213.30
1979	240.70
1980	286.00