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ECONOMIC ANALYSIS OF ACREAGE SUPPLY RESPONSE UNDER RISK: THE CASE OF SELECTED CROPS IN OKLAHOMA

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Field crops are of great importance to the agricultural economy of the State of Oklahoma. In 1979, the percents of total cash receipts contributed by wheat, cotton lint and seed, and feed grains were 15.6, 4.3, and 1.2, respectively (Oklahoma Crop and Livestock Reporting Service, 1979). In the same year, winter wheat ranked second, all hay third, cotton lint fourth, grain sorghum seventh, peanuts eighth, soybean tenth, and corn eleventh in terms of cash receipts from agricultural commodities. Among the states, and for the same crops, Oklahoma ranked second, fifteenth, seventh, fifth, fifth, twenty-sixth, and seventh in production, respectively (Oklahoma Crop and Livestock Reporting Service, 1979).

The importance of field crops varies across the state. This is partly attributed to climatic and soil variability across the state. The western two-thirds of the state is cooler and drier than the eastern third, and the average length of the growing season varies from 180 days in the Panhandle to 240 days in the extreme east (Gray and Galloway, 1959). Mean annual temperature ranges from the mid-fifties in the Panhandle to the mid-sixties in the southeast. Soil and topography are likewise variable across the state. Table I shows the percent contribution by crop reporting districts to total acreage planted to wheat, grain sorghum, corn, soybeans, cotton, and peanuts for the years

TABLE I

PERCENT CONTRIBUTION TO TOTAL ACREAGE PLANTED OF EACH CROP BY THE CROP REPORTING DISTRICTS

Crop Reporting District	Wheat			Sorghum			Corn			Soybeans			Peanuts			Cotton		
	1977	1978	1979	1977	1978	1979	1977	1978	1979	1977	1978	1979	1977	1978	1979	1977	1978	1979
Panhandle	18.5	16.1	15.3	51.4	50.7	51.4	62.2	53.3	54.0	.2	.3	.3	0	0	0	.1	<.1	<.1
West Central	14.3	15.7	16.1	9.4	7.9	8.6	3.2	5.0	5.6	.6	.6	.6	3.4	1.4	1.5	29.2	28.5	27.9
Southwest	19.6	19.4	19.6	9.3	8.9	7.0	3.5	7.1	6.6	.5	1.8	1.9	41.0	26.9	29.3	65.7	65.7	66.4
North Central	29.2	30.6	30.4	9.5	8.9	8.6	2.5	3.3	2.8	2.2	1.3	1.3	0	0	0	<.1	<.1	<.1
Central	12.2	12.9	12.9	7.6	8.1	7.7	6.4	9.6	8.0	9.5	7.6	7.4	8.1	14.6	14.0	4.7	4.1	3.9
South Central	2.6	2.6	2.5	2.6	2.9	3.1	5.7	7.5	6.4	6.5	6.0	6.3	33.4	35.3	37.0	2.5	1.5	1.7
Northeast	2.5	2.0	2.4	6.4	7.0	8.6	10.7	8.3	8.0	49.7	42.3	43.1	.2	.1	.1	.3	<.1	<.1
East Central	.4	.5	.6	3.1	3.6	3.6	4.3	3.8	5.6	21.4	26.5	26.6	13.5	20.3	16.9	.3	.1	<.1
Southeast	.2	.2	.2	.6	1.2	1.1	1.4	2.1	2.0	9.3	13.5	12.3	.4	1.3	1.2	0	0	0
Total in %	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

1977, 1978, and 1979. Table I indicates that the western two-thirds account for most of the acreage planted to wheat, corn, and grain sorghum, while the more moist northeast accounts for most of the soybeans. The west central and southwest crop reporting districts account for most of the acreage planted to cotton.

Noting that field crops contribute a significant share of farm income, and that their relative importance varies across the state, there is need to study their supply response relationships in order to:

i. Identify those factors which can be effectively manipulated in order to control surpluses and raise farm income.

ii. Evaluate the influence of alternative farm programs on agricultural supply. The importance of farm programs in Oklahoma is reflected by their 4.1 percent contribution to farmers' cash receipts in 1979 (Oklahoma Crop and Livestock Reporting Service, 1979). Actual cash payments by program for wheat, feed grains, and cotton are presented in Table II.

iii. Provide a better understanding of supply response relationships which will allow for more accurate crop forecasts in the State. This will prove useful to farmers in planning both short- and long-run investments.

It should be understood that the above needs may not necessarily be satisfied from a single study. As a part of studying supply response mechanism, modelling of the important relationships within the framework of economic theory is important. This has proved troublesome for previous researchers especially when it comes to empirical specification of the relationships.

TABLE II

FARM PROGRAM PAYMENTS TO PRODUCERS IN OKLAHOMA

Program	Feed Grains		Wheat		Cotton	
	1978	1979	1978	1979	1978	1979
Diversion Payments	2,036,966	1,472,040	--	--	517,625	--
Disaster Payments	2,439,525	667,982	5,811,836	1,843,132	3,522,367	551,579
Deficiency Payments	432,435	2,727,946	50,413,783	--	--	--
Wheat Haying and Grazing	--	--	6,717,040	--	--	--

Source: USDA. *Feed Grains, Wheat, Upland Cotton, and Rice Programs*. Agricultural Stabilization and Conservation Service (1977, 1978, 1979 issues).

The Problem

This study investigates acreage supply response relationships for wheat, grain sorghum, cotton, corn, peanuts, and soybeans in the State of Oklahoma. The need for this study is justified on two grounds which will be discussed under the headings Methodological Flaws in Supply Response Analyses and Policy Evaluation Needs.

Methodological Flaws in Supply Response Analyses

The relevant prices for production decisions are the prices expected to prevail at the end of the production period. Since expected prices are unobservable, some models have been proposed to provide a relationship between the expectations and variables which can be observed. In agricultural supply response studies, price expectations have been modelled by various weighted schemes of past realized prices (Nerlove, 1958; Just, 1974; Ryan, 1977; Lin, 1977). While these schemes have, in general, provided good statistical fit, they are not founded on economic theory, and on average they imply that producers can be continuously fooled which is contrary to the assumed optimization behavior of economic agents. An alternative approach to model producer's price expectations, which is consistent with optimization behavior of economic agents, will be used in this study. Specifically, it will be shown how the rational expectations hypothesis can be implemented empirically in modelling expected agricultural product prices (Muth, 1961). It is anticipated that these methods will prove to be better alternatives for empirical specification of expectations by agricultural economists.

The specification of supply response models is based on the theory of the firm, and then the same implications are carried to the aggregate level for empirical specification. Although rarely mentioned, such an approach implies that the structures of the micro and the macro functions are of the same form. Theil (1954, 1971) in his work on linear aggregation shows that, in general, the macro parameters are complex functions of the micro parameters and, except in some restrictive conditions, aggregate models specified as above will suffer aggregation bias. In this study the aggregation problem is addressed by specifying the restrictions imposed on the interpretation and application of the results for aggregate models.

Policy Evaluation Needs

The influence of price and yield variability on production decisions is a well-recognized phenomenon. Just (1975) shows that failure to account for risk on supply decisions will tend to underestimate the stabilization effectiveness of commodity programs. Quantitative knowledge of how producers react to changing risk is needed in evaluating alternative commodity programs and policies. The impact of changing risk on acreage supply response for Oklahoma field crops has not been studied.

The interaction between data and a postulated multiproduct supply response model is an issue which needs to be considered in supply analysis. A high level of aggregation, for example at regional or state level, tends to diffuse the appearance of a competitive relation between crops since relevant competing crops are likely to differ between areas. The data in Table I show this to be the case for

Oklahoma. For a given crop, there is need to investigate whether different parts of the state show variation in adjusting to a change of a given causative variable. For policy purposes, if such differences do exist, a policy goal can be achieved at a lower cost if the differentials are taken into account when implementing the policy.

Objectives of the Study

The primary objective of this study is to analyze the acreage supply response relationships for wheat, grain sorghum, corn, soybeans, cotton, and peanuts in Oklahoma. In order to be able to investigate if differences exist between different parts of the state in supply adjustments, the state will be divided into zones corresponding to the crop reporting districts, and supply response functions will be estimated on this basis. In order to achieve the primary objective the following will be accomplished.

i. Static theory of a multiproduct firm facing product price uncertainty will be used to derive a general supply function. Restrictions to be imposed on a reduced form supply response model will be determined on the basis of comparative static results.

ii. Empirical implementation of the rational expectations hypothesis in modelling expected product prices will be demonstrated.

iii. An explicit measure of price or returns risk will be defined and used to construct the desired risk variables.

iv. The Houck et al. method for modelling policy variables will be adapted and used to model policy variables.[1]

v. Using (i), (ii), (iii), and (iv), a reduced form econometric model will be specified and used to estimate the desired acreage supply response functions.

vi. Restrictions in the interpretation of the results will be specified on the basis of the known aggregation literature.

Hypotheses to be Tested

The following hypotheses will be tested in this study.

i. For a given crop, all crop reporting districts show identical supply response relationships. (There is no difference in structure among the crop reporting districts.)

ii. For a given crop, acreage supply changes for a given change in expected price or returns are identical among the crop reporting districts.

iii. For a given crop, acreage supply changes for a given change in risk are identical among the crop reporting districts.

Organization of the Remainder of the Thesis

The remainder of the thesis is organized in four chapters. Chapter II presents a review of literature, while methodology and theoretical considerations are presented in Chapter III. Data needs, sources, analysis, and discussion of results are presented in Chapter IV. Chapter V concludes the thesis by presenting a summary and direction for future research.

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[1] ERS, USDA. Analyzing the Impact of Government Programs on Crop Acreage. Technical Bulletin No. 1548. Washington: U.S. Government Printing Office, 1976.

CHAPTER II

LITERATURE REVIEW

Aggregate supply analyses are important for predictive purposes as well as for policy decisions. They are also important in the evaluation of programs designed to alleviate agricultural adjustment problems. While significant advances have been made in improving the performance of aggregate supply response models, important theoretical and methodological problems still remain (Nerlove and Bachman, 1960). Rather than presenting an exhaustive review of previous work, the focus for this study will be on the major theoretical and methodological contributions useful for supply response analysis. In order to achieve this objective, this chapter is organized under the following headings: Product Price Expectation, Risk in Aggregate Supply Response Analysis, Multiple Product Modelling, Government Programs, and Technological Changes and Structural Shifts.

Product Price Expectations

It is a well recognized fact that agricultural production decisions are made and most inputs are committed to production before product prices are realized. In addition to production lags, the production process in general involves investment in fixed assets--machinery, implements, and structures, whose use extends beyond one production period. These two effects create complex problems in determining the relevant observable variable to use as a proxy for the unobservable expected prices. The production lags and fixed assets imply that the supply of agricultural products does not adjust instantaneously. An important aspect of supply response modelling is the explanation of this adjustment process. The following models have been proposed and used to address the above problems.

Cobweb Type Models

The cobweb theory was developed to explain dynamic relationships in economics, although it is now argued that the model is just an adaptation of the static theory (Nerlove, 1979). Ezekiel (1938) presents a detailed account of the cobweb theory. He points out three conditions which need to be satisfied for the theory to be applicable:

i. Production is determined by producers' response to price under conditions of pure competition. Producers base future production plans on the current price, on the assumption that the same price will continue.

ii. The time needed for production requires at least one full period before production can be changed, once production plans are made.

iii. Price is set by the available supply.

On the basis of the three conditions above, and depending on the relative slopes of the supply and demand curves, the three well known types of oscillations can result. Defining P_t^* as the expected product price for period t, at period t-1, in the cobweb theory this is defined as $P_t^* = P_{t-1}$, where P_{t-1} is the product price realized in period t-1.

The early empirical application of the cobweb theory to model product price expectation is provided by the work of Bean (1929). He found that the price of the preceeding season is a dominant factor in the change in production in any given year. Cochrane (1947) attempted to adapt the cobweb theory in a way more compatible with price and quantity fluctuations by using the idea of a "planning supply function." But even then the theory suffers serious flaws. It is inconsistent with optimization behavior of producers by its implication that producers can be continually fooled. The complete adjustment of supply in one period seems to suggest that supply functions are reversible which is inconsistent with what is known about the influence of fixed assets on supply adjustments (Clark, 1959; Johnson, 1960).

Extrapolative Expectations

As an alternative to the cobweb theory, Metzler (1941) proposed the extrapolative model which Goodwin (1947) used to explain price expectations in markets with commodity cycles. Under the extrapolative expectation theory, the expected price is defined as $P_t^* = P_{t-1} + \alpha(P_{t-1} - P_{t-2})$, $\alpha \geq 0$, where P_t^* is the expected price for period t at period t-1, P_{t-1} and P_{t-2} are the prices observed in periods t-1 and t-2, respectively, and α is the coefficient of expectation.

The extrapolative model is actually a modification of the cobweb theory to take into account the most recent trend in price. It is obvious that when α is zero, the extrapolative expectation is reduced to the cobweb expectation. Ryan (1977) uses the extrapolative expectation to model the expected price for pinto beans in a study of the production response under risk of U.S. pinto beans. The model has not received wide applications in supply analyses probably because of its recognized limitation. It lacks economic theory justification, and assumes away other information sources in expectation formation.

Adaptive Expectations

The major contribution in aggregate supply analysis is based on Cagan's adaptive expectations model (1956). Nerlove (1956), using the adaptive expectations model, advanced the idea of an expected normal price. That is, production decisions are based on the long run average price. The popularity of the adaptive expectation model is demonstrated by its wide application in agricultural supply response studies for explaining expectation formation. Askari (1976) presents an extensive review of supply response studies using the adaptive expectation to model expected prices.

According to the adaptive expectations model, each year producers revise the price they expected to prevail in the following year in proportion to the error they made in predicting price for this year. That is, producers revise their expectations according to their most recent experiences. The model is presented as

$$P_t^* - P_{t-1}^* = \beta(P_{t-1} - P_{t-1}^*) \qquad 0 < \beta \leq 1$$

where P_t^* is the expected price for period t at period t-1, P_{t-1}^* is the expected price for period t-1 at period t-2, P_{t-1} is the price realized at period t-1, and β is the coefficient of expectation. It is easily shown that the expected price for period t at period t-1 can be represented by an infinite sum of past prices with geometric weights. That is

$$P_t^* = \beta \sum_{j=0}^{\infty} (1-\beta)^j \; P_{t-j-1}$$

Just (1974), using a decision theoretic approach, shows that the subjective mean of the expectation variable is identical to Cagan's adaptive expectations model.

The popularity of the adaptive expectations model is attributed to the following reasons (Nerlove, 1979):

i. Models including normal price perform better when applied to empirical data than those without such distributed lags.

ii. Adaptive expectations are compatible with dynamic stability under non-restrictive assumptions.

iii. There is some empirical evidence to support the adaptive expectations model.

However, the model suffers significant flaws which have led to questioning of its validity in modelling producers' price expectations (Nerlove, 1979; Grossman, 1975). The criticisms are directed toward the following:

i. There is no economic explanation for the lag structure.

ii. The model assumes that expectations are formed in a particular way. The lack of flexibility of the geometric lag structure has lead to the adoption of other lag structure, also ad hoc but more flexible, such as the polynomial lag (Lin, 1977).

iii. The introduction into a supply function of the expected normal price as a distributed lag of past prices with geometric weights leads to a reduced form supply function which is identical to a result obtained by a Koyck reduction. This leads to a problem of separating changes attributable to lagged adjustment from those resulting from expectation formation.

iv. The assumption that producers base their price expectations only on past realized prices is questionable.

v. The estimated coefficient of adjustment and the coefficient attached to the price variable have been found to be particularly sensitive to the omission of relevant explanatory variables in the model (Nerlove, 1979).

Rational Expectations Hypothesis

The rational expectations hypothesis proposed by Muth (1961) eliminates the theoretical weakness common to the other theories of expectations reviewed above. Muth asserts that since expectations are informed predictions of future events they are essentially the same as predictions of a relevant economic theory. The rational expectations hypothesis is based on three assumptions about individual behavior:

i. Information is scarce and the economic system generally does not waste it.

ii. The way expectations are formed depends specifically on the structure of the relevant system describing the economy.

iii. Public prediction will have no substantial effect on the operation of the economic system.

The implication of the rational expectations hypothesis is that if a producer operating under a free market has some idea of market conditions, he will use the information available on supply and demand in generating his expectations about future product prices. That is, expectation formation incorporates the structure of the relevant system describing the economy.

In order to make the hypothesis operational, Muth makes the following simplifying assumptions:

i. Random disturbances are normal.

ii. The equations of the system, including the expectations formula, are linear.

iii. Certainty equivalents exist for the uncertain future variables.

On the basis of the three assumptions, rational expectations are equivalent to conditional expectations of the variable based on all information available up to the time the forecast is being made, and they are minimum-mean-square error forecasts.

Despite being consistent with the underlying structure of economic behavior, the rational expectations hypothesis has not been widely used in the agricultural economics field. The only empirical study of supply found, which uses rational expectation to explain product price expectation is the study by Petzel (1978). The slow adoption of the rational expectation hypothesis is supply analysis can be attributed to the following reasons:

i. Rational expectations are difficult to estimate. Although the unobservable variable is a linear combination of observable variables, the involved coefficients in general are nonlinear combinations of structural parameters which are difficult to estimate.

ii. The hypothesis seems to assume more information than is generally available to producers. The assumption that economic agents are capable of translating all the available information into expectations is too restrictive.

iii. The hypothesis assumes economic agents respond only to conditional expectations rather than to higher moments. The assumption that economic agents are aware of the nature of the stochastic process generating the realized values of the expected variables is also questionable.

Since Muth proposed the hypothesis in 1961, some improvements have been made to make rational expectations models more operational. The ideas of weak rationality (Nelson, 1975; Shlomo and Bryan, 1981), and quasi rationality (Nerlove, 1979) permit the construction of proxies for rational expectations variables using less than full information. Advances made in univariate and multiple time series modelling of stochastic processes (Box and Jenkins, 1976; Nerlove, 1979) provide a manageable procedure for identifying and estimating models based on rational expectations. Wallis (1980) provides a general econometric approach for systems and single equation models incorporating rational expectations.

Most of the work done to test the rational expectations hypothesis is in the field of macroeconomics. Shiller (1972) presents an extensive review of the work done with macroeconomics models incorporating rational expectations. The works by Turnovsky and Wachter (1971), Alex (1977), and Bryan and Shlomo (1981) lend support to the rational expectations hypothesis. Only limited work has been done to evaluate agricultural producers' price expectations on the basis of the rational expectations. Bessler (1977), using simple univariate time series models, found the cumulative probability distribution of the one step ahead price forecasts to be consistent with the elicited subjective probability distribution over the same period. Fisher and Tanner (1978) conducted a study in Eastern Australia to test the performance of alternative theories of expectation formation. The study was conducted in the form of a survey in which farmers were asked about their production decisions and price expectations for the following season. Their results indicated that the adaptive expectations as a basis for price forecast performed better than the rational expectations hypothesis.

The use of the futures price as a proxy for the unobserved expected price has been advocated by Gardner (1976). His justification relies on the rational expectations hypothesis. Gardner argues that prices of a futures contract for next year's crop reflect the market's estimate of next year's cash price. Two studies have used futures prices as proxies for expected prices--the study of supply response for soybeans and cotton by Gardner (1976), and that of wheat acreage supply response under changing farm programs by Morzuch, Weaver, and Helmberg (1980). Lin (1977) proposes that a combination of historical price information and the futures price using Bayes' formula be used in constructing proxies for expected prices. To our knowledge, this approach has not yet been implemented empirically.

Risk in Supply Response

It is generally acknowledged that variability in price and yield plays a significant role in farmers' production decisions. Just (1975) points out the importance of having a quantitative knowledge of how farmers react to changing risk in evaluating alternative commodity programs. He indicates that while a good statistical fit is obtained with the standard Nerlovian model, its predictive power will generally be poor when compared with a model including risk variables explicitly. The good statistical fit of the reduced form Nerlovian model is attributed to the fact that the effects of changing risk enter the model through the lagged dependent variable.

The first attempt to incorporate risk in a positive supply response model is in a study by Behrman (1968) of four major annual crops in small agricultural regions of Thailand. In this study, risk is specified as the standard deviation of the crop price over the three preceeding production periods, relative to the standard deviation of the index of the alternative crops over the same period. Behrman finds risk to be an important variable in explaining crop acreage response in Thailand. The limitation of Behrman's approach of modelling risk relates to the fact that it does not incorporate producers' price expectations.

A rigorous approach to introducing risk in supply response models was first developed and used by Just (1974) in a study of crop acreage response in California. Making use of statistical decision theory, Just first shows that the subjective mean of the expected price can be expressed as an infinite sum of past realized prices with geometric weights. Subjective risk is then expressed as an infinite sum of the squared deviation of realized price from the subjective mean of expected price, weighted geometrically. The results of his study indicate that, with the exception of crops strongly regulated by government programs, risk is an important variable in explaining acreage supply response.

Ryan (1977) uses a model of producer behavior under uncertainty to derive risk variables which he incorporates in a risk model for U.S. pinto beans. On the basis of his theoretical analysis he identifies the following risk variables:

i. Weighted standard deviation of the preceeding three years of pinto bean price around the preceeding three year average.

ii. A weighted coefficient of variation of pinto bean price.

iii. The absolute value of the covariance of pinto bean price and sugar beet price divided by the preceeding three year average of pinto bean price and divided again by the standard deviation of sugar beet price.

The empirical results of his analysis indicate that the risk variables improve the statistical fit of the supply response equation. Ryan's approach suffers the same drawbacks as Behrman's by failing to incorporate price expectation in the risk variable.

Trail (1978) presents an approach simpler than that of Just for introducing risk in supply response models and yet retains the relationship between risk and expected crop price. The risk variable is formulated as the weighted absolute deviation of realized price from the expected price. That is

$$\sum_{j=1}^{m} \delta_j \left| P^*_{t-j} - P_{t-j} \right|$$

where P^*_t is the expected price for period t at period t-1, P_t is the realized price at period t, δ_j are ad hoc weights which sum to one. A limitation of this approach concerns the choice of appropriate weights to use.

An alternative approach also proposed by Trail (1978) fits the safety first criterion of defining risk. He refers to this method as the moving probability distribution method. In this approach, the riskiness of a crop is defined as the probability of its price falling below some specified level. Risk is then measured as the area in the left tail of an appropriate probability distribution fitted over an appropriate moving period. In his study of onion supply response in the U.S., the log-normal distribution is used, and the following steps are followed to compute the risk variable:

i. A runs test is used to test for randomness, and then a log-normal distribution is fitted to the whole price series. A goodness of fit test using the χ^2 test is applied to determine whether the data fits the log-normal distribution.

ii. Given that the data is random, and that it is adequately described by the log-normal distribution, the parameters of the distribution are calculated over a moving period which are then used to obtain the area in the lower tail of the distribution. The estimated probability is then used as an observation on risk.

While this approach of modelling risk seems to be more consistent with the way producers think about risk, its application is hindered by problems of determining that critical price value below which producers consider a disaster to occur.

Trail estimates supply response equations for onions using risk variables as defined by Behrman (1968), in addition to his two proposed approaches. He finds that the three methods for modelling risk yield similar results and none is found to be clearly superior.

Multiple Products Modelling

Farmers in general are engaged in the production of more than one crop, but there has been very limited empirical work on supply relationships of multiple products. Most empirical work on supply response includes one or two competing crops even when it is known that additional competing crops are involved. Data limitations and multicollinearity have been blamed for this limitation (Just, 1974).

The work by Powell and Gruen (1968) on the constant elasticity of transformation is regarded as a major contribution toward solving the problem of handling multiproducts in supply response analysis. By imposing a constant elasticity of transformation (CET) constraint on the production surface, the number of parameters to be estimated in a linear supply model is reduced by more than half from a fully specified and unconstrained model (An-Ning, 1978). The behavioral assumption inherent in the CET model is that producers seek to maximize profit.

Powell and Gruen (1968) use the CET model to estimate short run direct and cross price elasticities for wool, wheat, and feed grains in Australia. The CET model has been adapted and applied in three major supply response studies in the U.S. Whittaker (1977) uses the model in the study of regional field crops acreage response. His results indicate only 61 percent of the elasticities of transformation have anticipated signs. However, when Whittaker compares the results with those of ordinary least squares supply model (OLS) and the restricted least squares supply model (RLS) (the imposed restriction is homogeneity of degree zero in expected prices), the CET model performs best, followed by RLS and OLS, respectively. The criteria of comparison are accuracy of forecasts and conformity of estimated parameters to theoretical expectations.

Green (1978) uses the CET model to study the supply response of 13 major U.S. crops. His results indicate only 35 percent of the estimated model parameters have unexpected signs. In evaluating the elasticities of supply response, only 56 percent of them are found to be stable. The predictive performance of his model is also found to be generally poor. An-Ning (1978), using a similar model and estimation procedure as Green to study supply response of Texas agricultural commodities, encounters similar problems.

The results of these studies indicate that while the CET model offers a way of handling a large number of competing crops its performance has not been very satisfactory. Some theoretical problems regarding its construction still remain to be solved.

Commodity Programs Modelling

The need to minimize instability in the agricultural sector has led to a growing number of public programs in agriculture. Tweeten (1979), Cochrane and Ryan (1976) present comprehensive accounts of farm policies and programs from the early thirties to the late seventies. Program changes over time by crop and animal product categories are given. The recognition that government intervention in agriculture has an influence on supply response has led to studies to evaluate its effects on supply decisions. Due to data limitations, it is important that the main features of program changes be summarized in as few variables as feasible. Notable contributions in modelling government programs for supply analysis are studies by Just (1974), Houck et al. (1976), and Morzuch, Weaver, and Helmberger (1980). The decision as to which program features are to be included is determined by the researcher according to the objective of each particular study.

Technological Changes and Structural Shifts

Technological changes over time have been partly responsible for supply shifts. In supply analysis, technical progress is represented by a smooth time trend (Nerlove, 1956; Lin, 1957). This approach assumes that technology can be approximated by a linear trend. Another problem also related to technology involves structural change (Cochrane and Elmer, 1960). The standard regression model is not likely to capture structural changes since it is implied in these models that parameters are fixed. The use of dummy variables to account for structural shifts in supply analyses is suggested (Willis and Hayami, 1977). The major problem with this approach is identification of those periods exhibiting differences in structure.

Chapter Summary

A review of the major contributions in aggregate supply response analysis was presented. Modelling of expectations has evolved from the more ad hoc cobweb, extrapolative, and adaptive expectations models to the theoretically appealing rational expectations hypothesis. Empirical specification of expectations has, in general, followed the ad hoc models, the adaptive expectations model being the most widely used. The rational expectations model, despite its theoretical appeal, has not found much application in supply response analysis due to the difficulties of its empirical implementation.

The importance of risk in production decisions has seen a number of methods proposed to model yield, price, and returns risk for aggregate supply response analyses. The simplest approach uses a weighted moving squared deviation of realized prices or returns from the mean price or returns, respectively. This approach fails to incorporate producers' price or returns expectations in addition to employing an ad hoc weighting scheme. The more appealing approaches employ the expected prices or returns instead of the mean of realized price or returns. Empirical work by Trail (1978) shows that neither approach produces superior results. The work by Just (1974) shows that with the exception of crops heavily influenced by government programs risk is important in explaining acreage supply decisions. Even in those cases with strong government intervention, the inclusion of risk improves statistical fit of the models.

Multiple product modelling has proved troublesome in positive supply response studies due to data limitations and multicollinearity. By imposing a constant elasticity of transformation constraint on the production surface, the number of parameters to be estimated is reduced by more than half when compared to an unconstrained model. Although this is regarded as a major contribution in multiple product modelling, empirical results employing this approach have not been very satisfactory.

Technological changes over time are known to have had an influence on supply response and structural shifts. Modelling technological changes have employed a smooth time trend, and when a structural shift is suspected to have occurred a dummy variable is included to capture this change. The assumption that technological change can be represented by a smooth time trend is questionable, but a better modelling approach is yet to be developed.

CHAPTER III

METHODOLOGY

Introduction

In this chapter, a reduced form acreage supply response model is specified. In the course of developing the model, some of the methodological problems raised in Chapter I are addressed.

The chapter is organized as follows. First, a general product supply function is derived from the static theory of a multi-product firm facing product price uncertainty. Comparative static results, relevant for determining restrictions to impose on the supply response model, are derived. A method for constructing unobservable expected variables which conform to the optimization behavior of firms is presented. The Houck et al. (1976) method for constructing policy variables is briefly outlined, and the relevant policy variables to be included in the model are identified. A general econometric model of crop acreage supply response for a firm is then specified. Since in the estimation process highly aggregated data are used, naturally the aggregation problem exists. The problem is given a limited theoretical treatment here, specifically the necessary restrictions required to ensure at least partial consistency between the micro and macro functions are identified. This chapter closes with a statistical specification of the aggregate supply response model and identification of possible estimation procedures.

A Static Model of a Multi-Product Firm Facing Product Prices Uncertainty

There has been a growing interest in the study of the behavior of a competitive firm exhibiting non-linear risk preferences under alternative assumptions pertaining to sources of uncertainty. Just and Pope (1977) assume production uncertainty, Just (1975) considers both production and product price uncertainty, and Epstein (1977), Pope (1978), Sandmo (1971), and Blair (1978) consider only product price uncertainty. These studies show how non-linear risk preferences modify the Hicksian maximization conditions and the comparative static results.

In these studies, it is asserted that the objective of the firm is to maximize the expected utility of profit, and in the case of product price uncertainty, it is assumed that production decisions are made prior to the knowledge of the market price. Blair (1978) and Sandmo (1971) show that under risk aversion, the optimal input demand and output supply are lower under product price uncertainty than when the price is known with certainty. It should be pointed out that their results may not be true if the expected price is higher than the knwon true price. They also show that decreasing absolute risk aversion is a sufficient condition for an upward sloping product supply curve.

The analyses by Pope (1978) and Batra and Ullah (1974) show that in general, the usual comparative statics, symmetry conditions, and linear homogeneity of supply functions are ambiguous under non-linear risk preference conditions. These observations suggest that no useful restrictions can be imposed on a risk supply response model without making restrictive assumptions about the nature of the firm's underlying utility function. Pope (1978) shows that, for the general class of decision functions which he specifies as $E[U(\pi)] = \bar{\pi} + Z(\sigma)$, $\sigma = (\sigma_2, \ldots, \sigma_T)$ where $E[U(\pi)]$ is the expected utility of profit, $\bar{\pi}$ is the first moment of profit, σ_t is the t-th central moment of profit and Z is a linear or non-linear function of the central moments of profit, the result obtained under certainty remain unchanged. In addition, comparative static results based on risk parameters can be obtained explicity. Since the objective here is to determine a priori the restriction to impose on the supply response model, the choice of the utility function will be from this general class. It should be pointed out that the failure to reject the restrictions imposed on the risk model is not a proof that the specified utility function is a true one since the same restrictions can hold under an alternative utility function. On the other hand, the rejection of the imposed restrictions is a basis for rejecting the specified utility function.

Basic Assumptions and Model Development

1. The firm operates in a perfectly competitive industry. The fact that price is uncertain implies that the firm is a price taker in a probabilistic sense. Input prices, on the other hand, are assumed to be known with certainty.

2. Production decisions are made and inputs are committed to production before the realization of product price. This is a valid assumption in the case of agricultural products, due to the long time lag between the beginning of the production process and the realization of output.

3. The firm seeks to maximize the expected utility of profit and it exhibits non-increasing risk aversion behavior. Polynomial utility functions such as the quadratic can show increasing risk aversion if additional restrictions are not imposed on the function. To avoid these kinds of problems, it is assumed that the firm's behavior can be satisfactorily modelled by an exponential function, which exhibits constant absolute risk aversion behavior.

The firm produces m products using n inputs. The production function in implicit form is represented in equation (1).

$$\psi(Q_1, Q_2, \ldots, Q_m, X_1, X_2, \ldots, X_n) = 0 \tag{1}$$

where Q_i is the output of product i ($i = 1, 2, \ldots, m$), and

X_j is the production input ($j = 1, 2, \ldots, n$).

The price for product i is denoted by p_i and its subjective probability density function, which is assumed to be normal, is $g_p(p)$ with μ and σ^2 as its first two central moments. The price for input j is denoted by W_j. It is shown in Appendix A that under the assumption that the firm's utility function for profit is exponential, the relevant decision function is

$$E[U(\pi(\cdot))] = \sum_{i=1}^{m} \mu_i Q_i - \sum_{j=1}^{n} W_j X_j - \frac{b}{2} \sum_{i=1}^{m} \sum_{k=1}^{m} Q_i Q_k \sigma_{ik} \qquad b > 0 \tag{2}$$

where $E[U(\pi(\cdot))]$ is the expected utility of profit and b is the risk aversion coefficient.

In order to simplify the analysis, a rather strong assumption is made, that product prices are independent. This simplifies equation (2) to

$$E[U(\pi(\cdot))] = \sum_{i=1}^{m} \mu_i Q_i - \sum_{j=1}^{n} W_j X_j - \frac{b}{2} \sum_{i=1}^{m} Q_i^2 \sigma_i^2 \qquad b > 0 \tag{3}$$

The firm's objective is to maximize expected utility of profit (3) subject to a technological constraint specified by its production function (equation 1). Rather than maximizing (3) subject to (1), the primal-dual lagrangean approach of Silberberg (1978), which provides an easier way for deriving the comparative static results is used.

In order to specify the primal-dual lagrangean, the following functions are defined:

(a) the indirect expected utility of profit function

$$E[U^*(\pi^*(\underset{\sim}{\mu}, \underset{\sim}{\sigma}^2, \underset{\sim}{W}, b))] = \sum_{i=1}^{m} \mu_i Q_i^* (\underset{\sim}{\mu}, \underset{\sim}{\sigma}^2, \underset{\sim}{W}) - \sum_{j=1}^{n} W_j X_j^* (\underset{\sim}{\mu}, \underset{\sim}{\sigma}^2, \underset{\sim}{W}, b)$$

$$- \frac{b}{2} \sum_{i=1}^{m} \sigma_i^2 Q_i^{*2} (\underset{\sim}{\mu}, \underset{\sim}{\sigma}^2, \underset{\sim}{W}, b)$$

where $\underset{\sim}{\mu}$, $\underset{\sim}{\sigma}^2$, and $\underset{\sim}{W}$ are vectors.

This function represents the maximum level of expected utility of profit for any set of parameter values subject to $\psi(\underset{\sim}{Q}, \underset{\sim}{X}) = 0$. It should be noted that the indirect function depends only on the parameters μ_i, σ_i^2, b and W_j.

(b) function $K = F(\underset{\sim}{Q}, \underset{\sim}{X}, \underset{\sim}{\mu}, \underset{\sim}{\sigma}^2, \underset{\sim}{W}, b)$ defined as the difference between $E[U^*(\pi^*(\cdot))]$ and any other level of expected utility of profit. That is

$$K = F(\underset{\sim}{Q}, \underset{\sim}{X}, \underset{\sim}{\mu}, \underset{\sim}{\sigma}^2, \underset{\sim}{W}, b) = \left[\sum_{i=1}^{m} \mu_i Q_i - \sum_{j=1}^{n} W_j X_j - \frac{b}{2} \sum_{i=1}^{m} \sigma_i^2 Q_i^2 \right]$$

$$- [E[U^*(\pi^*(\cdot))]] .$$

It is obvious that K is either zero or negative, and has a maximum of zero at $Q_i = Q_i^*(\cdot)$ and $X_j = X_j^*(\cdot)$ for i = 1, 2, ..., m and j = 1, 2, ..., n, subject to $\psi(\underset{\sim}{Q}, \underset{\sim}{X}) = 0$. That is $F(\cdot)$ is negative semidefinite subject to the constraint.

Now the original constrained expected utility of profit maximization problem can be redefined as:

$$\text{Maximize } F(\underset{\sim}{Q}, \underset{\sim}{X}, \underset{\sim}{\mu}, \underset{\sim}{\sigma}^2, \underset{\sim}{W}, b) = E[U(\pi(\cdot))] - E[U^*(\pi)^*(\cdot))]$$

$$\text{Subject to } \psi(\underset{\sim}{Q}, \underset{\sim}{X}) = 0.$$

The primal-dual lagrangean becomes

$$L^*(\underset{\sim}{Q}, \underset{\sim}{X}, \underset{\sim}{\mu}, \underset{\sim}{\sigma}^2\underset{\sim}{W}, \lambda, b) = E[U(\pi(\cdot))] - E[U^*(\pi(\cdot))] + \lambda\psi(\underset{\sim}{Q}, \underset{\sim}{X}) \tag{4}$$

Differentiating L* with respect to Q_i, X_j, μ_i, σ_i^2, W_j, $(i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n)$, b and λ the following necessary first order conditions for maximum are obtained:

$$\frac{\partial L^*}{\partial Q_i} = \mu_i - b\sigma_i^2 Q_i + \lambda\psi_{Q_i} = 0 \tag{5}$$

$$\frac{\partial L^*}{\partial X_j} = -W_j + \lambda\psi_{X_j} = 0 \tag{6}$$

$$\frac{\partial L^*}{\partial \lambda} = \psi(\underset{\sim}{Q}, \underset{\sim}{X}) = 0 \tag{7}$$

$$\frac{\partial L^*}{\partial \mu_i} = Q_i - \frac{\partial E[U^*(\pi^*(\cdot))]}{\partial \mu_i} = 0 \tag{8}$$

$$\frac{\partial L^*}{\partial \sigma_i^2} = \frac{b}{2} Q_i^2 - \frac{\partial E[U^*(\pi^*(\cdot))]}{\partial \sigma_i^2} = 0 \tag{9}$$

$$\frac{\partial L^*}{\partial W_j} = -X_j - \frac{\partial E[U^*(\pi^*(\cdot))]}{\partial W_j} = 0 \tag{10a}$$

$$\frac{\partial L^*}{\partial b} = -\frac{1}{2}\sum_{i=1}^{m} \sigma_i^2 Q_i^2 (\underset{\sim}{\mu}, \underset{\sim}{\sigma}^2, \underset{\sim}{W}, b) - \frac{\partial E[U^*(\pi^*(\cdot))]}{\partial \sigma_i^2} = 0 \tag{10b}$$

Equations (5), (6), and (7) are the usual first order conditions for constrained maximization of the primal problem--equation (3) with (1) as the constraint. Equations (8), (9), and (10) are the envelope theorem results. By applying the envelope theorem, it is easily shown that:

$$\frac{\partial E[U^*(\pi^*(\cdot))]}{\partial \mu_i} = Q_i^* \, (\underset{\sim}{\mu}, \underset{\sim}{W}, \underset{\sim}{\sigma}^2) \tag{11}$$

$$\frac{\partial E[U^*(\pi^*(\cdot))]}{\partial W_j} = -X_j^* \, (\underset{\sim}{\mu}, \underset{\sim}{W}, \underset{\sim}{\sigma}^2) \tag{12}$$

$$\frac{\partial E[U^*(\pi^*(\cdot))]}{\partial \sigma_i^2} = -\frac{b}{2} Q_i^{*2} \, (\underset{\sim}{\mu}, \underset{\sim}{W}, \underset{\sim}{\sigma}^2) \tag{13a}$$

$$\frac{\partial E[U^*(\pi^*(\cdot))]}{\partial b} = -\frac{1}{2} \sum_{i=1}^{m} \sigma_i^2 Q_i^{*2} \, (\underset{\sim}{\mu}, \underset{\sim}{\sigma}^2, \underset{\sim}{W}, b) \tag{13b}$$

where equation (11) is the output supply function for product i and it is a function of own expected price, expected prices of competing crops, input prices, risk aversion coefficient and variance. Equation (12) is the demand function for input i and it is a function of the same parameters as the output supply function. Since the primary interest is in determining refutable restrictions to impose on a supply function, the usual qualitative marginal conditions for maximum obtainable from the first order conditions are not emphasized here. Instead, attention is focused on the comparative static results.

Comparative Static Results

Define $\underset{\sim}{Z}$ as a (m+n) x 1 vector whose elements are the Q_is (i = 1, ..., m) and X_js (j = 1, ..., n) and $\underset{\sim}{\alpha}$ as a (2m+n+1) x 1 vector whose elements are μ_is (i = 1, 2, ..., m), σ_i^2s (i = 1, ..., m), b and W_js (j = 1, ..., n). The matrix of second partials of L* with respect to

$\underset{\sim}{Z}$, $\underset{\sim}{\alpha}$, and λ can be written in partitioned form as

$$H = \begin{bmatrix} L^*_{\underset{\sim}{Z}\underset{\sim}{Z}} & L^*_{\underset{\sim}{Z}\underset{\sim}{\alpha}} & L^*_{\underset{\sim}{Z}\lambda} \\ L^*_{\underset{\sim}{\alpha}\underset{\sim}{Z}} & L^*_{\underset{\sim}{\alpha}\underset{\sim}{\alpha}} & L^*_{\underset{\sim}{\alpha}\lambda} \\ L^*_{\lambda\underset{\sim}{Z}} & L^*_{\lambda\underset{\sim}{\alpha}} & 0 \end{bmatrix}$$

It should be noted that $L^*_{\lambda\underset{\sim}{\alpha}}$ and $L^*_{\underset{\sim}{\alpha}\lambda}$ are null vectors since the parameters do not enter the constraint and λ does not enter the primal-dual objective function. Using Young's theorem, it can be shown that H is symmetric and so are L^*_{ZZ} and $L^*_{\underset{\sim}{\alpha}\underset{\sim}{\alpha}}$.

The sufficient second order conditions for maximum require that all border preserving principle minors of H of order k have sign $(-1)^k$. Since the focus is on how the supply of product Q_i changes as the parameters ($\underset{\sim}{\alpha}$) change, only $L_{\underset{\sim}{\alpha}\underset{\sim}{\alpha}}$ is evaluated.

Silberberg (1978) shows that $L^*_{\underset{\sim}{\alpha}\underset{\sim}{\alpha}}$ is negative semi-definite subject to the constraint, and since parameters enter the objective function linearly, and none enters the constraint, refutable hypotheses can be obtained from the comparative static results of $L^*_{\underset{\sim}{\alpha}\underset{\sim}{\alpha}}$. The fact that $L^*_{\underset{\sim}{\alpha}\underset{\sim}{\alpha}}$ is negative semi-definite implies that all its diagonal elements are non-positive. The determinant of $L^*_{\underset{\sim}{\alpha}\underset{\sim}{\alpha}}$ is presented in (14).

$$|L_{\alpha\alpha}| = \begin{vmatrix}
\frac{-\partial Q_1^*}{\partial \mu_1} & \cdots & \frac{-\partial Q_1^*}{\partial \mu_m} & \frac{-\partial Q_1^*}{\partial \sigma_1^2} & \cdots & \frac{-\partial Q_1^*}{\partial \sigma_m^2} & \frac{-\partial Q_1^*}{\partial W_1} & \cdots & \frac{-\partial Q_1^*}{\partial W_n} & \frac{\partial Q_1^*}{\partial b} \\
\vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots \\
\frac{-\partial Q_m^*}{\partial \mu_1} & \cdots & \frac{-\partial Q_m^*}{\partial \mu_m} & \frac{-\partial Q_m^*}{\partial \sigma_1^2} & \cdots & \frac{-\partial Q_m^*}{\partial \sigma_m^2} & \frac{-\partial Q_m^*}{\partial W_1} & \cdots & \frac{-\partial Q_m^*}{\partial W_n} & \frac{\partial Q_m^*}{\partial b} \\
\frac{\partial X_1^*}{\partial \mu_1} & \cdots & \frac{\partial X_1^*}{\partial \mu_m} & \frac{\partial X_1^*}{\partial \sigma_1^2} & \cdots & \frac{\partial X_1^*}{\partial \sigma_m^2} & \frac{\partial X_1^*}{\partial W_1} & \cdots & \frac{\partial X_1^*}{\partial W_n} & \frac{\partial X_1^*}{\partial b} \\
\vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots \\
\frac{\partial X_m^*}{\partial \mu_1} & \cdots & \frac{\partial X_m^*}{\partial \mu_m} & \frac{\partial X_m^*}{\partial \sigma_1^2} & \cdots & \frac{\partial X_m^*}{\partial \sigma_m^2} & \frac{\partial X_1^*}{\partial W_1} & \cdots & \frac{\partial X_m^*}{\partial W_n} & \frac{\partial X_m^*}{\partial b} \\
bQ_1^*\frac{\partial Q_1^*}{\partial \mu_1} & \cdots & bQ_1^*\frac{\partial Q_1^*}{\partial \mu_m} & bQ_1^*\frac{\partial Q_1^*}{\partial \sigma_1^2} & \cdots & bQ_1^*\frac{\partial Q_1^*}{\partial \sigma_m^2} & bQ_1^*\frac{\partial Q_1^*}{\partial W_1} & \cdots & bQ_1^*\frac{\partial Q_1^*}{\partial W_n} & bQ_1^*\frac{\partial Q_1^*}{\partial b} + Q_1^{*2} \\
\vdots & & \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots \\
bQ_m^*\frac{\partial Q_m^*}{\partial \mu_1} & \cdots & bQ_m^*\frac{\partial Q_m^*}{\partial \mu_m} & bQ_m^*\frac{\partial Q_m^*}{\partial \sigma_1^2} & \cdots & bQ_m^*\frac{\partial Q_m^*}{\partial \sigma_m^2} & bQ_m^*\frac{\partial Q_m^*}{\partial W_1} & \cdots & bQ_m^*\frac{\partial Q_m^*}{\partial W_n} & bQ_m^*\frac{\partial Q_m^*}{\partial b} + Q_m^{*2} \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \sum_{i=1}^{m} \sigma_i^2 Q_i^* \frac{\partial Q_i^*}{\partial b}
\end{vmatrix} \leq 0 \tag{14}$$

From (14), the following comparative statics and reciprocity conditions are obtained:

$$\frac{-\partial Q_i^*}{\partial \mu_i} \leq 0 \quad \text{or} \quad \frac{\partial Q_i^*}{\partial \mu_i} > 0 \qquad i = 1, \ldots, m \tag{15}$$

$$\frac{\partial X_i^*}{\partial W_j} \leq 0 \qquad j = 1, \ldots, n \tag{16}$$

$$bQ_i^* \frac{\partial Q_i^*}{\partial \sigma_i^2} \leq 0 \tag{17a}$$

Since b and Q_i^* are positive, it implies that

$$\frac{\partial Q_i}{\partial \sigma_i^2} \leq 0 \tag{17b}$$

$$\sum_{i=1}^{m} \sigma_i^2 Q_i^* \frac{\partial Q_i^*}{\partial b} \leq 0 \rightarrow \sum_{i=1}^{m} \frac{\partial Q_i^*}{\partial b} \leq 0 \tag{17c}$$

$$\frac{\partial Q^*_i}{\partial W_j} = \frac{-\partial X^*_j}{\partial \mu_i} \qquad (18)$$

$$\frac{\partial Q^*_i}{\partial \mu_k} = \frac{\partial Q^*_k}{\partial \mu_i} \qquad (19)$$

$$\frac{\partial X^*_j}{\partial W_l} = \frac{\partial X^*_l}{\partial W_j} \qquad (20)$$

Condition (15) implies that an increase in own expected price, holding other parameters constant, will increase output of product Q_i. That is, the supply function for Q_i is upward sloping. The supply of product Q_i is a non-increasing function of price variance as shown in equation (17b). That is, a unit increase in price variance, holding other parameters constant, either will leave output unchanged or will lead to a decline in output. Condition (17c) shows that output supply is a non-increasing function of the risk aversion coefficient. As the coefficient of risk aversion increases, holding other parameters constant, output will either remain unchanged or will decline. Condition (16) shows that input demand functions are downward sloping. Conditions (18), (19), and (20) are the usual reciprocity or symmetry results. The above results imply the following restrictions on an econometrically estimated supply function:

1. The coefficient on own expected price is positive.
2. Given estimated supply functions for products Q_i and Q_j, the change in Q_i for a unit change in the expected price of Q_j should be equal to the change in Q_j for a unit change in the expected price of Q_i, holding other parameters constant. Note that nothing is implied about the sign of these changes from the comparative static results, without additional information on the relationship in production of the involved products.

3. The coefficient on the risk variable (price variance) is negative or statistically not different from zero.
4. The change in Q_i for a unit change in the price of input X_j is equal to the negative of the change in input X_j per unit change in the price of product Q_i, holding other parameters constant.

In general, due to data limitations and multicollinearity problems, all the restrictions as specified above may not be tested. This also applies to testing for homogeneity of degree zero in output and input prices. At this point, on the basis of the assumed firm's behavior, the supply function for product Q_i is

$$Q_i = Q_i(\mu_1, \mu_2, \ldots, \mu_i, \ldots, \mu_m, W_1, W_2, \ldots, W_n, \sigma_1^2, \ldots, \sigma_i^2, \ldots, \sigma_m^2) \tag{21}$$

The supply function derived from the theory of the firm is an oversimplification of what actually influences supply response. It is a known fact that government programs, technological changes over time, and weather also influence supply response. Weather influences supply through its influence on yield. Therefore, the influence of weather on supply response can adequately be handled through the yield variable. The supply function in (21) is modified to take into account these additional factors. Defining PL_{ki} as the policy variable k affecting crop i and Y_i^* as the expected yield equation (21) is modified to

$$Q_i = Q_i(\underset{\sim}{\mu}, \underset{\sim}{W}, \underset{\sim}{\sigma}^2, \underset{\sim}{PL}, Y_i^*) \tag{22}$$

where $\underset{\sim}{\mu}$ is a m x 1 vector of expected product prices,

$\underset{\sim}{W}$ is a n x 1 vector of input prices, where $\underset{\sim}{\sigma}^2$ is a m x 1 vector of product price variances,

$\underset{\sim}{PL}$ is a L x 1 vector of policy variables, and

Y_i^* is the expected yield of crop Q_i.

Before an econometric model is specified, the problem of constructing risk variables, expected yield, expected product prices, and policy variables is addressed in the next three sections.

Construction of Risk Variables

There are at least two schools of thought concerning how risk is perceived by decision makers (Young et al., 1979). The safety first approach looks at risk as the probability of either net returns or price falling below a predetermined disaster level. The problem in applying this criterion to construct risk variables for aggregate analysis concerns the determination of a representative disaster level. In Chapter II, a method based on safety first criterion was reviewed (Trail, 1978), but since it will not be used in this study, no further reference to this approach will be made. The second approach looks at risk as the deviation of expected price or net returns from the realized price or net returns. In more general terms, this conforms to using variance and covariance terms to measure risk. A version of this second approach for thinking about risk is used to construct risk variables for the acreage supply response analysis.

Defining R_{ii} as the price risk for crop i and R_{il} as the price risk for crops i and l, the following formulas for constructing risk variables are proposed:

$$R_{ii} = \sum_{n=1}^{N} \delta_n \, (P^*_{t-n,j} - P_{t-n,j})^2 \qquad (23)$$

$$R_{il} = \sum_{n=1}^{N} \delta_n (P^*_{t-n,i} - P_{t-n,i})(P^*_{t-n,l} - P_{t-n,l}) \qquad (24)$$

where $\sum_{n=1}^{N} \delta_n = 1$ and

$t = 1, 2, \ldots, T.$

Formula (23) expresses price risk for crop i as a weighted moving average of the squared deviation of the expected price from the realized price, while formula (24) provides a way to measure the covariation of the prices for crops i and l. The weighting is justified by the fact that current events are likely to have more weight on decision making then those in the remote past.

Crop Yield Expectation

At the beginning of the production period, crop yield to be realized is unknown. A number of methods have been suggested in the literature to explain how producers formulate yield expectations.

The simplest model assumes that producers formulate their yield expectation on the basis of past yield (Chern and Just, 1978). That is,

$$Y^*_t = E[Y_t | Y_{t-1}, Y_{t-2}, \ldots |] \qquad (25)$$

which reduces to $Y^*_t = Y_{t-1}$ if it is assumed that only last year's yield is taken as a prediction of this year's yield (the same result is obtained if yield is assumed to follow a random walk process).

A more complex yield expectations model is based on the adaptive expectations model

$$Y^*_t - Y^*_{t-1} = \gamma(Y_{t-1} - Y^*_{t-1}) \qquad 0 < \gamma \leq 1 \qquad (26)$$

where Y^*_t is yield expected in period t at period t-1, Y^*_{t-1} is the yield expected in period t-1 at period t-2, Y_{t-1} is the yield realized in period t-1, and γ is the coefficient of expectation. It can be shown that using equation (26) expected yield can be represented by an infinite sum of past yields with geometric weights. That is

$$Y_t^* = \gamma \sum_{j=0}^{\infty} (1-\gamma)^j Y_{t-j-1} \tag{27}$$

Behrman (1968) proposes a time trend to approximate future yield, this being obtained by regressing Y_t on time.

$$Y_t^* = \hat{b}_0 + \hat{b}_1 \text{ Time} \tag{28}$$

where $\hat{b}_0$ and $\hat{b}_1$ are regression coefficients estimates. Since none of the above methods can be rejected or accepted a priori, for the purpose of simplifying the econometric model, expected yield is represented by last year's yield. That is

$$Y_t^* = Y_{t-1} \quad .$$

Agricultural Policy Variables

Among the field crops involved in this study, wheat, cotton, corn, grain sorghum, and peanuts are heavily influenced by government programs. Over the years, these programs have assumed many features, but the main objective has remained that of stabilizing prices and farm incomes. Houck et al. (1976) have developed a procedure summarizing the various features of the programs in two major variables: (1) effective or weighted support price which is defined such that both acreage restrictions and price support are incorporated; and (2) weighted diversion payment which is defined such that payments for withholding land from production and any acreage restrictions that accompany such payments are incorporated.

Houck et al. (1976) developed the following conceptual framework relating government programs to acreage planted and diverted, as the basis for developing formulas for constructing the variables. Figure 1 shows the relationship between acreage planted of a given crop and price. In the absence of acreage restrictions, when the government announces a support price, it will be viewed as a price guarantee. This implies that at a higher announced support price more acreage will be planted, and at a lower support price, less acreage will be planted. This is represented as a movement along the curve S_1S_1, assuming that other supply shifters remain constant.

When the support price is PA, with no acreage restriction, A_1 acreage will be planted. If for policy purposes the desired acreage is A_2, the relevant support price would be ES in the absence of an acreage restriction. If for social reasons it is desired to maintain farm income at a certain level, a support price PA will be announced, but in order for producers to obtain this price they will be required to reduce acreage planted so that A_1A_2 acres are withdrawn from production thus conforming to the policy goal. Houck et al. (1976) call ES the effective support rate

$$ES = rPA$$

where r is some adjustment factor incorporating the acreage restriction. With no acreage restriction, r = 1, and as acreage restrictions become tighter, then r moves closer to zero. The actual computation of ES is as follows:

$$ES_i = rPA_i = \frac{A_i}{A_{oi}} PA_i$$

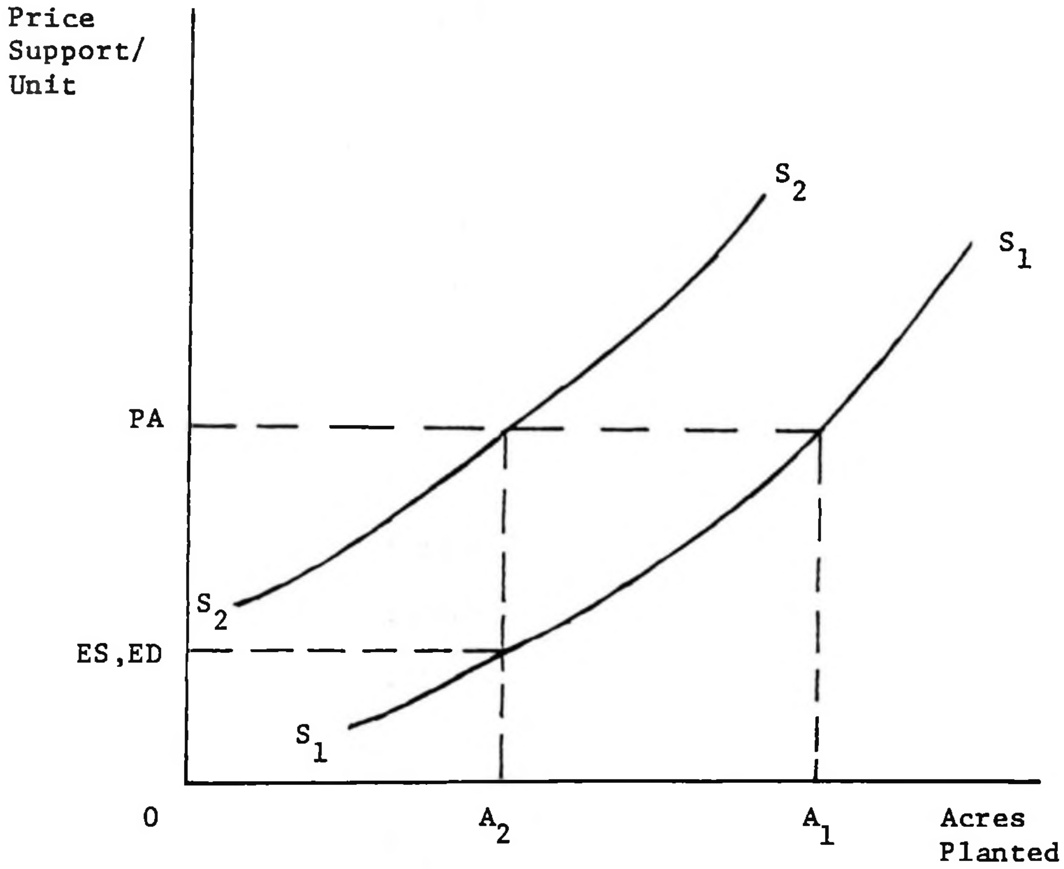

Figure 1. Relationship Between Support Programs and Acreage Planted

where PA_i = announced support price for crop i,

A_{oi} = base acreage for crop i,

A_i = allowable acreage for crop i under the price program, and

ES_i = effective support price for crop i.

If it is assumed that the government wishes to reduce acreage to A_2 solely through payment for idled land, an unrestricted support price PA would be announced, and then payments attractive enough would be offered, so that producers divert sufficient acreage to meet the policy objective. This would lead to the shift of the supply curve from S_1S_1 to S_2S_2 and A_1A_2 acres will be withdrawn from production. This approach of meeting policy objective is represented by the following formula (Houck et al., 1976):

$$ED = wPR$$

where PR is the payment rate for diversion, ω is that part of base acreage eligible for diversion, and ED is the effective diversion rate. It is obvious that ED will be between zero and one. Actual construction of the variable is based of the following formula:

$$ED_i = wPR_i = \frac{D_i}{A_{oi}} PR_i$$

where ED = effective diversion payment rate for crop i,

D_i = acreage diversion requirement for crop i,

A_{oi} = base acreage for crop i, and

PR_i = diversion payment rate for crop i.

It should be recognized that the two policy variables do not cover all the policy options. Therefore, in the course of empirical specification of an acreage supply response model additional policy variables deemed important will be incorporated explicitly.

Product Price Expectation Formation

It has been shown that expected product prices are among the variables that explain product supply response. That is production decisions are partly based on the anticipated or forecasted prices and not on the currently observed prices. The influence of expected prices on production decisions will likely depend on the degree of confidence the producer attaches to his expectations.

Modelling expectations of unobservable variables need to reflect the mechanism used by economic agents to gauge their expectations. Some survey studies have been carried out to try to understand how producers forecast future prices. Heady and Kaldor (1954) carried out a three year study (1947 to 1949) of farmers' expectations in 10 southern counties of Iowa, and while they found that some farmers used simple extrapolative rules to forecast future prices, the general observation was that farmers tried to understand the mechanism determining prices. Similar observations were made in a study of midwestern farmers by Partinheimer and Bell (1961) in which they found that most of the farmers surveyed either based their forecasts on product supply or on both supply and demand. These studies suggest that, in general, producers use other information sources on market conditions in addition to past realized prices to gauge their expectations on future prices. That is, producers try to optimize their forecast conditional on information at their disposal. Heady and Kaldor (1954) indicate in their study that the farmers surveyed had a "crude" understanding of probability distributions which will be generalized here to mean that farmers have subjective probability distributions over the anticipated price.

In Chapter II a survey of the methods which have been used to model expectations for econometric studies was presented. Among these methods, the rational expectations hypothesis proposed by Muth (1961) is more appealing since it has an economic theory justification and conforms to the hypothesized optimization behavior of economic agents. Muth (1961, p. 316) assumes that ". . . expectations, since they are informed predictions of future events, are essentially the same as the prediction of the relevant economic theory." Predictions are informed in the sense that all the information relevant in forecasting the future value of the uncertain event is utilized. This implies that the structure of the relevant system is incorporated in the forecasting rule. Expectations are rational if the forecasted and realized prices have the same probability distribution and can be expressed as the conditional expectation (in the statistical sense) based on all observations on it and of related variables up to the time of the forecast.

One of the major criticisms of the rational expectations hypothesis is that it assumes more information than is generally available and used by economic agents. It is more likely that farmers attribute various degrees of strength to the factors which are relevant in forecasting prices, disregarding those factors which are considered to be minor and base their expectations only on a proper subset of all the relevant factors. In addition, the limited ability to translate information into forecasts suggests that only a subset of all the available information is actually considered in forecasting prices.

Definition of Terms and Assumptions

Before showing how the rational expectations hypothesis can be applied to model product price forecasts, the relationship between a is used to predict P_t. Then P_t^* and P_t^{**} are related by

$$P_t^* = E[(P_t^{**} + \eta_t)|\Omega_{t-1}] \tag{29}$$

$$= P_t^{**} + \eta_t^*$$

where η_t^* represents that portion of P_t that cannot be predicted from V_{t-1} but can be predicted if Ω_{t-1} is utilized. Since conditional expectations are uncorrelated with the realized error, equation (29) describes a decomposition of the full rational expectation into two orthogonal components. Therefore, using P_t^{**} as a measure of P_t^* will be uncorrelated with η^* and therefore the usual error in measurement problem will not be introduced. This observation has great implications when we construct proxies for the rational expectations using less than the full information set.

For the rest of the analysis, the following assumptions are made:

1. Producers have an identical information set and they use an identical forecasting rule.
2. Information is not lost. That is, $\Omega_{t-1} \subset \Omega_t$. The implication of this assumption is that there is a learning process as additional information becomes available which is used in forming future expectations.

Rational Expectations Model

In order to obtain rational product price forecasts, the structure of the system of interest needs to be specified. A simple supply and demand system is presented below:

$$Q_t^d = a_0 + a_1 P_t + a_2 I_t + \varepsilon_t \qquad a_1 < 0,\ a_2 > 0 \tag{30}$$

$$Q_t^s = b_0 + b_1 P_t^* + b_2 C_t + \xi_t \qquad a_0 > b_0,\ b_1 > 0 \tag{31}$$

$$Q_t^d = Q_t^s \tag{32}$$

$$P_t^* = E[P_t | \Omega_{t-1}] \tag{33}$$

where Q_t^d is the aggregate demand for product Q at time t,

Q_t^s is the aggregate supply of product Q at time t,

I_t is the aggregate disposable income at time t,

C_t is the index of prices paid by farmers for production items--non-farm origin,

P_t is the realized price for product Q at time t,

P_t^* is the expected price for product Q, the expectation being formed at the beginning of the production period,

Ω_{t-1} is the set of information available at time t-1. This includes lagged values of the variables, and

E is the expectation operator.

Q_t^d, Q_t^s, P_t and P_t^* are endogenous variables while I_t and C_t are exogenous variables. The model as specified is identified. To complete the specification of the model, it is assumed that the disturbance terms are identically, independetly, and normally distributed with zero means and variances σ_1^2 and σ_2^2, respectively. ε_t and ξ_t are independent.

The demand equation (30), shows that demand is based on observed price P_t, but in the case of supply (equation (31)) the relevant price is the expected price (P_t^*) due to the time lag involved in the production process. That is, while demand can adjust instantaneously in response to price changes, agricultural production cannot, and hence decisions are based on the price expected to prevail at the end of the production period. Equation (33) shows that the anticipated price (P_t^*) is given as the expectation of P_t implied by the market model, conditional on information Ω_{t-1} available at time t-1.

The reduced form equation for P_t is obtained by making use of the identity equation (32). The result is presented in equation (34).

$$P_t = \frac{b_0 - a_0}{a_1} + \frac{b_1}{a_1} P_t^* + \frac{b_2}{a_1} C_t - \frac{a_2}{a_1} I_t + e_t \tag{34}$$

where $e_t = \frac{1}{a_1} (\xi_t - \varepsilon_t)$.

By taking conditional expectation of (34) and rearranging terms, the rational expectation of P_t is

$$P_t^* = \frac{b_0 - a_0}{a_1 - b_1} + \frac{b_2}{a_1 - b_1} E[C_t|\Omega_{t-1}] - \frac{a_2}{a_1 - b_1} E[I_t|\Omega_{t-1}] \tag{35}$$

Equation (35) shows that the rational expectation is a linear combination of the predictions of the exogenous variables. The structure of the model is incorporated in the expectations through the structural parameters.

To complete the specification of the rational expectations equation, a method for forecasting the exogenous variables is presented. On the assumption that the exogenous variables are independent of the structure of the market system presented, the relevant information for forecasting them are their respective past realized values. It is assumed that $\{I_t\}$ and $\{C_t\}$ processes can be modelled by the following autoregressive integrated moving average (ARIMA) models.

$$\zeta^1(B) I_{t-1} = \theta^1(B) a^1_{t-1} \tag{36}$$

$$\zeta^2(B) C_{t-1} = \theta^2(B) a^2_{t-1} \tag{37}$$

Where a^1_{t-1} and a^2_{t-1} are the innovations of the processes, B is a back shift operator, $\zeta^i(B)$ (i = 1, 2) is a non-stationary autoregressive operator with d roots on the unit circle and the rest outside the unit circle. $\zeta^i(B)$ can also be written as $\zeta^i(B) = \phi^i(B)\nabla^d$, where $\phi^i(B)$ is a stationary autoregressive operator of order p. Stationarity implies that the roots of the polynomial $\phi(B) = 0$ lie outside the unit circle. ∇^d defines the number of differencings required to induce stationarity to the series. Therefore, the polynomial $\zeta^i(B)$ in B is of order p + d. $\theta^i(B)$ is the moving average operator, assumed to be of order q and satisfies the invertibility condition. That is, the roots of the polynomial $\theta^i(B) = 0$ lie outside the unit circle.

It is assumed that the polynomials $\zeta^i(B)$ and $\theta^i(B)$ in B can be written as

$$\begin{aligned} \zeta^i(B) &= 1 - \zeta_1^i B - \zeta_2^i B^2 - \dots - \zeta_{p+d}^i B^{p+d} \\ & \qquad\qquad\qquad\qquad\qquad\qquad i = 1, 2 \\ \theta^i(B) &= 1 - \theta_1^i B - \theta_2^i B^2 - \dots - \theta_q^i B^q \end{aligned}$$

Using the given model specification (Box and Jenkins, 1976), it can be shown that the minimum mean square error forecasts for I_t and C_t made at the time t-1 are

$$\begin{aligned} E[I_t | I_{t-1}, I_{t-2}, \dots] = \hat{I}_{t-1}(1) &\equiv \zeta_1^1 I_{t-1} + \zeta_2^1 I_{t-2} + \dots + \\ &+ \zeta_{p+d}^1 I_{t-(p+d)} - \theta_1^1 a_{t-1}^1 - \dots - \theta_q^1 a_{t-q}^1 \end{aligned} \tag{38}$$

$$\begin{aligned} E[C_t | C_{t-1}, C_{t-2}, \dots] = \hat{C}_{t-1}(1) &\equiv \zeta_1^2 C_{t-1} + \zeta_2^2 C_{t-2} + \dots \\ &+ \zeta_{p+d}^2 C_{t-(p+d)} - \theta_1^2 a_{t-1}^2 - \dots - \theta_q^2 a_{t-q}^2 \end{aligned} \tag{39}$$

By substituting $\hat{I}_{t-1}(1)$ and $\hat{C}_{t-1}(1)$ for $E[I_t|\Omega_{t-1}]$ and $E[C_t|\Omega_{t-1}]$, respectively, in equation (35), the rational expectation is simplified to

$$P_t^* = \frac{b_0 - a_0}{a_1 - b_1} + \frac{b_2}{a_1 - b_1}\hat{C}_{t-1}(1) - \frac{b_2}{a_1 - b_1}\hat{I}_{t-1}(1) \tag{40}$$

If the structural parameters were known, then P_t^* could be obtained directly from equation (40). However, since in practice the structural parameters are unknown, two methods are outlined below which can be used to construct proxies for P_t^* and still conform to the rational expectations hypothesis.

Regression Approach. Since $E[P_t|\Omega_{t-1}]$ is linear in Ω_{t-1}, following Sargent's argument (1973), the rational expectation is formed as if it were the prediction from a least squares regression of P_t on Ω_{t-1} ($E[P_t|\Omega_{t-1}]$ is treated as a regression function). Therefore, the conditional expectation can be written as follows:

$$E[P_t|\Omega_{t-1}] = \beta\Omega_{t-1} \tag{41}$$

and

$$\begin{aligned} P_t &= \hat{\beta}\Omega_{t-1} + \tilde{\varepsilon}_t \\ &\equiv \hat{P}_t + \tilde{\varepsilon}_t \end{aligned} \tag{42}$$

where $\tilde{\varepsilon}_t$ is the residual term which is orthogonal to the information set. $\hat{P}_t$ is then used as a proxy for P_t^*. Empirically, $\hat{P}_t$ is obtained by regressing P_t on elements of Ω_{t-1}, in this case the lagged values of P_t, C_t, and I_t.

Extrapolative Predictor Approach. It was shown that, when only a subset of the relevant information is used to form expectations, a partial rational expectations (P_t^{**}) is obtained. A situation where this subset of information contains only past realized values of the product price is considered here. Muth (1961) shows that when the variable being forecasted follows the first order moving average process in its first difference, the adaptive expectations model and the rational expectations are equivalent. This restrictive case seems to suggest that if the stochastic process of the expectation variable is identified as being the first order moving average process in the first difference of the variable, then the adaptive expectations model is appropriate in the sense of partial rationality. Otherwise, error in variables will be introduced. This suggests that any ad hoc extrapolative predictor will not do unless the underlying stochastic process generating the observed values of the variable is identified and used appropriately in defining the lag structure.

Nelson (1975) suggests that the appropriate approach to follow is to try to identify a suitable model for $\{P_t\}$ from the general class of ARIMA models by time series methods. Box and Jenkins (1976) methods are particularly suited for model identification and estimation. As an example, assume $\{P_t\}$ is a series of average seasonal prices for wheat, and that by Box-Jenkins methods it is found that $\{P_t\}$ can be adequately modelled by ARIMA (1,1,0). That is $\{P_t\}$ follows the first order autoregressive process in its first difference. Then the partial rational expectation is $P_t^{**} = (1+\hat{\phi})P_{t-1} - \hat{\phi}P_{t-2}$, where $\hat{\phi}$ is the estimate of the autoregressive parameter. Since P_t^{**} is orthogonal to the forecast error, it satisfies the condition for partial rationality and hence it can be used as a proxy for P_t^*.

Relationship Between Expected Price and Support Price

It was indicated previously that producers perceive a subjective probability distribution over the expected price. Since support prices are known at the time production decisions are being made, it is highly likely that producers take them into consideration in forecasting future prices. If the expected price is lower than the support price, it is likely that production decisions will be based on the support price. In this sense, the relevant subjective probability distribution for expected price is truncated from below. It is therefore proposed that after the series of proxies for expected prices is constructed, the support price be substituted for expected price in all those years in which the expected price is less than the support price. The adjusted series will correspond to the drawing of a sample from the relevant truncated probability distribution.

A Method for Combining Variables

Data limitations and/or a high degree of multicollinearity precludes the consideration of more than one or two competing crops in a supply response model. Exclusion of important competing crops can be avoided if some variables can be combined. According to economic theory, economic agents alter their decisions on the basis of relative price changes rather than absolute price changes. This suggests that, for a given crop, it is valid to use expected price or expected returns per acre relative to expected prices or expected returns per acre of competing crops, respectively. Relative expected price and relative expected returns per acre variables are constructed using formulas (43a) and (43b), respectively.

$$REP_{ti} = \frac{P^*_{ti}}{\left[\left(\sum_{\substack{\ell=1\\ \ell\neq i}}^{m-1} Q_{t-1,l}\, P^*_{tl} \Big/ \sum_{\substack{\ell=1\\ \ell=i}}^{m-1} Q_{t-1,l}\right)\right]} \qquad \begin{matrix} i = 1, \ldots, m \\ t = 1, \ldots, T \end{matrix} \qquad (43a)$$

$$REP_{ti} = \frac{Y^*_{ti} \times P^*_{ti}}{\left[\left(\sum_{\substack{\ell=1\\ \ell\neq i}}^{m-1} AC_{t-1,l} \times (Y^*_{tl} \times P^*_{tl}) \Big/ \sum_{\substack{\ell=1\\ \ell\neq 1}}^{m-1} AC_{t-1,l}\right)\right]} \qquad (43b)$$

$$i = 1, \ldots, m;\ t = 1, \ldots, T$$

where REP_{ti} = relative expected price of crop i for period t,

P^*_{ti} = expected price of crop i for period t at period t-1,

P^*_{tl} = expected price of competing crop ℓ for period t at period t-1,

$Q_{t-1,l}$ = total output of competing crop ℓ lagged one period,

REP_{ti} = relative expected returns per acre of crop i for period t,

Y^*_{ti} = expected yield of crop i for period t at period t-1,

Y^*_{tl} = expected yield of competing crop ℓ for period t at period t-1, and

$AC_{t-1,l}$ = total acreage of competing crop ℓ lagged one period.

Lagged output or acreage is used in constructing the variables to conform with the procedure used to construct proxies for expected prices, in addition to avoiding the problem of simultaneity in the estimation process. The decision as to which of the two formulas to use, depends on how the supply response model is specified. It this study relative expected returns per acre will be used.

It was shown that for a given crop the main features of government programs can be summarized into two variables--effective support rate (ES) and effective diversion rate (ED). Relative effective support rate (RES) per acre and relative effective diversion rate (RED) per acre can be constructed by using formula (43b). This method allows the reduction of policy variables to be considered from 2m to two.

The supply response model for crop i to be specified in the next section will have relative effective support rate (RES), relative effective diversion rate (RED), and relative expected returns per acre (RER) as explanatory variables. By following this method for combining variables, all important competing crops can be considered, and at the same time the degree of multicollinearity is minimized, and degrees of freedom conserved.

Acreage Supply Response Model of a Firm

In the general supply function of a firm, output is the decision variable. Empirical specification is based on the acreage planted as a proxy for planned production for the following reasons (Behrman, 1968):

i. Data on planned output are generally unavailable.

ii. Realized output differs substantially from planned output because of the influence of environmental factors on yield and hence output. While some of these factors can be controlled, the high opportunity cost involved makes the control of some of them unprofitable.

Acreage planted, on the other hand, is to a large extent under the control of producers, and thus only a minor difference is expected between the planned and planted acreage. However, it should be noted that using planted acreage as a proxy for planned production has its drawbacks which are outlined below:

i. Land being a heterogenous factor, a producer can decide to increase the planned output of a given crop by devoting less but better land to the crop. This approach of increasing output can result from either government policies or other production inputs constraining the number of acres which can be planted.

ii. Land is just one of the many inputs used in agricultural production, and thus a decision to allocate a certain area of land to a given crop is consistent with a wide range of planned outputs. This suggests that an index of all inputs used to produce that particular crop would be a better proxy for planned output. However, since such data is unavailable, this approach is ruled out.

It should also be noted that planted acreage can deviate from desired acreage either due to institutional or resource constraints. Therefore, there is a need to relate planted acreage which is observable to the desired acreage which is unobservable. This is done by using the partial adjustment model (Nerlove, 1956).

The following firm level acreage supply response model is assumed:

$$\begin{aligned} AC^{*j}_{t,i} = {} & \beta_{oi} + \beta^{j}_{1i} RER^{j}_{t1,i} + \beta^{j}_{2i} IP^{j}_{t2,i} + \beta^{j}_{3i} RES^{i}_{t3,i} + \beta^{j}_{4i} RED^{j}_{t4,i} \\ & + \beta^{j}_{5i} \sum_{n=1}^{N} \delta_n (RER_{t-n,5i} - RR_{t-n,5i})^{2,j} + V^{j}_{ti} \end{aligned} \tag{44}$$

$i = 1, \ldots, m;\ j = 1, \ldots, L;\ t = 1, \ldots, T$

where AC^{*j}_{ti} = desired acreage for crop i by producer j at period t,

RER^{j}_{ti} = relative expected returns per acre for crop i by producer j at period t,

RR^{j}_{ti} = realized relative returns per acre for crop i by producer j at period t,

IP^{j}_{ti} = index of production costs for crop i as applied to producer j at period t,

$\sum_{n=1}^{N} \delta_n (RER_{t-n,i} - RR_{t-n,i})^2$ = a measure of relative returns risk as applied to producer j at period t, and

V^j_{ti} = disturbance term.

Partial Adjustment Model

In order to relate the desired acreage which is unobservable to planted acreage, the partial adjustment model is used as shown in equation (45).

$$AC_t - AC_{t-1} = (AC^*_t - AC_{t-1}) \qquad 0 < \omega \leq 1 \tag{45}$$

where AC_t = planted acreage at period t,

AC_{t-1} = planted acreage at period t-1,

AC^*_t = desired acreage at period t, and

ω = the coefficient of adjustment.

By combining equations (44) and (45), the acreage supply response equation of crop i for producer j in terms of planted acreage is obtained.

$$\begin{aligned} AC^j_{t,i} = {} & \omega\beta^j_{oi} + \omega\beta^j_{1i} RER^j_{t1,i} + \omega\beta^j_{2i} IP^j_{t2,i} + \omega\beta^j_{3i} RES^j_{t3,i} \\ & + \omega\beta^j_{4i} RED^j_{t4,i} + \omega\beta^j_5 \sum_{n=1}^{N} \delta_n (RER_{t-n,5i} - RR_{t-n,5i})^{2,j} \\ & + (1-\omega) AC^j_{t-1,6i} + \omega V^j_{ti} \end{aligned} \tag{46}$$

In order to simplify the notation and the theoretical developments to follow, the variables and parameters are redefined as follows:

$X^j_{t,1i} = RER^j_{t,1i}$

$X^j_{t,2i} = IP^j_{t,2i}$

$X^j_{t,3i} = RES^j_{t3,i}$

$$X^j_{t,4i} = RED^j_{t4,i}$$

$$X^j_{t,5i} = \sum_{n=1}^{N} \delta_n (RER_{t-n,5i} - RR_{t-n,5i})^{2,j}$$

$$X^j_{t,6i} = AC^j_{t-1,6i}$$

$$A^j_{oi} = \omega\beta^j_{oi}$$

$$A^j_{1i} = \omega\beta^j_{1i}$$

$$A^j_{2i} = \omega\beta^j_{2i}$$

$$A^j_{3i} = \omega\beta^j_{3i}$$

$$A^j_{4i} = \omega\beta^j_{4i}$$

$$A^j_{5i} = \omega\beta^j_{5i}$$

$$A^j_{6i} = 1 - \omega$$

$$V*^j_{ti} = \omega V^j_{ti}$$

The acreage supply response model is simplified to:

$$\begin{aligned} AC^j_{t,i} = {} & A^j_{oi} + A^j_{1i}X^j_{t,1i} + A^j_{2i}X^j_{t,2i} + A^j_{3i}X^j_{t,3i} + A^j_{4t}X^j_{t,4i} \\ & + A^j_{5i}X^j_{t,5i} + A^j_{6i}X^j_{t,6i} + V*^j_{ti} \end{aligned} \tag{47}$$

It should be remembered that, with the exception of A_6, all other parameters are nonlinear due to the adjustment coefficient entering the model nonlinearly.

Aggregation Problem

The acreage supply response model specified refers to a single producer or firm. In general, such models are rarely estimated because of the following reasons:

1. Data is not available for individual producers.
2. Even if data were available at the level of the producer, the large number of producers involved makes this approach impractical.

The general approach has been to carry the implications of a model specified for a single producer to the industry level. While the same approach is followed in this study, there is a need to point out the problems resulting from such an approach, and the restrictions it imposes on the interpretation and application of the results. First, the aggregate acreage supply response model is presented in equation (48).

$$
\begin{aligned}
AC_{ti} = {} & A_{oi} + A_{1i}X_{t,1i} + A_{2i}X_{t,2i} + A_{3i}X_{t,3i} + A_{4i}X_{t,4i} \\
& + A_{5i}X_{t,5i} + A_{6i}X_{t,6i} + V^{*}_{t,i}
\end{aligned}
\qquad (48)
$$

where $AC_{t,i}$ = the sum of individual producers' acreage allocated to crop i; that is $AC_{t,i} = \sum_{j=1}^{L} AC_{t,ij}$,

$X_{t,1i}$ = the average of individual producers' relative expected returns per acre; that is, $X_{t,1i} = \frac{1}{L} \sum_{j=1}^{L} X_{t,1ij}$,

$X_{t,2i}$ = the average of individual producers' index of prices paid for inputs used in the production of crop i; that is, $X_{t,2i} = \frac{1}{L} \sum_{j=1}^{L} X_{t,1ij}$,

$X_{t,3i}$ = the average of individual producers' relative effective support rate for crop i; that is, $X_{t,3i} = \frac{1}{L} \sum_{j=1}^{L} X_{t,3ij}$,

$X_{t,4i}$ = the average of individual producers' relative effective diversion rate for crop i; that is, $X_{t,4i} = \frac{1}{L} \sum_{j=1}^{L} X_{t,4ij}$,

$X_{t,5i}$ = the average of individual producers' risk on relative returns per acre for crop i; that is, $X_{t,5i} = \frac{1}{L} \sum_{j=1}^{L} X_{t,5ij}$,

$X_{t,6i}$ = the sum of individual producers' acreage allocated to crop i, lagged one period; that is, $X_{t,6i} = \sum_{j=1}^{L} X_{t,6ij}$, and

V^*_{ti} = the sum of the disturbances from individual producers' supply response equations; that is, $V^*_{ti} = \sum_{j=1}^{L} V^*_{t,ij}$.

In order to explain the nature of the aggregation problem, and its implication on the empirical results, the flow diagram used by Ijiri (1971) and Chipman (1975) is utilized (Figure 2).

$$\begin{tikzcd}
\boxed{X} \arrow[r, "f"'] \arrow[d, shift left, "h"] & \boxed{Y} \arrow[d, shift left, "g"] \\
\boxed{X^*} \arrow[r, "f^*"] \arrow[u, shift left, "h^*"] & \boxed{Y^*} \arrow[u, shift left, "g^*"]
\end{tikzcd}$$

Figure 2. Relationship Between Micro and Macro Systems

From Figure 2, X and Y are proper sets of micro exogenous and endogenous variables. In this study, the elements of set X are the explanatory variables as specified in equation (46) while those of the set Y are the acreages allocated to each crop by individual producers. The macro system is represented by the proper sets X* and Y* with macro exogenous and endogenous variables as their respective elements. The micro and macro systems are related through the functions f, f*, g, g*, h, and h*. The focus will be on functions f, f*, g and h.

The function h maps set X onto set X^*; that is, $h: X \to X^*$. In this study, h represents the weighting schemes of the micro exogenous variables to obtain the macro exogenous variables as discussed previously. The function g maps Y onto Y^*; that is, $g: Y \to Y^*$, which in this case is the summation of individual producers' acreage for a given crop. The function f* which maps X into Y ($f: X \to Y$) represents the micro parameters. Depending on the relationship between X and Y, f can be linear or non linear. In this study, f is non linear as a result of the adjustment coefficient ω. The function f* which maps X^* onto Y^* ($f^*: X^* \to Y^*$) represents the macro parameters.

As indicated before, the acreage supply response model was specified on the basis of micro theory and the same form of the model is assumed at the macro level. This extension of the relationship assumed at the micro level to the macro level is the same as saying that f and f* have the same form. The work by Theil (1954, 1971) on linear aggregation shows that a given macro parameter is dependent on both the corresponding and non corresponding micro parameters. That is a given macro parameter is a complex function of the micro parameters. Similar findings were shown by Fikri and George (1975) and Akkina (1974). Kelegian (1980) in his study of the disaggregation and aggregation of non linear equations concludes that the complex structure of the macro parameters derived from a relationship between micro and macro variables makes such a structure intractable empirically.

Referring to Figure 2, if $\hat{Y}^*_i$ is the prediction of the aggregate acreage planted for crop i, this prediction can be obtained in two ways: (1) $\hat{Y}^* = g \cdot f(\underset{\sim}{x}_i)$, $\underset{\sim}{x}_i \varepsilon X$. This implies that, having estimated f, $\hat{Y}_i$ is obtained from the knowledge of $\underset{\sim}{x}_i (\underset{\sim}{x}_i \varepsilon X)$ which when summed, where summation is represented by function g, yields the predicted aggregate acreage for crop i. (2) $\hat{Y}^* = f^* \cdot h(\underset{\sim}{x}_i)$, $\underset{\sim}{x}_i \varepsilon X$. This implies that, by applying relevant weighting schemes to $\underset{\sim}{x}_i \varepsilon X$, the relevant aggregate of the exogenous variables ($\underset{\sim}{x}_i^* \varepsilon X^*$) is obtained. Then assuming f* has been estimated, by knowledge of $\underset{\sim}{x}_i$ and hence $\underset{\sim}{x}_i^*$, Y* can be predicted.

Since the function f represents the micro relationships in which the actual acreage decisions are being made, the focus should be on the prediction at the macro level. How good is the prediction made directly using the macro variables, relative to the indirect prediction via the micro variables? It is obvious that the two predictions will be the same only if $g \cdot f = f^* \cdot h$. Since g and h are linear operations it is reasonable to say that the necessary restrictions need to be imposed on the form of the function f*. That is not any f* will do (not any assumed macro structure will do). Theil (1971) and Chipman (1975) show that under the assumption that the micro parameters are the same for all individuals, the assumption that the micro structure is of the same form as the macro structure will not introduce aggregation bias. Since in practice this assumption is unrealistic, it is likely that the relationship $g \cdot f = f^* \cdot h$ will not hold, and aggregation bias is likely to be introduced.

In a theoretical treatment, Chipman (1975, 1976) and Ijiri (1971) show how f* can be chosen to minimize bias. Unfortunately, their methods are intractable empirically. While the discussion as presented does not offer a solution to the problem, the following implications can be drawn:

1. The aggregate acreage supply response as presented is just an approximation of the true aggregate model. The parameters of

the aggregate model are likely to be a complex function of the micro parameters.

2. The form of the aggregate model is likely to introduce aggregation bias unless we are willing to assume that the micro parameters are the same for all individuals.
3. The predictive performance of the aggregate model is likely to be poor outside the estimation period. No proper account has been taken to relate the micro parameters to the macro parameters other than extending the same functional form to the aggregate level.
4. The use of the aggregate model to study structural relationships rather than for prediction purposes seems to be more appropriate. This is not to suggest that such models cannot be used for forecasting, but large forecasting errors are to be expected, especially as the lead time increases.

Stochastic Assumptions and Estimation Methods

Thus far, nothing has been said about the stochastic behavior of the supply response model. The choice of an appropriate estimation method is dependent on the stochastic assumption imposed on the model. The aggregate acreage supply response model for crop i is presented in equation (49) in the more general matrix notation.

$$\underset{\sim}{AC}_i = X_i \underset{\sim}{A}_i + \underset{\sim}{V}_i^* \qquad i = 1, \ldots, m \tag{49}$$

where $\underset{\sim}{AC}_i$ is a T x 1 vector of aggregate acreage for crop i,

X_i is a T x K_i matrix of regressors--as discussed previously, where $\underset{\sim}{A}_i$ is a T x 1 vector of parameters to be estimated, and

$\underset{\sim}{V}_i^*$ is a T x 1 vector of disturbances.

It is assumed that $\underset{\sim}{V}_i^*$ is normally distributed with mean $E(\underset{\sim}{V}_i)$ equal to zero and variance covariance matrix $\sigma^2\Gamma$ where Γ is a T x T symmetric and positive definite matrix and σ^2 is finite $(0 < \sigma^2 < \infty)$.

The following general assumptions will be maintained throughout the discussion:

1. X_i matrix of regressors is partly stochastic--recall that one of the regressions is the lagged acreage for crop i.
2. The regressors are linearly independent (full column rank).
3. $\text{plim} \frac{X_i'X_i}{T} = Q$ is finite and nonsingular.
4. $\text{plim} \frac{X_i'\underset{\sim}{V}_i^*}{T} = \underset{\sim}{0}$.
5. $T > K_i$, where T is the number of observations and K_i is the number of regressors.

Two cases concerning the form of Γ_T are considered. For each case, the estimation procedure and the properties of the estimators of the parameters will be given.

Spherical Disturbances

By spherical disturbances it is meant that the disturbances are neither autocorrelated nor heteroschedastic. That is

$$EV_t^*V_t^* = \sigma^2 \qquad \text{for } t = 1, \ldots, T$$

$$EV_t^*V_t^* = 0 \qquad \text{for } t \neq s.$$

Where E is the expectation operator. The condition for spherical disturbances is satisfied when Γ_T is an identity matrix in which case the variance-covariance matrix for the disturbance vector is reduced to $\sigma^2 I_T$. When the disturbances are spherical, the vector of parameters can be estimated by ordinary least squares (OLS), and the vector of parameter estimators becomes

$$\hat{\underset{\sim}{A}}_i = (X_i'X_i)^{-1} X_i'\underset{\sim}{A}C_i \tag{50}$$

The OLS estimators have the following properties:

i. They are biased. Recall that the vector of regressors includes a lagged dependent variable, implying that X_i and V_i are only contemporaneously uncorrelated; that is,

$$E\hat{\underset{\sim}{A}}_i = \underset{\sim}{A}_i + E[(X_i'X_i)^{-1}X_i'\underset{\sim}{V}_i^*] \neq \underset{\sim}{A}_i.$$

ii. $\hat{\underset{\sim}{A}}_i$ is consistent. This can be shown by writing $\hat{\underset{\sim}{A}}_i = \underset{\sim}{A}_i + (X_i'X_i)^{-1}X_i'\underset{\sim}{V}_i^*$ and taking probability limits.

$$\begin{aligned} \text{plim } \underset{\sim}{A}_i &= \underset{\sim}{A}_i + \text{plim}\left(\frac{X_i'X_i}{T}\right)^{-1} \text{plim } \frac{X_i'\underset{\sim}{V}_i^*}{T} \\ &= \underset{\sim}{A}_i + Q^{-1} \cdot 0 \text{ (by assumption (4), plim } \frac{X_i'\underset{\sim}{V}_i^*}{T} = 0) \\ &= \underset{\sim}{A}_i. \end{aligned}$$

iii. It can be shown that $\sqrt{T}(\underset{\sim}{A}_i - \underset{\sim}{A}_i)$ coverges in distribution to $N(0, \sigma^2 Q^{-1})$ and this implies that the usual tests of hypotheses are asymptotically justified (Schmidt, 1976).

In order to carry out tests of hypotheses, there is a need to obtain the asymptotic variance of the estimators.

$$\begin{aligned} \text{Var }(\hat{\underset{\sim}{A}}_i) &= \frac{1}{T} \text{ plim } [T(\hat{\underset{\sim}{A}}_i - \underset{\sim}{A}_i)(\hat{\underset{\sim}{A}}_i - \underset{\sim}{A}_i)'] \\ &= \frac{1}{T} \sigma^2 Q^{-1}. \end{aligned}$$

Since σ^2 is unknown, the estimate of the asymptotic variance of $\hat{\underset{\sim}{A}}_i$ is

$\frac{1}{T} S^2 (\frac{1}{T}X_i'X_i)^{-1} = S^2(X_i'X_i)^{-1}$; where $S^2 = \underset{\sim}{\hat{V}^{*\prime}_i}\underset{\sim}{\hat{V}^*_i}/T\text{-}K$ and $\underset{\sim}{\hat{V}^*_i}$ is a vector of residuals.

Recall that the aggregate acreage supply response model as specified has the adjustment coefficient entering nonlinearly except for the coefficient on the lagged acreage variable where it enters linearly. Therefore, the estimate of the adjustment coefficient is obtained from the estimated coefficient on the lagged acreage variable which is then used to obtain the estimates of the other parameters.

Explicit values of all parameters can be obtained directly by using nonlinear least squares (NLS) or maximum likelihood estimation methods (Judge, 1980; Just, 1973; Estes et al., 1981). Below, a conditional maximum likelihood estimation procedure based on the above mentioned references is presented.

The equation for the t^{th} observation of the aggregate supply response equation can be written as

$$\begin{aligned} AC_{t,i} = {} & \omega A_0^* + A_1^*\omega X_{t,1i} + A_2^*\omega X_{t,2i} + A_{3i}^*\omega X_{t,3i} + A_{4i}^*\omega X_{t,4i} \\ & + A_{5i}^*\omega X_{t,5i} + (1 - \omega)AC_{t-1,6i} + V_{ti}^* \end{aligned} \tag{51}$$

For a given value of ω, equation (41) is linear in the other parameters, and OLS can be applied to estimate them. By moving the lagged acreage variable to the left side equation (51) can be written in the following form:

$$\begin{aligned} AC_{ti}(\omega) = {} & A_0^* + A_1^*X_{t,1i}(\omega) + A_2^*X_{t,2i}(\omega) + A_{3i}^*X_{t,3i}(\omega) \\ & + A_{4i}^*X_{t,4i}(\omega) + A_{5i}^*X_{t,5i}(\omega) + V_{t,i}^* \end{aligned} \tag{52}$$

Under the assumption of normality and spherical disturbance, using equation (52) the likelihood function given ω is presented in equation (53).

$$L(\underset{\sim}{A}^{*}\sigma_i^2 | \omega, \underset{\sim}{AC}_i, X_i) = (2\pi)^{-T/2}(\sigma_i^2)^{-T/2} \, e \, \frac{1}{2}\sigma_i^2[(\underset{\sim}{AC}_i(\omega) - X_i(\omega)\underset{\sim}{A}_i^{*})' (\underset{\sim}{AC}_i(\omega) - X_i(\omega)\underset{\sim}{A}_i^{*})] \tag{53}$$

$$\underset{\sim}{A}_i \varepsilon R^{K_i}; \quad \sigma_i^2 > 0.$$

From equation (53), the conditional log likelihood function is

$$\ln L(\underset{\sim}{A}_i^{*}\sigma_i^2 | \omega, \underset{\sim}{AC}_i X_i) = -\frac{T}{2}\ln(2\pi) - \frac{T}{2}\ln(\sigma_i^2) - \frac{1}{2}\sigma_i^2[(\underset{\sim}{AC}_i(\omega) - X_i(\omega)\underset{\sim}{A}_i^{*})'(\underset{\sim}{AC}_i(\omega) - X_i(\omega)\underset{\sim}{A}_i^{*})] \tag{54}$$

When equation (54) is partially differentiated with respect to $\underset{\sim}{A}_i^{*}$ and σ_i^2 and equating the partial derivatives to zero the following conditional maximum likelihood estimators, which are essentially least squares estimators, are obtained:

$$\hat{\underset{\sim}{A}}^{*}(\omega) = [X_i(\omega)'X_i(\omega)]^{-1} X_i(\omega)'\underset{\sim}{AC}_i(\omega) \tag{55}$$

$$\hat{\sigma}_i^2(\omega) = \frac{1}{T}[(\underset{\sim}{AC}_i(\omega) - X_i(\omega)\ \underset{\sim}{A}_i^{*}(\omega))'(\underset{\sim}{AC}_i(\omega) - X_i(\omega)\ \underset{\sim}{A}^{*}(\omega))] \tag{56}$$

By substituting (55) and (56) into (53), the concentrated likelihood function is obtained which is only dependent on ω. This is presented in equation (57).

$$L^{*}(\omega) = (2\pi)^{-T/2}\ (\sigma_i^2(\omega))^{-T/2}\ e^{-T/2} \tag{57}$$

It is obvious that (57) is equivalent to the original conditional likelihood function, partially maximized with respect to $\underset{\sim}{A}_i^{*}$ and σ_i^2.

Since ω lies in a short interval--(0,1], a search procedure can be applied to locate the neighborhood of the maximum, and by using some efficient iterative method within this neighborhood, the maximum can be located. That value of $\omega(\hat{\omega})$ maximizing the likelihood function is the maximum likelihood estimator of ω and $\hat{\underset{\sim}{A}}{}_i^*(\hat{\omega})$ and $\hat{\sigma}_i^2(\hat{\omega})$ are the desired maximum likelihood estimators.

It should be noted that maximizing (57) is equivalent to minimizing $\sigma_i^2(\omega)$. This suggests that a search procedure based on least squares can be used. That is, OLS estimates $\hat{\underset{\sim}{A}}{}_i^*(\omega)$ and $\hat{\sigma}_i^2(\omega)$ are computed for values of ω in the interval (0,1]. That value of $\omega(\hat{\omega})$ yielding the smallest $\sigma_i^2(\hat{\omega})$ is also a maximum likelihood estimator of ω. In general, one begins the search over a coarse grid to locate the neighborhood of the minimum, and then makes the intervals finer within the neighborhood to locate the global minimum.

The Case of Autocorrelated Disturbances

The assumption of autocorrelated disturbances is equivalent to assuming that the Γ_T matrix has unit elements on the diagonal, and the off diagonal elements take any values on the real line, but still retaining the symmetry and positive definiteness conditions. In this study, the simplest form of autocorrelation is assumed. That is, the disturbances follow the first order autoregressive process, as shown in equation (58).

$$V^*_{ti} = \rho V^*_{t-1,i} + \tilde{\varepsilon}_{ti} \qquad |\rho| < 1, \ \tilde{\varepsilon}_{ti} \sim \text{iidN}(0,\sigma_i^2) \tag{58}$$

$$t = 1, 2, \ldots, T$$

where ρ is the first order autocorrelation coefficient and $\tilde{\varepsilon}_{ti}$ is a random shock assumed to be identically and independently distributed with mean zero and variance $\sigma^2_{\tilde{\varepsilon}i}$. Estimating the model by OLS when the disturbances are autocorrelated will lead to biased and inconsistent estimators since

$$EX_i'\underset{\sim}{V}{}_i^* \neq 0 \text{ and } \operatorname{plim} \frac{1}{T} X_i'\underset{\sim}{V}{}_i^* \neq 0$$

In order to see how an alternative estimation method is developed, the aggregate supply response model for the t^{th} observation only is rewritten as in equation (59).

$$AC_{ti} = A_{oi} + \sum_{i=1}^{K_i-1} A_{11}X_{t,li} + A_{K_i} AC_{t-1,K_i,i} + V_{ti} \tag{59}$$

Defining L as the backshift operator so that $V^*_{t-1,i} = LV^*_{ti}$, equation (58) can be written as follows:

$$(1 - \rho L)V^*_{t,i} = \tilde{\varepsilon}_{ti}$$

$$V^*_{t,i} = \frac{\tilde{\varepsilon}_{ti}}{1 - \rho L}$$

On substituting $\tilde{\varepsilon}_{ti}/1 - \rho L$ for V^*_{ti} in equation (59) and rearranging terms, equation (60) is obtained.

$$\begin{aligned} AC_{ti} - \rho AC_{t-1i} &= (1 - \rho)A_{oi} + \sum_{1=1}^{K_i-1} A_{li}(X_{t,li} - X_{t-1,li}) \\ &\quad + A_{K_i} (AC_{t-1,K_i} - \rho AC_{t-2,K_i}) + \tilde{\varepsilon}_{ti} \end{aligned} \tag{60}$$

Equation (60) can be written in the following form:

$$AC_{ti}(\rho) = A_{oi}(\rho) + \sum_{1=1}^{K_i-1} A_{li}X_{t,li}(\rho) + A_{K_i} AC_{t-1,K_i}(\rho) + \tilde{\varepsilon}_{ti} \tag{61}$$

Equation (61) shows that for a given value of ρ, the A_{1i} $(1 = 0, 1, \ldots, K_i)$ parameters enter the model linearly, and since $\tilde{\varepsilon}_{ti}$ is spherical, OLS can be used to obtain consistent estimates of these parameters conditional on ρ. Since ρ lies in a finite interval $(-1,1)$, a search procedure can be used to obtain conditional estimates of $\sigma^2_{\tilde{\varepsilon}i}$ and $\underset{\sim}{A}_i$. By choosing a sufficient number of points in the interval--say, $-.999$ to $.999$--for every point chosen, $\hat{\sigma}^2_{\tilde{\varepsilon}i}(\rho)$ and $\hat{\underset{\sim}{A}}_i(\rho)$ are calculated. The optimum parameter estimates are those corresponding to that value of $\rho(\hat{\rho})$ yielding the minimum residual sum of squares. In practice, one begins with a coarse grid to locate the neighborhood of the minimum, which is later made finer within this neighborhood, to locate the minimum. Under the assumption of normality, that value of $\rho(\hat{\rho})$ corresponding to the minimum residual sum of squares, and the associated conditional parameter estimates $\hat{\underset{\sim}{A}}_i(\hat{\rho})$ and $\hat{\sigma}^2_{\tilde{\varepsilon}i}(\hat{\rho})$ are also maximum likelihood estimators. This is shown below.

Given ρ, the likelihood function can be written as:

$$
\begin{aligned}
L(\underset{\sim}{A}_i\sigma^2_{\tilde{\varepsilon}i}|\rho,\ AC_iX_i) = (2\pi)^{-T/2}(\sigma^2_{\tilde{\varepsilon}i})^{-T/2}\, e - \tfrac{1}{2}\sigma^2_i[(\underset{\sim}{AC}_i(\rho) - X_i(\rho)\underset{\sim}{A}_i)'\\
(\underset{\sim}{AC}_i(\rho) - X_i(\rho)\underset{\sim}{A}_i)] \qquad (62)\\
\underset{\sim}{A}_i \varepsilon R^{K_i};\ \sigma^2_{\tilde{\varepsilon}i} > 0
\end{aligned}
$$

and the logarithm of the likelihood function conditional on ρ is

$$
\begin{aligned}
\mathrm{LnL}(\underset{\sim}{A}_i\sigma^2_{\tilde{\varepsilon}i}|\rho,\ \underset{\sim}{AC}_i, X_i) = -\frac{T}{2}\ln(2\pi) - \frac{T}{2}\ln(\sigma^2_{\tilde{\varepsilon}i}) - \frac{1}{2}\,\sigma^2_{\tilde{\varepsilon}i}[(\underset{\sim}{AC}_i(\rho) - \\
X_i(\rho)\underset{\sim}{A}_i)'(\underset{\sim}{AC}_i(\rho) - X_i(\rho)\underset{\sim}{A}_i)] \qquad (63)
\end{aligned}
$$

For a given ρ, partially differentiating $\ln L(\cdot 1 \cdot)$ with respect to $\underset{\sim}{A}_i$ and $\sigma^2_{\tilde{\varepsilon}i}$ and equating the partial derivatives to zero yields the following maximum likelihood estimators:

$$\hat{\underset{\sim}{A}}_i(\rho) = [X_i(\rho)'X_i(\rho)]^{-1} X_i(\rho)'\underset{\sim}{AC}_i(\rho) \tag{64}$$

$$\sigma^2_{\tilde{\varepsilon}i}(\rho) = \frac{1}{T} [(\underset{\sim}{AC}_i(\rho) - X_i(\rho)\underset{\sim}{A}_i(\rho))'(\underset{\sim}{AC}_i(\rho) - X_i(\rho)\underset{\sim}{A}_i(\rho))] \tag{65}$$

Substitutind (64) and (65) into (62) yields the concentrated likelihood function presented in equation (66).

$$L^*(\rho) = (2\pi)^{-T/2} (\hat{\sigma}^2_{\varepsilon}(\rho))^{-T/2} e^{-T/2} \tag{66}$$

It is observed that the concentrated likelihood function depends only on ρ and that maximizing it is equivalent to minimizing $\hat{\sigma}^2_{\tilde{\varepsilon}i}(\rho)$. Thus, using a search procedure over ρ as described previously, the maximum of $L^*(\rho)$ can be located. That value of $(\hat{\rho})$ maximizing the likelihood function and the corresponding $\hat{\underset{\sim}{A}}_i(\hat{\rho})$ and $\sigma^2_{\tilde{\varepsilon}i}(\hat{\rho})$ are the desired maximum likelihood estimators.

It should be noted that $\underset{\sim}{A}_i$ is nonlinear in ω except for the coefficient on the lagged acreage. This implies that $\hat{\underset{\sim}{A}}_i(\hat{\rho})$ are nonlinear in ω. By obtaining the estimate of ω from the coefficient on the lagged acreage variable, this can be used to separate ω from the other parameter estimates. An alternative procedure would be to use a two dimensional search over the ranges of ρ and ω. That pair of values of $(\hat{\rho})$ and $(\hat{\omega})$ minimizing the residual sum of squares are the maximum likelihood estimators of ρ and ω, respectively, and $\hat{\underset{\sim}{A}}{}^*_i(\hat{\rho},\hat{\omega})$ and $\hat{\sigma}^2_{\tilde{\varepsilon}i}(\hat{\rho},\hat{\omega})$ are the desired parameter estimates.

Joint Estimation Method

The estimation procedures presented thus far can only be used to estimate the acreage supply response equations singly. Recall that, for each crop reporting district, acreage supply response equations for six crops will be estimated. It is likely that the disturbances in the different equations are contemporaneously correlated. If, indeed, the disturbances in different equations are correlated, a gain in efficiency can be achieved by using a joint estimation method which takes into account this contemporaneous correlation. A seemingly unrelated regression method proposed by Zellner (1962) seems appropriate. Only the case of spherical disturbances in each equation is considered here, although the method can easily be extended to the case where the disturbances are both contemporaneously and serially correlated.

From equation (49), the acreage supply response equations for m crops can be written as follows:

$$\begin{bmatrix} \underset{\sim}{AC}_1 \\ \underset{\sim}{AC}_2 \\ \vdots \\ \underset{\sim}{AC}_m \end{bmatrix} = \begin{bmatrix} X_1 & & & \phi \\ & X_2 & & \\ & & \ddots & \\ \phi & & & X_m \end{bmatrix} \begin{bmatrix} \underset{\sim}{A}_1 \\ \underset{\sim}{A}_2 \\ \vdots \\ \underset{\sim}{A}_m \end{bmatrix} = \begin{bmatrix} \underset{\sim}{V}^*_1 \\ \underset{\sim}{V}^*_2 \\ \vdots \\ \underset{\sim}{V}^*_m \end{bmatrix} \qquad (67)$$

where $\underset{\sim}{AC}_i$ and $\underset{\sim}{V}^*_i$ are of dimension T x 1, X_i is T x K_i, and $\underset{\sim}{A}_i$ is K_i x 1. The above equations can be written as:

$$\underset{\sim}{AC} = Z\underset{\sim}{\Delta} + \underset{\sim}{V}^* \qquad (68)$$

where $\underset{\sim}{AC}$ and $\underset{\sim}{V}^*$ are of dimension mT x 1, Z is mT x 1 and Δ is K x 1 with $K = \sum_{i=1}^{m} K_i$. It is assumed that $E[\underset{\sim}{V}^*] = 0$ and $E[\underset{\sim}{V}^*_i \underset{\sim}{V}^{*\prime}_j] = \sigma_{ij} I_T$. The covariance matrix of the joint disturbance vector is $E[\underset{\sim}{V}^* \underset{\sim}{V}^{*\prime}] = \Sigma_m \otimes I$ where ⊗ stands for Kronecker product.

The covariance matrix is unknown, therefore it has to be estimated before the generalized least squares (GLS) estimator can be determined. The first stage, then involves estimating each equation by ordinary least squares (OLS) to obtain least squares residuals ($\underset{\sim}{\hat{V}}*$). The estimator $\hat{\Sigma}$ then has elements given by

$$\hat{\sigma}_{ij} = \frac{\underset{\sim}{\hat{V}}'_i \underset{\sim}{\hat{V}}_j}{T} \qquad i,j = 1, 2, \ldots, m$$

and the GLS estimator is

$$\underset{\sim}{\hat{\Delta}} = Z'(\hat{\Sigma}^{-1} \otimes I)^{-1} \; Z'(\hat{\Sigma}^{-1} \otimes I)\underset{\sim}{AC} \qquad (69)$$

Equation (69) provides the parameter estimates for each equation which are more efficient than OLS estimates if the disturbances of different equations are contemporaneously correlated.

Chapter Summary

A general acreage supply response model for field crops is specified and possible estimation procedures are suggested, depending on the stochastic assumptions about the disturbance term. A step-by-step approach is followed to answer some of the methodological questions raised in Chapter I.

First, a general firm's output supply function is derived from the theory of a multiproduct firm facing product price uncertainty. It is shown that the output of a given crop is a function of own expected price, and expected prices of competing crops, input prices, and price variances. On the basis of the derived comparative static results, it is shown that the supply function is upward sloping and it is a nonincreasing function of product price variance. Some modifications to this function are necessary to take into account the influence of government policies and expected yield on supply response.

One of the methodological problems raised in Chapter I concerns the modelling of expected prices in a manner conforming to the assumed optimization behavior of economic agents. In this chapter, the justification for using the rational expectations to model expected product prices is demonstrated. Two methods for constructing proxies for the unobservable expected product prices are presented--the regression and the extrapolative predictor methods.

A number of methods for modelling the unobservable expected yield are presented. All the methods are ad hoc, and it is suggested that the choice of a method be based on simplicity in empirical implimentation. For this study expected crop yield will be represented by past period's yield.

In the general firm's supply function risk enters as price variance. A modification to model price risk which conforms with how decision makers this about risk is proposed. For this study price risk is represented as a weighted moving average of the square of the deviation of the expected price from the realized price.

In specifying a general firm's supply response model, the justification to use desired acreage as a proxy for desired output is given. The partial adjustment model is used to relate the unobservable desired acreage to the planted acreage.

The general implications of the firm's acreage supply response model are carried to the aggregate level. The aggregation problems resulting from such an approach are illustrated. It is shown that such an approach imposes restrictions in the interpretation and the use of empirical results obtained from such a model. Specifically, it is argued that the aggregate model so specified is just an approximation to the true model, and that it is likely that aggregation bias is introduced. The predictive performance of such a model outside the estimation period is likely to be poor, and it is suggested that such a model will be more useful in studying aggregate structural relationships.

The estimation method of the aggregate acreage supply response model is shown to depend on the assumptions made about the stochastic behavior of the disturbance term. It is shown that, under the assumption of spherical disturbances, ordinary least square methods can be used to obtain consistent parameter estimates. Since the expectation parameter enters the model nonlinearly, a conditional maximum likelihood estimation method which can be used to obtain explicit values of all parameters is presented. Under the assumption that the disturbances are autocorrelated, the use of OLS will result in biased and inconsistent parameter estimates. Under such conditions, a maximum likelihood estimation technique is proposed. Its implementation is described, and it is shown that it is equivalent to using a conditional least squares method. It is shown that if the disturbance terms in a set of acreage supply response equations are contemporaneously correlated, a gain in efficiency is realized if the equations are estimated jointly. Zellner's seemingly unrelated regression method is proposed to estimate such equations.

CHAPTER IV

DATA NEEDS, ANALYSIS, AND DISCUSSION OF RESULTS

A general acreage supply response model was developed in Chapter III. The model is summarized in equation (46). The explanatory variables being considered in the model are relative expected returns per acre, risk on relative returns per acre, relative effective diversion rate per acre, relative effective support rate per acre, and planted acreage lagged one period. The presentation of variables in this form allows the inclusion of all important competing crops, and yet conserves degrees of freedom and minimizes the degree of multicollinearity.

In this chapter, data needs and the construction of the explanatory variables is discussed. Conditional maximum likelihood estimation method is used to empirically specify the models. A discussion of the results and their implications is presented. A procedure for testing the hypotheses specified in Chapter I is presented and the test results are evaluated. The chapter closes by presenting an overall evaluation of the methodology and the empirical results in line with the problem identified in Chapter I.

Data Needs and Variable Construction

The data needed for the explanatory variables are not directly available from published sources; instead, they have to be constructed. The secondary (published) data required, and the construction of each variable, are discussed in this section.

Secondary Data

The secondary data used in this study cover the period 1951 through 1979. The data and their sources are as follows:

i. Acres planted and crop yield data at Crop Reporting District level are obtained from the Oklahoma Department of Agriculture, Oklahoma Agricultural Statistics, Oklahoma Crop and Livestock Reporting Service. Yearly issues, from 1951 to 1979, are used.

ii. Average seasonal prices received by Oklahoma farmers, and index of prices paid for production items--non-farm origin (1967=100) at national level are obtained from USDA, Agricultural Prices, Economics, Statistics, and Cooperative Service, Washington, D. C. Annual summaries are used.

iii. Support price data at state level, and peanut acreage allotment data at national level, are obtained from USDA, Agricultural Statistics, Washington: U. S. Government Printing Office, 1964-1979 issues.

iv. Disposable income data are obtained from U. S. Department of Commerce, Current Business, monthly issues.

Variable Construction

When supply response models are estimated by econometric methods, data limitations, and/or a high degree of multicollinearity among the variables, prevent the inclusion of a large number of variables in the models. Dropping variables from a model, when they are supposed to be there, introduces specification errors. The approach to be followed in this analysis is to combine some of the explanatory variables. Thus, for a given crop, the expected crop prices and yield are combined into one variable--the expected returns per acre weighted by expected returns per acre of the competing crops. The effective support rate and effective diversion rates are also combined in the same manner. For each crop, and in each crop reporting district, the choice of competing crops is based on their distribution in the district and their relative importance in terms of acreage planted. These are presented in Appendix B. Therefore, due to differences in yield among crop reporting districts and/or competing crops being considered, for a given crop the variables are constructed for each crop reporting district. The procedure for constructing each variable is now presented.

<u>Relative Expected Returns Per Acre</u>. First, expected crop prices are obtained by utilizing equation (41). Seasonal average prices received by Oklahoma farmers are each regressed on lagged disposable income and the index of prices paid for production items--non-farm origin. A Markovian economic environment is assumed, so that only one period lag of the exogenous variables is used. The obtained predicted prices are adjusted to account for the influence of support prices in expectation formation as discussed in Chapter III. The adjusted series are the desired proxies for expected crop prices and these are presented in Appendix C. Expected returns per acre for a given crop are obtained by multiplying the expected price with expected yield per acre, where the one period lag of realized yield is used as a proxy for expected yield for period t at period t-1. Using equation (43b) the expected returns per acre for crop i relative to expected returns

per acre of competing crops are obtained. To avoid the problem of simultaneity, one period lagged acreage is used as weights. The constructed relative expected returns per acre data for the six crops in each crop reporting district are presented in Appendix C.

Risk on Relative Returns Per Acre. The desired risk variables are constructed according to equation (23). By substituting relative expected returns and relative realized returns per acre for expected and realized prices, respectively, risk is expressed as the squared deviation of the relative expected returns per acre from realized returns per acre over an appropriately chosen moving period and using chosen weights. For this study, the moving period is three years, and the weights are $\delta_1 = \frac{1}{2}$, $\delta_2 = \frac{1}{3}$, and $\delta_3 = \frac{1}{6}$. The choice of weights and the moving period are ad hoc.

Policy Variables. The initial effort to construct data for effective support and divserion rates at the state level using formulas presented in Chapter III was hampered by lack of published data for the entire period (1951-1979). It is assumed that data for these variables constructed at the national level will reflect reasonably well the program effectiveness at the state level. The data at the national level is obtained from USDA, *Analyzing the Impact of Government Programs on Crop Acreage*, Technical Bulletin No. 1548, Washington: U. S. Government Printing Office, 1967. The data presented therein extends only up to 1974. The data series are extended up to 1979 using the formulas presented in Chapter III. For the purpose at hand, the data are converted into effective support and diversion rates per acre, using the state average yield of the corresponding crops.

Relative effective support and diversion rates per acre are then computed by the same method as relative expected returns per acre. Due to differences between crop reporting districts regarding the competing crops being considered, the combined policy variables are different for each crop reporting district, except in those cases where competing crops are identical.

Analysis and Discussion of Results

The aggregate acreage supply response model presented in Chapter III is nonlinear in the adjustment coefficient. Three estimation methods are proposed—ordinary least squares (OLS), seemingly unrelated regression, and conditional maximum likelihood technique. The OLS parameter estimates will be biased due to the presence of lagged acreage as an explanatory variable, but they will be consistent. The seemingly unrelated regression parameter estimates will be more efficient than the OLS estimates if the disturbance terms in the acreage equations are contemporaneously correlated.

In the initial estimation of the acreage supply response equations, both OLS and seemingly unrelated regression estimation methods were used. In using seemingly unrelated regression, the acreage equations for wheat, sorghum, corn, cotton, and peanuts were estimated jointly by crop reporting district. While the jointly estimated parameters were more efficient than the OLS estimates, the high correlation between the acreage variable and the other variables resulted in unstable coefficients with many wrong signs in both cases. Therefore, both methods are dropped and the conditional maximum likelihood method is used in the final analysis. This method allows moving the lagged acreage variable to the left-hand side and estimating the other parameters conditional on the adjustment coefficient (ω).

The results are presented in Tables III, IV, V, VI, VII, and VIII. The figures in parentheses are the t statistics for testing the hypothesis that the co-responding parameters are equal to zero. An asterisk on the t value implies that the corresponding coefficient is statistically different from zero at the .05 probability level.

Wheat Acreage Supply Response Equations

The estimated wheat acreage supply response equations by crop reporting district are presented in Table III. D1 is a dummy variable added to account for the large price increases experienced during the Russian grain deal. It is assigned a value of one for the period 1973 to 1976 and zero otherwise. A time trend variable is added to account for the general increase in acreage planted on wheat over time. This general upward trend is observed in all crop reporting districts except the Northeast which shows only a minor acreage variation over the entire estimation period.

On the basis of the restrictions identified in Chapter III, coefficients on the relative expected returns and relative effective support rate per acre variables should be positive. Coefficients on the risk and relative effective diversion rate variables should be negative. The empirically specified wheat acreage supply response equations show only 55 percent of coefficients on the relative expected returns variable with the expected sign and none on the risk variable. With regard to the policy variables, 55 percent of the coefficients on the relative effective support rate variable have the expected sign

TABLE III

ACREAGE SUPPLY RESPONSE EQUATIONS FOR WHEAT[1]

Crop Reporting District	Intercept	Relative Expected Returns Per Acre	Risk on Relative Expected Returns Per Acre	Relative Effective Support Rate	Relative Effective Diversion Rate	D1	Time Trend	$\hat{\omega}$	R^2	DW
Panhandle	-286563.1 (1.5937)	505654.9 (1.4148)	2489101.0 (1.3896)	-118341.3 (.4204)	-55136.22 (.7962)	328886.7 (1.2675)	28378.54 (1.0620)	.23	.55	1.57
West Central	-207197.3 (1.6669)	-227781.0 (2.3796)*	127430.7 (2.03004)*	31912.41 (.38706)	-70059.58 (3.3027)*	218905.3 (3.0130)*	20068.82 (5.4457)*	.54	.82	1.82
Southwest	-567338.9 (1.7941)	48936.13 (.1842)	261126.5 (.2128)	-80707.03 (.9331)	-102369.2 (2.9939)*	222775.6 (1.4546)	43297.38 (4.1722)*	.51	.76	1.84
North Central	-440463.1 (1.0747)	-316450.8 (1.7613)	609961.7 (2.6265)*	-140425.5 (.7744)	-91735.03 (2.2828)*	200429.0 (1.3771)	45424.04 (5.9367)*	.48	.83	1.99
Central	-255086.2 (2.9564)*	-81135.99 (1.7551)	142632.3 (3.2223)*	100900.5 (1.5812)	-61399.92 (3.9643)*	154282.1 (2.8052)*	20530.67 (6.9581)*	.47	.86	1.6
Northeast	34911.18 (.4788)	14317.48 (.4890)	5401.034 (.9662)	5920.422 (.1884)	-925.1057 (.3660)	15995.40 (.5086)	1062.292 (.5793)	.56	.11	1.82
South Central	-119580.2 (4.4520)*	16410.89 (1.1655)	50137.16 (2.9114)*	32091.00 (1.3790)	-11200.85 (4.2386)*	53224.21 (3.8362)*	3688.752 (5.2802)*	.56	.87	2.28
East Central	-13709.65 (1.2587)	920.5524 (.1307)	45979.62 (2.9649)*	9263.919 (.7325)	-3572.441 (2.0661)	3971.541 (.7028)	690.6213 (2.1836)*	.44	.39	1.76
Southeast	5454.581 (2.1267)*	-362.6990 (.6847)	651.3975 (1.7548)	-441.8704 (.5002)	-173.1597 (1.5042)	5042.303 (5.8098)*	-72.9993 (1.2320)	.55	.77	2.59

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[1] The figures in parentheses are the t values. An asterisk on the t value implies that the associated coefficient is statistically different from zero at .05 probability level. R^2 is the coefficient of multiple correlation and DW is the Durbin-Watson statistic.

and all the coefficients on the relative effective diversion rate variable have the expected sign. All the coefficients on the dummy variable (D1) are positive, implying that the aggregate acreage planted on wheat in each district was positively responsive to the large price increase in the period 1973 to 1976.

The percent of the total variation in aggregate acreage planted which is accounted for by the variables in the models ranges from 11 percent in the Northeast to 87 percent in the South Central. The low R^2 (11 percent) for the Northeast was expected due to very minor variation in acreage planted to wheat in this district over the entire estimation period.

Corn Acreage Supply Response Equations

The estimated corn acreage supply response equations are presented in Table IV. Two variables which were not specified in Chapter III have been added. D1 is a dummy variable identical to that in the wheat equations which is added to account for the influence of the large price increase during the Russian grain deal on acreage planted to corn. Preliminary evaluation of the acreage data by graphical methods showed that, on average, all crop reporting districts had large increases in acreage planted to corn between 1951 and 1959, which declined up to 1965, and then remained essentially constant over the rest of the estimation period. Panhandle crop reporting district has shown an opposite trend--large increases in acreage planted are observed in the period 1965 to 1979 with minor variation, this being explained by increased use of irrigation. It is recalled that during the Korean War acreage restrictions on corn were removed, and this partly explains the

TABLE IV

ACREAGE SUPPLY RESPONSE EQUATIONS FOR CORN[1]

Crop Reporting District	Intercept	Relative Expected Returns Per Acre	Risk on Relative Expected Returns Per Acre	Relative Effective Support Rate	Relative Effective Diversion Rate	D1	D2	$\hat{\omega}$	R^2	DW
Panhandle	-4743.96 (1.3917)	-142063.4 (1.2927)	1974083.0 (3.1939)*	358210.2 (.8432)	127815.8 (.9229)	371268.4 (1.1688)	299988.4 (.8764)	.01	.67	1.95
West Central	228.7056 (.2683)	3945.131 (3.5311)*	-1946.063 (2.1214)	3687.842 (2.5870)*	937.4448 (1.2836)	-4966.008 (5.6309)*	-3491.356 (3.4623)*	.60	.69	1.95
Southwest	4570.838 (4.0441)*	4210.802 (5.4589)*	-2923.825 (3.8743)*	3628.771 (3.7917)*	1652.988 (2.8010)*	-10399.92 (14.8633)*	-2458.877 (2.9053)*	.92	.92	1.95
North Central	3442.522 (2.7427)*	4279.917 (2.3768)*	427.2749 (.1921)	2436.286 (1.0375)	356.7182 (.3855)	-9813.446 (5.9575)*	-5914.867 (2.1254)*	.54	.79	2.18
Central	2722.235 (1.1947)	23563.10 (7.9402)*	35688.61 (7.0478)*	37.5929 (.0083)	3170.057 (1.4981)	-19792.28 (5.4866)*	-9538.97 (3.1473)*	.45	.95	2.17
South Central	19739.88 (4.8864)*	3910.212 (.2913)	124407.5 (1.4924)	-27581.09 (1.4785)	713.7805 (.7869)	-33848.61 (7.9651)*	-3349.383 (.7397)	.41	.81	2.62
Northeast	31551.55 (.9154)	15012.40 (.3043)	-158233.5 (1.4177)	-2900.666 (.0865)	-1484.823 (.1485)	-82396.25 (2.1363)*	-13554.56 (.5693)	.31	.32	2.71
East Central	23994.19 (2.9441)*	45000.08 (1.5539)	-35471.20 (.5064)	-27154.44 (1.3695)	1170.250 (1.2049)	-42191.72 (7.4087)*	-2386.299 (.4415)	.54	.79	2.03
Southeast	7128.726 (3.1769)*	1884.863 (.2660)	154809.6 (1.9753)	-8562.043 (.9705)	85.9988 (.1630)	-11394.96 (4.7708)*	-3578.158 (1.2177)	.51	.65	2.58

[1] The figures in parentheses are the t values. An asterisk on the t value implies that the associated coefficient is statistically different from zero at .05 probability level. R^2 is the coefficient of multiple correlation and DW is the Durbin-Watson statistic.

high corn acreages in the fifties. The dummy variable D2 is added to account for this large increase in acreage planted to corn. It is assigned a value of zero for the period 1951 to 1959 and a value of one for the period of 1960 to 1979.

The results show that 89 percent of the coefficients on the relative expected returns per acre variable have the expected sign, while 44 percent of the coefficients on the risk variable have the anticipated sign. With regard to the policy variables, 55 percent of the coefficients on the relative effective support rate variable carry the expected sign, while only one coefficient on the relative effective diversion rate variable carries the expected sign. The signs on the dummy variables correctly reflect the pattern of acreage planted in the respective periods. The percent of total variation in aggregate acreage planted, which is explained by the included explanatory variables, ranged from 32 percent in the Northeast to 95 percent in the Central district.

Sorghum Acreage Supply Response Equations

The results of the estimated sorghum acreage supply response equations are presented in Table V. D1 is the same variable as specified for wheat and corn. D5 is a dummy variable added to account for the observed decline in acreage planted in the period 1954 through 1969. It is assugned a value of one within this period, and zero otherwise.

The results show that 78 percent of the coefficients on the relative expected returns per acre variable carry the expected sign while 33 percent of the risk coefficients carry the expected signs.

TABLE V

ACREAGE SUPPLY RESPONSE EQUATIONS FOR SORGHUM[1]

Crop Reporting District	Intercept	Relative Expected Returns Per Acre	Risk on Relative Expected Returns Per Acre	Relative Effective Support Rate	Relative Effective Diversion Rate	D5	D1	$\hat{\omega}$	R^2	DW
Panhandle	287543.9 (5.3806)*	48147.17 (1.1812)	166322.8 (3.4762)*	-113189.14 (1.8176)	-6308.8790 (.7964)	29707.94 (1.0100)	90290.64 (1.8843)	.87	.61	1.95
West Central	32156.7 (.5573)	-53822.98 (.6235)	16876.53 (.2047)	118363.3 (1.6169)	-9071.7630 (.8850)	51061.84 (2.3828)*	-32256.79 (.8123)	.50	.69	2.42
Southwest	56760.38 (1.8006)	10580.52 (.4356)	3872.657 (.1308)	729605.9 (2.9050)*	4831.524 (2.0927)	-25259.71 (2.3422)	914.5986 (.0573)	.99	.69	2.30
North Central	-26405.96 (.8306)	96639.23 (1.3677)	606393.1 (1.8158)	26775.47 (1.5093)	1549.331 (2.1911)	-12326.41 (1.4466)	15527.58 (.5455)	.40	.60	2.67
Central	4747.138 (.2198)	207215.4 (2.6984)*	-227955.0 (1.4106)	23107.65 (.05004)	-1233.394 (.2659)	-68997.0 (2.4142)*	161785.0 (3.6886)*	.35	.45	2.06
South Central	64406.82 (9.5174)*	-75251.42 (4.7411)*	126665.4 (2.6687)*	-14503.65 (.9105)	-8214.539 (2.8431)*	-6483.91 (1.1599)	4616.82 (.6788)	.63	.71	2.19
Northeast	69529.20 (1.8244)	44774.15 (.6173)	-26053.7 (.6443)	13967.31 (.8697)	1485.265 (.8753)	4011.656 (.3825)	-13623.0 (1.4985)	.99	.45	2.90
East Central	20397.68 (2.1046)	35620.64 (1.7364)	-17163.06 (.1911)	1326.256 (.1889)	979.9008 (.6167)	2881.264 (.9673)	1339.97 (.3791)	.99	.25	2.05
Southeast	2766.373 (1.3119)	198.9616 (.0744)	8943.212 (2.7266)*	-513.2622 (.3620)	-371.0374 (1.4787)	3263.106 (3.3857)*	-231.5884 (.1931)	.76	.73	2.14

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[1] The figures in parentheses are the t values. An asterisk on the t value implies that the associated coefficient is statistically different from zero at .05 probability level. R^2 is the coefficient of multiple correlation and DW is the Durbin-Watson statistic.

The percent of coefficients on the relative effective support and relative diversion rate variables with expected signs are 66 percent and 55 percent, respectively. The percent of the variation in aggregate acreage planted, which is explained by the included variables, ranges from 25 percent in the East Central to 73 percent in the Southeast.

Cotton Acreage Supply Response Equations

The estimated cotton acreage supply response equations are presented in Table VI. Two variables not previously discussed were included to model specific program features. D3 is a dummy variable which is assigned a value of one in periods when marketing quotas applied and zero otherwise. Over the estimation period marketing quotas have been in effect from 1954 to 1970. D4 is a dummy variable included to reflect Soil Bank diversion program. It is assigned a value of one for the period 1956 to 1958 and zero otherwise.

The results show that all coefficients on the relative expected returns per acre and the risk variables carry the expected signs. With regard to the policy variables the percent of the coefficients on the relative effective support and relative effective diversion rates variables with expected signs are 67 and 33, respectively. A priori, the coefficients on the dummy variables are expected to carry a negative sign, but this restriction is not met in all equations. The percent of the total variation in acreage planted, which is explained by the included variables, ranges from 30 percent in the Southwest to 92 percent in the South Central.

TABLE VI

ACREAGE SUPPLY RESPONSE EQUATIONS FOR COTTON[1]

Crop Reporting District	Intercept	Relative Expected Returns Per Acre	Risk on Relative Expected Returns Per Acre	Relative Effective Support Rate	Relative Effective Diversion Rate	D3	D4	$\hat{\omega}$	R^2	DW
Panhandle	52.4684 (.5332)	192.2273 (1.9192)	-45.1007 (.3938)	-49.3413 (.2031)	-57.7836 (1.3737)	-1568.401 (.3773)	-250.2927 (.4911)	.22	.33	2.46
West Central	590.7514 (.0346)	50397.0 (3.7916)*	-11294.55 (1.4989)	40725.86 (3.6597)*	4236.996 (1.6297)	1171.663 (.0903)	20783.97 (.39096)	.57	.60	2.13
Southwest	54081.06 (1.2594)	73248.0 (2.1206)*	-73447.39 (2.4958)*	49376.37 (1.8433)	855.7642 (.06742)	-4035.063 (.1169)	170929.4 (1.7712)	.54	.30	2.00
North Central	-845.3025 (2.3637)*	85.8014 (.1688)	-534.0513 (4.5221)*	1060.246 (3.6037)*	61.1730 (.8901)	1663.016 (4.3542)*	18631.0 (4.3291)*	.53	.78	1.80
Central	4115.450 (1.0329)	23611.70 (4.5703)*	-1695.0630 (.2415)	-115180.50 (2.6570)*	-6840.485 (3.2667)*	5175.14 (.8285)	-22595.14 (2.2134)*	.50	.73	2.60
South Central	-14914.74 (5.4732)	16903.46 (6.5752)*	-4496.968 (1.1860)	11571.99 (2.4599)*	1224.435 (1.9564)	8240.534 (2.3440)*	17835.14 (3.6076)*	.50	.92	2.28
Northeast	-2970.748 (1.3067)	5201.712 (4.2491)*	-4121.467 (3.4106)*	17563.10 (1.3785)	.02272 (.0002)	2171.982 (.9028)	-2299.658 (.7673)	.53	.81	2.15
East Central	-3922.842 (.6138)	4157.661 (.4217)	-9473.157 (.3509)	12111.37 (1.4243)	-30.7957 (.2247)	1635.08 (2.4384)*	29995.26 (1.9879)	.57	.63	2.11
Southeast	1250.045 (.8022)	2280.160 (3.3551)*	-5508.190 (2.9879)*	-350.0503 (.3643)	17.5237 (.1609)	3132.203 (1.8089)	9263.132 (4.7454)*	.69	.78	2.54

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[1] The figures in parentheses are the t values. An asterisk on the t value implies that the associated coefficient is statistically different from zero at .05 probability level. R^2 is the coefficient of multiple correlation and DW is the Durbin-Watson statistic.

Peanuts Acreage Supply Response Equations

Table VII presents results for the estimated acreage supply response equations for peanuts. Due to insignificant acreage planted in the Panhandle, North Central, and Northeast, these districts are excluded. Peanuts have been heavily influenced by marketing quotas. The acreage data for each crop reporting district show only minor variation over the entire estimation period. It was decided to include an acreage allotment variable in order to evaluate its direct influence on peanut planted acreage. A priori, it is expected that acreage allotment will be positively related to acreage planted.

The results show that all the coefficients on the relative expected returns per acre variable carry the expected sign, while 67 percent of the risk coefficients carry the expected sign. The coefficients on the relative effective support rate and acreage allotment variables each carry only one unexpected sign. In general, the percent of the observed variation in planted acreage, which is explained by the included variables, is low. It ranges from 38 percent in the Southwest to 63 percent in the Central district. The low explanatory power is consistent with the low acreage variation over the estimation period.

Soybean Acreage Supply Response Equations

The estimated equations for soybean acreage supply response are presented in Table VIII. The data used for the analysis covers the period 1963 through 1979. Data on planted acreage for earlier years was not available. The results show the percent of coefficients on relative expected returns per acre, risk, and relative effective support rate variables with expected signs are 78, 55, and 67 percent,

TABLE VII

ACREAGE SUPPLY RESPONSE EQUATIONS FOR PEANUTS[1]

Crop Reporting District	Intercept	Relative Expected Returns Per Acre	Risk on Relative Expected Returns Per Acre	Relative Effective Support Rate	Acreage Allotment	$\hat{\omega}$	R^2	DW
West Central	-2426.510 (1.4549)	38.2831 (1.3232)	23.8080 (1.2478)	46.5764 (3.4020)*	2.6268 (2.0628)	.77	.42	1.03
Southwest	39807.86 (2.5606)*	240.13 (1.1224)	-331.1836 (1.7716)	11.7826 (.1057)	-4.5215 (.4816)	.99	.38	1.11
Central	-77635.78 (3.9487)*	618.2484 (1.2465)	35.5096 (.0624)	-127.2266 (.6531)	68.2475 (4.7830)*	.83	.63	1.75
South Central	-68894.63 (2.5621)*	365.3619 (.4108)	-586.2538 (.5559)	349.5417 (.8536)	68.8544 (4.1335)*	.98	.43	1.57
East Central	-38930.83 (2.3818)*	110.8029 (.2424)	-450.0772 (1.4472)	220.7618 (.9515)	40.95532 (3.6921)*	.89	.39	1.62
Southeast	-30014.59 (2.8595)*	4040.833 (2.0545)	-1381.525 (.7852)	924.3627 (1.3871)	133.6062 (2.7081)*	.13	.62	1.93

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[1] The figures in parentheses are the t values. An asterisk on the t value implies that the associated coefficient is statistically different from zero at .05 probability level. R^2 is the coefficient of multiple correlation and DW is the Durbin-Watson statistic.

TABLE VIII

ACREAGE SUPPLY RESPONSE EQUATIONS FOR SOYBEANS[1]

Crop Reporting District	Intercept	Relative Expected Returns Per Acre	Risk on Relative Expected Returns Per Acre	Relative Effective Support Rate		R^2	DW
Panhandle	92.999 (1.4754)	282.654 (2.1557)	-962.2736 (1.9424)	36.9530 (.6326)	.89	.47	1.78
West Central	-1142.035 (4.1571)*	362.3531 (1.6897)	-1659.355 (2.1626)	740.5422 (8.4272)*	.99	.87	1.12
Southwest	1187.672 (3.2453)*	-331.5219 (.9483)	1229.130 (.9293)	52.3387 (.3155)	.99	.13	1.78
North Central	1013.988 (1.3307)	2201.029 (3.8018)*	-1564.187 (1.1679)	562.5856 (1.3864)	.86	.60	2.77
Central	17654.74 (3.6329)*	47884.67 (5.3112)*	87951.46 (2.5722)*	3558.656 (1.1021)	.38	.85	2.33
South Central	7966.948 (3.8916)*	-1813.729 (.5285)	-26045.21 (1.7673)	-103934.7 (2.0259)	.41	.40	1.71
Northeast	60624.13 (4.0106)*	30254.58 (1.7760)	-225882.8 (2.2996)*	6671.223 (.8882)	.72	.31	1.02
East Central	19521.01 (2.1689)	8237.540 (.5038)	54308.35 (.5391)	38877.71 (1.8102)	.65	.28	2.60
Southeast	16135.36 (3.8996)*	6489.279 (.8300)	45134.38 (1.1389)	-35683.05 (1.6081)	.60	.68	1.25

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[1] The figures in parentheses are the t values. An asterisk on the t value implies that the associated coefficient is statistically different from zero at .05 probability level. R^2 is the coefficient of multiple correlation and DW is the Durbin-Watson statistic.

respectively. The percent of observed variation in planted acreage which is explained by the included variables varies from 13 percent in the Southwest to 87 percent in the West Central.

Short and Long Run Relative Returns Elasticities

In order to evaluate the responsiveness of planted acreage to changes in relative returns per acre, short and long run elasticities are computed for the six crops by crop reporting district. These are presented in Table IX. Recall from Chapter III that the estimated acreage supply response equations are of the following form:

$$AC_t(\hat{\omega}) = \hat{\beta}_0(\hat{\omega}) + \hat{\beta}_1 X_{t1}(\hat{\omega}) + \ldots + V_t^*$$

where $AC_t(\hat{\omega}) = AC_t - (1 - \hat{\omega})AC_{t-1}$ and

$$X_{t1}(\hat{\omega}) = \hat{\omega}X_{t1}.$$

Therefore, if $X_{t1}(\hat{\omega})$ is assumed to be the relative expected returns variable, the short run elasticity estimate at the mean is

$$\hat{\beta}_1 \hat{\omega} \frac{\overline{X}_1(\hat{\omega})}{\overline{AC}(\hat{\omega})}$$

and the long run elasticity estimate at the mean is

$$\hat{\beta}_1 \frac{\overline{X}_1(\hat{\omega})}{\overline{AC}(\hat{\omega})}$$

The results in Table XI show that, with the exception of the short run elasticity for soybeans in the Panhandle and Central regions, all other short run elasticities for all crops are less than one. That is, a one percent change in relative returns per acre leads to less than one percent change in acreage planted. This observation conforms to

TABLE IX

LONG AND SHORT RUN RELATIVE RETURNS ELASTICITIES[1]

Crop Reporting District	Wheat	Corn	Sorghum	Peanuts	Soybeans	Cotton	
Panhandle	.0690	-.0527	.1232	---	1.0649	.2511	S
	.3000	-.1463	.1416	---	1.1955	1.1412	L
West Central	-.1345	.7100	.1733	.0290	.3533	.3363	S
	.2491	1.1959	.3465	.0377	.3569	.5901	L
Southwest	.0123	.8850	.0772	.0388	-.1849	.1627	S
	.0241	.9619	.0781	.0392	-.1868	.31912	L
North Central	-.1088	.4602	.4613	---	.5058	.0482	S
	-.2266	.8522	1.1523	---	.5581	.0909	L
Central	-.0560	.4777	.6060	.0741	2.5822	.6611	S
	-.1192	1.0615	1.9904	.0892	6.7952	1.3221	L
South Central	.0099	.0514	-.0620	.0173	-.0760	.3715	S
	.0175	.1254	-.0814	.0176	-.1853	.7430	L
Northeast	.0545	.4659	.1193	---	.1932	.7576	S
	.0912	1.5029	.1205	---	.2683	1.4294	L
East Central	.0113	.6233	.4024	.0082	.1000	.1497	S
	.0257	1.1542	.4064	.0092	.1100	.2627	L
Southeast	-.0503	.0723	.0163	.2934	.1299	.5535	S
	-.0914	.1418	.0214	2.2570	.2166	.8022	L

[1] S stands for short run and L for long run.

what was expected a priori--asset fixity, long time lag required to adjust production, and uncertainty are likely to limit the level of acreage adjustment to a given change in relative returns. In the long run, resources can fully be adjusted and hence acreage planted is expected to be more responsive to changes in relative returns per acre.

While all the long run elasticities are consistently larger than the short run elasticities, most of them are less than one. The results seem to suggest that even when sufficient time for adjustment is allowed, acreage planted remains returns inelastic. This observation is contrary to observations made in other supply response studies employing alternative methods to model expectations. For all crops, differences exist between regions with regard to short and long run acreage response to changes in relative returns per acre. Whether significant differences exist among crop reporting districts cannot be evaluated by looking at the elasticity figures. This subject will be addressed in the section testing the hypotheses presented in Chapter I.

Acreage Response to Changing Risk

One of the objectives of this study was to provide quantitative knowledge about the influence of changing risk on acreage supply response for the six crops in Oklahoma. Under the assumption of constant absolute risk aversion behavior, it is shown in Chapter III that an increase in risk holding other factors constant should decrease output. The empirical results are mixed with respect to satisfying this restriction. In the case of wheat, the results indicate that across all crop reporting districts acreage planted to wheat increases as risk increases, holding other factors constant. In the case of cotton, this restriction is satisfied across all crop reporting districts. For the other crops, the restriction is satisfied in some crop reporting districts but not in others. It is suspected that the chosen moving period and weights are not uniformly applicable to all six crops and to all crop reporting districts. Further investigation will be required before a definite conclusion can be reached.

A priori, it is expected that those crops strongly influenced by government programs will not show significant response to changing risk. Among the crops under study, soybeans are least influenced by government programs, while peanuts and cotton are the most controlled crops. If the signs are ignored, and the results evaluated only on the basis of statistical significance, the percent of risk coefficients which are statistically significant from zero at .05 probability level are as follows: wheat, 55 percent; corn, 33 percent; sorghum, 33 percent; cotton, 44 percent; peanuts, zero percent; and soybeans, 22 percent. The results show that, while peanuts conform to a priori expectation, results for the other crops are not conclusive. It should be remembered that all crops are covered by some form of price guarantee (price supports) which minimizes the influence of market price instability on production decisions.

Hypotheses Tests

In Chapter I it was asserted that for a given crop different parts of the state will show variation in adjusting to a change of a given causative variable. On this basis three hypotheses were proposed to evaluate the validity of the assertion. These hypotheses are restated below.

i. For a given crop, all crop reporting districts show identical supply response relationships. That is, there is no difference in structure among crop reporting districts. Failure to reject the null hypothesis would imply that as far as policy prescription is concerned all crop reporting districts will show similar response. With regard to empirical specification of acreage supply response models, the data for all crop reporting can be combined and estimate only one equation.

ii. For a given crop, acreage supply changes for a given change in relative expected price or returns are identical among crop reporting districts.

iii. For a given crop, acreage supply changes, for a given change in risk are identical among crop reporting districts.

In order to test the above hypotheses, a model which combines the data for all crop reporting districts and which incorporates dummy variables and interaction terms to allow for differences in intercepts and slopes among crop reporting districts is estimated. This will be referred to as the full model and it assumes the following form:

$$\underset{\sim}{AC}{}_i^{*} = X_{oi}A_{oi} + D\underset{\sim}{\beta}_{1i} + X_i\underset{\sim}{A}_i + D|\underline{\bar{X}}|X_i\underset{\sim}{\beta}_2 + \underset{\sim}{V}_i \tag{70}$$

where D is an 8T x 8 matrix of dummy variables,

D_1 (1, 2, ..., 8) is assigned a value of 1 if it represents district 1 and zero otherwise. The dummy variable for the ninth district is dropped.

$D|\underline{\bar{X}}|X_i$ is an 8T x 8k matrix of interaction terms. X_i is a T x K_i matrix of explanatory variables for crop i.

To test for structural stability is equivalent to testing the null hypothesis that $\beta_1 = \beta_2, \ldots, = \beta_{8(1 + K_i)} = 0$. That is, the coefficients on the intercept dummies and interaction terms are jointly equal to zero.

Equation (60) is estimated by methods discussed in Chapter III and the error sum of squares obtained. A variant of equation (60) with all the dummy variables and interaction terms set to zero is similarly estimated and the error sum of squares obtained. The desired test statistic for structural stability test is:

$$F = \frac{(ESS_{reduced} - ESS_{full})/\text{number of restrictions}}{ESS_{full}/8T - (1 + K + 8(1 + K))}$$

where ESS is the error sum of squares.
Reduced models for testing the other hypothesis are obtained by successively setting to zero the coefficients on the interaction terms found between the dummy variables and the returns and risk variables. The desired test statistics are then obtained as above.

The test statistics for testing the three hypotheses are presented in Table X.

The results show that the hypothesis that the structure is identical across the crop reporting districts is rejected at .05 probability level in the case of wheat, peanuts, soybeans, and cotton. The implications for these observations are: (1) differences exist among crop reporting districts for these crops to justify estimating their acreage supply response functions separately, and (2) further investigation as to the nature of these differences is needed to see if they can be taken advantage of in policy prescription. The hypothesis that, for a given crop, a change in relative expected returns has identical effect on acreage response across crop reporting districts is rejected at .05 probability level in the case of corn and

TABLE X

F-TEST STATISTICS FOR TESTING FOR STRUCTURAL STABILITY, IDENTICAL RETURNS, AND RISK COEFFICIENTS ACROSS CROP REPORTING DISTRICTS[1]

Crop	Structural Stability	Identical Returns Coefficients Across Crop Reporting Districts	Identical Risk Coefficients Across Crop Reporting Districts
Wheat	2.4783* (26,114)	.8568 (8,114)	.2296 (8,114)
Corn	1.0904 (56,128)	4.3095* (8,128)	.5782 (8,128)
Sorghum	1.3292* (56,153)	1.6265 (8,153)	.5327 (8,153)
Peanuts	4.6992* (30,73)	3.0104* (5,73)	4.5359* (5,73)
Soybeans	1.8958* (40,144)	1.6950 (8,144)	1.8323 (8,144)
Cotton	1.6363* (56,110)	.8961 (8,110)	.1210 (8,110)

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[1] The asterisk on the test statistic implies that the hypothesis is rejected at .05 probability level. The figures in parentheses are degrees of freedom.

peanuts, but the hypothesis is not rejected in the case of wheat, cotton, soybeans, and sorghum. On the basis of this test, any policy prescriptions which involve some form of price incentives can probably be more cost effective if the differences as suggested by this test are taken into account. For example, the elasticities presented in Table IX can be used to work out the desired differentials. In the case of response to risk, the hypothesis is rejected at .05 probability level for peanuts only.

Chapter Summary

In this chapter, the acreage supply response model developed in Chapter III is empirically specified. The restrictions derived from comparative static results and the hypothesis presented in Chapter I are tested. The empirical results are intended to validate the model developed in Chapter III in the framework of the problem posed in Chapter I. The results are not summarized under the headings Structural Relationships, Elasticity Results, and Hypotheses Test Results.

Structural Relationships

The major objective of this study was to study supply response relationships for wheat, corn, sorghum, cotton, peanuts, and soybeans. The theory of the firm is used to develop the general supply function and determine testable restrictions which can be imposed on the model. It is shown in Chapter III that supply is positively related to price but negatively related to risk. When the model is expanded to include policy variables, it is shown that supply is an increasing function of effective support rate but a decreasing function of effective diversion rate. In the empirical specification of the models these variables are modified to relative expected returns per acre, risk on relative returns per acre, relative effective support, and relative effective diversion rates per acre. The same restrictions as implied by the original variables are expected to hold.

The results show that, for the relative expected returns per acre variable, the percent of coefficients with expected signs are 55 percent for wheat, 89 percent for corn, 78 percent for sorghum, 100 percent for cotton, 100 percent for peanuts, and 78 percent for soybeans. As regards the risk variable, the percent of coefficients with expected signs are zero percent for wheat, 44 percent for corn, 33 percent for sorghum, 100 percent for cotton, 63 percent for peanuts, and 55 percent for soybeans. The results show that, for a given crop, the restriction on relative expected returns per acre variable is satisfied by more equations than the restriction on the risk variable. In addition, less variation between crops is observed in satisfying the restriction on relative expected returns per acre variable than on the risk variable.

Since the restrictions were not uniformly satisfied by all crops, across all crop reporting districts, the following alternatives were attempted:

i. Two alternative sets of weights were used to construct risk variables. The first set is $\delta_1 = 1$, $\delta_2 = 0$, and $\delta_3 = 0$ and the second set is $\delta_1 = .75$, $\delta_2 = .25$, and $\delta_3 = 0$. In both cases the supply response models were estimated by the maximum likelihood methods. The empirical results (not reported) obtained showed no improvement as far as satisfying the restrictions specified by economic theory.

ii. The procedures for modelling expectations and risk developed by Just (1974) were used. The same method for combining variables was maintained. The supply response models were empirically specified using the maximum likelihood procedure presented by Just. The empirical results (not reported) did not show any improvement in satisfying the restrictions specified by economic theory.

These observations seem to suggest that the apparent deviations of some of the results from expectations are not caused by the procedures used to model expectations and risk.

The observed variation within and between crops reporting districts in satisfying the restrictions and in statistical fits, can be attributed to a number of possible factors. These are presented below, although none can be identified as a definite cause without further investigation.

1. For a given crop, different crop reporting districts may have other unique factors influencing acreage supply response. When the same set of explanatory variables is used across all crop reporting districts, their performance with respect to explanatory power should be expected to differ.
2. In this study, no distinction is made between irrigated and non-irrigated acreage. Since gross returns per acre rather than net returns per acre are utilized to construct the variables, combining the variables may have altered the relationship between acreage planted and the variable being weighted. It is important to note that production costs differ between crops, and for a given crop, difference in costs exists between irrigated and non-irrigated acreage. Since it is likely that production decisions are based on either

relative price or net returns changes, the use of gross returns can distort the relationships. Data limitations on cost of production by crops prevented the use of net returns in the analysis.

3. The presence of outliers in the data used in the analysis can also distort the results. Without prior knowledge it is impossible to identify those outliers attributable to measurement errors from those caused by specific phenomena. Mechanical adjustment of the data, addition of dummy variables which cannot be given a useful interpretation, are unacceptable. The same applies to dropping such observations. In this analysis some observations subjectively considered to be too extremely out of range are excluded. It is acknowledged, however, dropping such observation can lead to errors if specific economic or noneconomic factors are responsible, rather than measurement errors.

Elasticity Estimates

The short run elasticity estimates are all less than one in absolute value for most crop reporting districts. This implies that there is a limited response of acreage planted to changes in relative returns per acre in the short run. This observation conforms to theoretical expectations. High costs of adjustment, asset fixity, and a long lag from one production period to another limit the degree of flexibility in acreage planted in the short run.

A priori, given sufficient time for production to be completed and resources to adjust, it is expected that acreage planted will be more responsive to changes in relative returns. While all the long run returns elasticities are consistently higher than the short run elasticities, most of them are less than one.

Hypotheses Test Results

The estimation of acreage supply response functions at crop reporting district level is justified on two grounds. First that a high level of aggregation tends to diffuse the appearance of a competitive relation between crops. Disaggregating the state into more homogeneous zones will allow the choice of relevant competing crops to consider. Secondly, if, for a given crop, differences exist between districts in adjusting the supply for a change of a given causative variable, cost effectiveness of public programs can be improved if these differences are taken into account. Three hypotheses were presented in Chapter I to test for differences among crop reporting districts.

The hypothesis that, for a given crop, the same supply relationships (same structure) hold across all the crop reporting districts is rejected at .05 probability level in the case of wheat, peanuts, soybeans, and cotton. For these crops, it is justifiable to estimate acreage supply response functions at crop reporting district level.

The hypothesis that, for a given crop, all crop reporting districts show the same response to a given change in the relative expected returns per acre is rejected at .05 probability level in the case of corn and peanuts. For these crops, the results suggest that for those public programs involving some form of price incentive, a given program goal can be attained at a lower cost if these differences are taken into account, holding other factors constant.

With regard to the risk variable, the hypothesis that response to changing risk is the same across crop reporting districts is rejected only in the case of peanuts.

CHAPTER V

SUMMARY AND CONCLUSIONS

The main objective of this study is to analyze supply response relationships for wheat, corn, sorghum, peanuts, and soybeans in Oklahoma. In this study, it is shown how the rational expectations hypothesis can be used as an alternative to the ad hoc models of expectation formation to empirically specify producers' price expectation formation. The study provides preliminary quantitative knowledge on the influence of changing risk on acreage supply response for the above crops. Structural stability across the state is evaluated on the basis of acreage supply response functions estimated at crop reporting district level.

Summary

The aggregate supply response model used is developed from the theory of a multiproduct firm facing product price uncertainty. For a given product, supply is shown to be a function of expected product prices, input prices, and risk (variance). Testable restrictions are obtained from comparative static results. It is shown that supply of a given product is an increasing function of expected price, and a non-increasing function of price risk. The supply function is modified to incorporate policy variables and expected crop yields.

Since realized output can deviate substantially from planned output desired acreage is used as a proxy for planned output. A linear supply response model with desired acreage as the decision variable is assumed. Using the partial adjustment model the desired acreage is expressed in terms of observable planted acreage. The adjustment coefficient enters the model non linearly except on the lagged acreage variable.

Specification of the Explanatory Variables

The rational expectations hypothesis is used as an alternative to the ad hoc models in modelling producers' price expectations. Two methods which conform to the rational expectations hypothesis are presented for empirical specification of expectations. The regression approach assumes that a system of interest on which expectation formation is based is fully specified. The realized product price is regressed on the lagged values of the exogenous variables, and the predicted price is used as a proxy for the expected price for period t at period t-1. In the presence of a large number of exogenous variables, and if more than one lag needs to be considered, data limitations will be a problem. In this analysis, a simple supply-demand model in which the market clears in one period is used to construct proxies for expected product prices. The exogenous variables involved are disposable income and the index of prices paid for production items—non-farm origin. By assuming a Markovian economic environment, only a one period lag of the exogenous variables is required. The second approach for constructing rational expectations is the extrapolative predictor approach. This approach uses only past realized values of the expectation variable. This method requires the identification of the stochastic process generating the realized values of the expected variable. By applying the Box-Jenkins methods, an adequate model can be identified from the general class of ARIMA models. The expectation so constructed in only weakly rational since it uses only a subset of all the relevant information for expectation formation. This approach is not empirically used in this study.

The major policy variables used in the acreage supply response model are effective support rates and effective diversion rates. These variables combine both program payments and any restriction required to receive program payments. It is shown that effective support rate has a positive effect on acreage planted while effective diversion rate has a negative effect on acreage planted.

The large number of inputs used in the production process makes direct use of input prices in the model impractical due to data limitations. It is proposed to use an index of prices paid for production items.

In the presence of more than one competing crop, the number of explanatory variables to consider grows substantially. In order to conserve degrees of freedom and to minimize degrees of multicollinearity, expected product prices are combined with the respective crop yields to obtain expected returns per acre. For a given crop, the expected returns per acre are weighted by expected returns of competing crops. The policy variables are combined in the same manner. The general acreage supply function which is subjected to empirical specification has as explanatory variables the relative expected returns per acre, risk on the relative expected returns per acre, relative effective diversion payment rate, relative effective support rate, and the index of prices paid for production items. Due to the lack of input price indexes which are crop specific, the more general index was chosen, and later dropped due to its poor performance in the preliminary analysis. Therefore, the final version of the model does not include a cost variable.

For each crop, the same set of explanatory variables (using different data) is used for all crop reporting districts. The acreage supply response models are estimated by using a maximum likelihood estimation method.

Evaluation of Results

The evaluation of the empirical results is based on how well the equations satisfy the restrictions specified by theory, and on statistical fit. None of the crops satisfied all the restrictions on the estimated coefficients across all the crop reporting districts. Of particular interest are the coefficients on the relative expected returns per acre variable and the risk variable. With regard to the coefficients on the relative expected returns variable, the percent of coefficients with anticipated signs across crop reporting districts are as follows: wheat, 55 percent; corn, 89 percent; sorghum, 78 percent; cotton, 100 percent; peanuts, 100 percent; and soybeans, 77 percent. The percent of coefficients on the risk variables with correct signs are zero percent for wheat, 44 percent for corn, 33 percent for sorghum, 100 percent for cotton, 67 percent for peanuts, and 55 percent for soybeans. Among the six crops, only cotton shows correct signs on both variables. The risk variable consistently shows lower percent of coefficients with correct signs and shows more variation across crops than the relative expected returns variable. The use of gross returns rather than net returns is a possible cause of the observed deviation of signs from theoretical expectation.

The percent of the observed variation in acreage planted which is explained by the explanatory variables in the models (indicated by R^2) varies widely across crop reporting districts. The ranges are .32 to .92 for cotton, .11 to .87 for wheat, .13 to .85 for soybeans, .38 to .63 for peanuts, .25 to .73 for sorghum, and .32 to .92 for corn. The results suggest that, for some crop reporting districts, there are other important explanatory variables in addition to the ones being considered in the analysis.

The results on the influence of changing risk on acreage supply response are mixed. For peanuts, which is a heavily controlled crop, risk changes have no significant influence on acreage supply response. Cotton, another heavily controllec crop, shows that only in 54 percent of the crop reporting districts risk has no significant influence on supply response. The other crops show wide variation across districts in addition to having many wrong signs.

The elasticity estimates show that, on average, planted acreage is irresponsive to changes in relative returns in both the short and long run. While the long run elasticity estimates conform to theoretical expectations, long run elasticity estimates do not. Further analysis is required before any definitve conclusion can be made regarding the long run elasticity estimates.

Implications of the Hypotheses Test Results

The hypothesis that, for a given crop all crop reporting districts show identical relationships (identical structure) is rejected at .05 probability level in the case of wheat, sorghum, peanuts, soybeans, and cotton. This implies that differences in structure do exist for these crops across crop reporting districts. The implication of this observation is that estimating acreage supply response functions by crop reporting districts is justifiable for these crops. Further investigation as to the nature and magnitude of the differences among crop reporting districts is required in order to determine whether they can be employed in policy implementation.

The hypothesis that, for a given crop, the coefficient on the relative returns variable is the same across crop reporting districts is rejected at .05 probability level in the case of corn and peanuts. By employing the elasticity estimates for each crop reporting district, the differential in policy prescription among the crop reporting districts to achieve a given goal can be determined. The assumption being made is that other factors remain constant which, admittedly, is unrealistic.

Limitations of the Study

The theoretical supply function derived from the theory of the firm has input prices as factors influencing supply. Due to lack of suitable cost data, the influence of changing production costs on acreage supply response is not empirically investigated. The use of relative expected returns can be misleading since a given crop can show a larger increase in gross returns than competing crops, but if net returns are examined, a reverse relationship may be true (due to differences among crops in production costs). Since it is likely that decisions are based on either relative price changes or relative changes in net returns per acre, the use of relative expected gross returns to explain supply response may be misleading unless it is ascertained that the same relationship is maintained between changes in relative expected gross returns and relative expected net returns. Data limitations on cost of production figures did not permit the use of net returns.

In this study, variables are combined to conserve degrees of freedom and to minimize the degree of multicollinearity. While this approach allows the inclusion of all important competing crops in the acreage supply response model, the isolation of the influence of individual competing crops on the acreage supply response of a given crop is not possible. Thus, if the objective is to evaluate the impact of changes in expected returns and/or commodity programs of competing crops on the acreage supply response of the crop of interest, the approach used in this study will not be applicable.

Directions for Future Research

Two methods for constructing proxies for rational expectations were proposed, but their relative performance in supply analysis is not investigated in this study. In addition, the performance of a supply response model with rational expectations, when compared to models employing alternative expectations schemes is not evaluated here. Therefore, future work on supply analysis should be directed in the evaluation of alternative approaches for constructing rational expectations, and the performance of models with rational expectations versus models employing alternative expectations schemes.

The restrictions imposed on the risk coefficient are not uniformly met in this study. The wide variation observed among crops and crop reporting districts necessitates further investigation on modelling the risk variable. The moving probability method used by Traill (1978) can be tried if suitable disaster levels can be determined. These results can then be compared to the resulted obtained in this study.

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APPENDICES

APPENDIX A

DERIVATION OF THE DECISION FUNCTION

Derivation of the decision function.

$$E[U(\pi(\cdot))] = \sum_{i=1}^{m} \mu_i Q_i - \sum_{j=1}^{n} W_j X_j - \frac{b}{2} \sum_{i=1}^{m} \sum_{k=1}^{n} Q_i Q_k \sigma_{ik}, \qquad \sigma_{ik} > 0$$

The assumed utility function of profit is exponential.

$$U(\pi)(\cdot) = - e^{-b\pi} \qquad b > 0$$

Under the assumption that profits are normally distributed with mean μ_π and variance σ_π^2 the expected utility of profit is:

$$E[U(\pi(\cdot))] = \int_{-\infty}^{\infty} e^{-b\pi} \frac{e^{-1/2 \quad \sigma_\pi^2 (\pi - \mu_\pi)^2} d\pi}{(2\nu\sigma_\pi^2)^{1/2}},$$

$$\pi \varepsilon R; \ \sigma_\pi^2 > 0; \ \mu_\pi \varepsilon R$$

$$= \int_{-\infty}^{\infty} \frac{1}{(2\nu\sigma_\pi^2)^{1/2}} \exp - \frac{1}{2} \sigma_\pi^2 [2b\sigma_\pi^2 \pi + (\pi - \mu_\pi)^2] \, d\pi$$

Completing the square on the exponent and rearranging terms we obtain:

$$E[U(\pi(\cdot))] = - \exp^{-[b\mu_\pi - \frac{b^2}{2}\sigma^2]} \int_{-\infty}^{\infty} \frac{1}{(2\nu\sigma^2)^{1/2}} \exp^{-\frac{1}{2}\sigma\pi^2 [\pi - (\mu_\pi - b\sigma_\pi^2)]^2} d\pi$$

$$= - \exp - [b\mu_\pi - \frac{b^2}{2} \sigma_\pi^2]$$

Maximizing $- \exp - [b\mu_\pi - \frac{b^2}{2} \sigma_\pi^2]$ is equivalent to minimizing $-[b\mu_\pi - \frac{b^2}{2} \sigma_\pi^2]$ or equivalently maximizing $-[b\mu_\pi - \frac{b^2}{2} \sigma_\pi^2]$ or $\mu_\pi - \frac{b}{2} \sigma_\pi^2$.

If we also assume that P_i ($i = 1, \ldots, m$) are normally distributed with mean μ_i and variance σ_i^2, then from the result:

$$\pi = \sum_{i=1}^{m} P_iQ_i - \sum_{j=1}^{n} W_jX_j$$

It is easily shown that $E(\pi) \equiv \mu_\pi \equiv \sum_{i=1}^{m} \mu_iQ_i - \sum_{j=1}^{n} W_jX_j$ and Var $(\pi) = \sigma_\pi^2 \equiv$ $\sum_{i=1}^{m} \sum_{k=1}^{m} Q_iQ_k\sigma_{ik}$ from which the result

$E[U(\pi(\cdot))] = \sum_{i=1}^{m} \mu_iQ_i - \sum_{j=1}^{n} W_jX_j - \frac{b}{2} \sum_{i=1}^{m} \sum_{k=1}^{m} Q_iQ_k\sigma_{ik}$ is obtained.

APPENDIX B

COMPETING CROPS FOR EACH CROP BY CROP REPORTING DISTRICT

COMPETING CROPS

Panhandle

Wheat	Sorghum, Corn, and Cotton
Sorghum	Wheat, Corn, and Cotton
Corn	Wheat, Sorghum, and Cotton
Cotton	Sorghum and Corn
Soybeans	Corn and Cotton

North Central

Wheat	Sorghum, Corn, and Cotton
Sorghum	Corn and Wheat
Corn	Wheat, Sorghum, and Cotton
Cotton	Wheat, Sorghum, and Soybeans
Soybeans	Cotton, Sorghum, and Wheat

Central

Wheat	Cotton, Sorghum, and Corn
Sorghum	Cotton, Wheat, Peanuts, and Corn
Corn	Wheat, Sorghum, Peanuts, and Corn
Peanuts	Sorghum, Corn, and Cotton
Cotton	Sorghum, Corn, and Peanuts
Soybeans	Sorghum, Cotton, and Corn

Southwest

Wheat	Cotton, Sorghum, Corn, and Peanuts
Sorghum	Wheat, Corn, Cotton, and Peanuts
Corn	Cotton, Soybeans, Sorghum, and Wheat
Peanuts	Cotton, Corn, Sorghum, and Soybeans

Southwest (continued)

Cotton	Wheat, Sorghum, and Corn
Soybeans	Cotton, Sorghum, Corn, and Peanuts

West Central

Wheat	Sorghum, Cotton, and Corn
Sorghum	Wheat, Corn, and Cotton
Corn	Sorghum, Wheat, and Cotton
Peanuts	Sorghum, Cotton, Corn, and Wheat
Cotton	Wheat, Corn, Sorghum, Peanuts, and Soybeans
Soybeans	Cotton, Sorghum, and Corn

Northeast

Wheat	Sorghum, Corn, and Soybeans
Corn	Sorghum and Soybeans
Sorghum	Soybeans and Corn
Soybeans	Corn and Sorghum
Cotton	Corn, Sorghum, and Soybeans
Peanuts	Corn, Sorghum, and Soybeans

South Central

Wheat	Cotton, Soybeans, Peanuts, Corn, and Sorghum
Sorghum	Cotton, Soybeans, Peanuts, and Corn
Corn	Cotton, Peanuts, and Soybeans
Peanuts	Soybeans, Peanuts, and Cotton
Cotton	Soybeans, Peanuts, Corn, and Sorghum
Soybeans	Cotton, Peanuts, and Corn

Southeast

Wheat	Soybeans and Corn
Sorghum	Soybeans and Corn

Southeast (continued)

Corn	Soybeans and Peanuts
Peanuts	Soybeans and Corn
Cotton	Soybeans and Corn
Soybeans	Peanuts and Corn

East Central

Wheat	Peanuts, Soybeans, Corn, and Cotton
Sorghum	Corn, Soybeans, Peanuts, and Cotton
Corn	Soybeans, Peanuts, and Cotton
Peanuts	Soybeans, Cotton, and Corn
Cotton	Soybeans, Peanuts, and Corn
Soybeans	Peanuts, Cotton, and Corn

APPENDIX C

EXPECTED PRICES AND RELATIVE EXPECTED RETURNS PER ACRE DATA

TABLE XI

EXPECTED CROP PRICES

Year	Wheat $/bushel	Corn $/bushel	Sorghum $/cwt	Peanuts $/lb	Soybeans $/bushel	Cotton $/lb
1951	2.52	1.71	2.40	.1150	2.95	.3594
1952	2.32	1.57	2.28	.1200	2.56	.3430
1953	2.20	1.60	2.43	.1190	2.56	.3080
1954	2.23	1.60	2.28	.1220	2.22	.3158
1955	2.07	1.62	2.03	.1220	2.41	.3170
1956	2.00	1.58	1.97	.1135	2.34	.2934
1957	2.00	1.50	2.02	.1107	2.30	.2881
1958	1.95	1.40	2.04	.1068	2.16	.3123
1959	1.87	1.38	2.05	.1075	2.38	.3040
1960	1.81	1.34	2.01	.1080	2.18	.2897
1961	1.85	1.31	1.96	.1105	2.30	.3304
1962	2.00	1.34	2.00	.1107	2.37	.3247
1963	2.00	1.30	2.00	.1120	2.27	.3247
1964	2.00	1.32	2.00	.1120	2.63	.3250
1965	2.57	1.28	2.00	.1120	2.61	.3335
1966	2.61	1.31	2.05	.1135	2.71	.3042
1967	2.63	1.35	2.14	.1201	2.50	.3178
1968	2.77	1.35	2.14	.1238	2.78	.3249
1969	2.82	1.35	2.14	.1275	2.74	.3498
1970	2.93	1.35	2.14	.1275	2.13	.3705
1971	3.02	1.35	2.21	.1342	2.87	.3500
1972	3.39	1.41	2.39	.1425	3.12	.3585
1973	2.67	1.84	2.71	.1642	4.69	.4152
1974	3.04	2.06	3.18	.1830	4.43	.4077
1975	3.07	2.30	3.56	.1972	5.05	.4661
1976	3.04	2.35	3.69	.2070	5.12	.4739
1977	3.28	2.39	4.07	.2100	5.63	.4780
1978	3.28	2.59	4.01	.2112	6.45	.5074

TABLE XII

RELATIVE EXPECTED CROP RETURNS PER ACRE IN EAST CENTRAL CROP REPORTING DISTRICT

Year	Wheat $/acre	Corn $/acre	Sorghum $/acre	Cotton $/acre	Peanuts $/acre	Soybeans $/acre
1951	--	--	--	--	--	--
1952	--	.6070	.4112	1.3041	1.5797	--
1953	--	.3049	.4909	2.4825	1.4527	--
1954	.6953	.2984	.3529	1.6545	2.2539	--
1955	1.2651	.3315	.2698	2.4697	1.0831	--
1956	.3931	.3527	.2364	1.7376	1.3893	--
1957	.9703	.6128	.5240	1.4847	.9785	--
1958	.3259	.4785	.3918	1.5683	1.1592	--
1959	.5056	.3386	.3660	1.8916	1.3710	--
1960	.5564	.5603	.4817	1.3592	1.2904	--
1961	.6533	.4177	.4754	1.2694	1.7399	--
1962	.6953	.5992	.5031	.9961	1.6435	--
1963	.5351	.4720	.3822	1.1817	1.4235	--
1964	.5771	.3836	.4546	1.9774	1.4383	.4894
1965	.7419	.4075	.3338	1.2888	1.8411	.7797
1966	.6627	.3817	.3573	1.4368	1.5442	.6655
1967	.842	.3489	.4725	.8173	2.4721	.8981
1968	.8289	.4716	.4405	.6514	2.6750	1.2714
1969	.5288	.4479	.4135	1.0169	2.4564	.7727
1970	.7789	.4021	.4001	1.3062	1.8996	.8152
1971	1.2332	.7872	.5560	.7376	2.7159	.9040
1972	1.0103	.5777	.5085	.7214	3.5783	.7909
1973	.9086	.6358	.4977	1.2502	1.1701	1.1543
1974	.4107	.4491	.4096	1.0644	2.3188	.9560
1975	.3494	.5582	.3364	.9434	2.3213	1.1112
1976	.4599	.4156	.5699	1.1324	3.6341	1.0102
1977	.4984	.4181	.5147	1.0966	2.1210	1.0872
1978	.5550	.4946	.4160	.7761	2.9098	1.1824

TABLE XIII

RELATIVE EXPECTED CROP RETURNS PER ACRE IN SOUTH CENTRAL CROP REPORTING DISTRICT

Year	Wheat $/acre	Corn $/acre	Sorghum $/acre	Cotton $/acre	Peanuts $/acre	Soybeans $/acre
1951	--	--	--	--	--	--
1952	--	.7798	.4615	1.7414	1.0541	--
1953	--	.5431	.4173	2.1955	1.3118	--
1954	.6189	.2619	.3153	3.1667	1.7389	--
1955	.8372	.5645	.3383	2.6164	1.1562	--
1956	.3458	.6169	.3195	2.6293	1.3326	--
1957	1.1869	.6244	.7981	1.3386	1.3258	--
1958	.3671	.4705	.4143	2.6260	.94468	--
1959	.4370	.3625	.3217	3.6671	.85026	--
1960	.5818	.5312	.4910	1.9554	1.3752	--
1961	.6353	.4808	.51108	1.9542	1.3113	--
1962	.6675	.6083	.4827	1.7770	1.3383	--
1963	.7235	.7227	.6064	1.3072	1.8325	--
1964	.7283	.4836	.4906	2.1782	1.2288	.7938
1965	.7937	.4993	.4163	1.7825	2.0435	.9177
1966	.8377	.4791	.4938	1.8292	1.4845	.8189
1967	.7018	.4893	.6023	1.0989	2.6345	.9597
1968	.8074	.5752	.5570	.9778	3.0894	1.1574
1969	.6393	.6044	.4533	1.5710	2.2759	.8822
1970	.9410	.5177	.5793	1.3006	2.1448	1.0750
1971	1.1010	.7436	.7196	.9106	3.0795	.8746
1972	.7268	.6553	.5722	1.1338	3.0088	.9204
1973	.7115	.4130	.4440	1.3485	2.9912	1.1884
1974	.6368	.5988	.5962	1.2494	2.6159	.9319
1975	.4823	.5242	.6187	.9813	2.8452	1.2617
1976	.6460	.7769	.8336	.7064	4.2551	1.2312
1977	.5299	.8301	.6983	.9487	2.7770	.9019
1978	.6898	.9085	.5478	1.1271	2.4525	.9562

TABLE XIV

RELATIVE EXPECTED CROP RETURNS PER ACRE IN NORTHEAST CROP REPORTING DISTRICT

Year	Wheat $/acre	Corn $/acre	Sorghum $/acre	Cotton $/acre	Soybeans $/acre
1951	--	--	--	--	--
1952	--	1.7913	.5252	2.1448	--
1953	--	1.2729	.5825	1.9451	--
1954	1.1593	1.3876	.3036	2.6440	--
1955	2.2219	2.0451	.3128	1.4237	--
1956	1.0315	2.2439	.1501	2.3436	--
1957	1.9418	1.4870	.1730	.8197	--
1958	.5576	1.2748	.1471	1.3560	--
1959	.8165	1.5544	.2345	2.0841	--
1960	.7543	1.3524	.2181	1.1528	--
1961	.6889	1.06863	.1893	1.2471	--
1962	.9416	1.2745	.1831	1.5827	--
1963	.8186	1.1795	.1424	1.8455	--
1964	.8697	1.0893	.2446	1.5890	.5878
1965	1.3830	1.3063	.2262	1.8839	.8503
1966	1.1373	1.1788	.2150	1.7652	.5214
1967	1.1627	.5984	.1796	1.6734	.8663
1968	1.1540	1.0444	.1718	1.5584	1.0481
1969	1.2185	1.1614	.2265	--	.9176
1970	1.3292	.9747	.2603	2.1520	.7442
1971	1.7912	1.0469	.2678	1.0418	.8576
1972	1.4020	1.1757	.2450	3.9435	.8466
1973	1.0654	.9217	.2219	2.6463	1.1765
1974	.8566	1.0193	.2439	3.0135	1.0238
1975	.8133	.9861	.2819	0	1.1790
1976	.9241	.9448	.2884	0	1.6065
1977	.9637	.8879	.2914	3.3174	1.1742
1978	.8730	.7665	.3999	1.5486	1.0026

TABLE XV

RELATIVE EXPECTED CROP RETURNS PER ACRE IN WEST CENTRAL CROP REPORTING DISTRICT

Year	Wheat $/acre	Corn $/acre	Sorghum $/acre	Cotton $/acre	Peanuts $/acre	Soybeans $/acre
1951	--	--	--	--	--	--
1952	--	.6439	.4913	2.2328	1.8938	--
1953	--	1.5882	1.7412	7.3279	1.9791	--
1954	.6818	.4797	.7791	2.6600	4.0655	--
1955	1.1582	.5894	.3942	1.9826	2.7936	--
1956	.4386	1.3964	.7836	3.8326	5.9981	--
1957	1.3219	.3533	.5714	1.4582	8.1711	--
1958	.8933	.7931	.6366	2.3684	6.0917	--
1959	1.0509	.6960	.6401	2.0257	3.9993	--
1960	.7256	.8510	.7422	2.4884	3.5486	--
1961	.7481	.6935	.6978	2.4216	4.2883	--
1962	.7881	.7932	.8131	1.7046	5.4545	--
1963	.6877	.9009	.7690	2.1290	5.3028	--
1964	.8694	.6481	.6508	2.0115	5.9424	.8910
1965	.9319	.4754	.6569	1.7242	6.3520	.6878
1966	1.1613	.4989	.5425	1.4308	5.5553	.7536
1967	.9889	.5052	.8106	1.3734	5.2656	.6971
1968	.8161	.6927	.8545	1.9185	6.1961	.9996
1969	.8839	.7169	.7923	1.8025	5.0187	.7085
1970	1.1412	.7541	.6908	1.3816	5.4028	1.0957
1971	1.2282	1.0301	.6179	1.0972	6.8397	.7550
1972	.8558	1.4771	.8457	1.5107	7.1930	1.0609
1973	.9231	1.3561	.6650	1.6517	6.1663	1.0802
1974	.8286	.8331	.8666	1.7087	6.3030	.9940
1975	.7641	1.2316	.9757	1.5638	5.4219	1.5333
1976	.7238	1.5056	1.1473	1.6654	5.9094	1.1158
1977	.8478	1.2565	.9721	1.4851	8.0383	1.1510
1978	.5720	1.1195	1.0921	2.3663	4.5468	.6434

TABLE XVI

RELATIVE EXPECTED CROP RETURNS PER ACRE IN SOUTHWEST CROP REPORTING DISTRICT

Year	Wheat $/acre	Corn $/acre	Sorghum $/acre	Cotton $/acre	Peanuts $/acre	Soybeans $/acre
1951	--	--	--	--	--	--
1952	--	.7773	.4445	1.9100	2.6695	--
1953	1.2843	2.3421	1.7994	4.3310	5.6042	--
1954	.7715	.6162	.7051	2.1268	4.3622	--
1955	.7339	.6071	.4437	1.7235	2.6657	--
1956	.7826	1.3830	.6467	3.5930	5.9166	--
1957	.6358	.8223	.5684	1.8981	4.3335	--
1958	.1380	1.1097	.7072	3.0213	5.5138	--
1959	.4663	.6103	.6151	2.2938	3.4732	--
1960	.9163	1.1561	.8898	2.4010	6.1073	--
1961	.5865	.7091	.6517	2.0886	4.7492	--
1962	.4496	.9084	.7761	2.1633	4.8345	--
1963	.7413	.7403	.8421	1.8113	6.9703	--
1964	.5109	.7432	.8035	1.6619	6.2301	.5764
1965	.5865	.6734	.6897	1.7120	6.1902	.3774
1966	.4197	.4486	.6395	1.1988	4.3266	.4884
1967	.2781	.4172	.9922	1.5038	5.4065	.5486
1968	.3720	.6628	1.0198	1.6516	7.5283	.6133
1969	.3497	.6682	.8254	1.7490	5.5567	.5085
1970	.3440	.8647	.7252	1.3040	4.6338	.6549
1971	.2052	.8644	.5706	.9224	5.2795	.5451
1972	.3904	1.6240	1.1307	1.7621	9.1659	.6751
1973	.8462	1.4312	.6927	1.7955	7.7119	.8714
1974	.6810	.8188	.8598	1.9617	7.1421	.8662
1975	.6781	1.3377	1.0410	1.7421	7.0721	1.1128
1976	.5559	1.4716	1.2421	1.6435	7.7320	.8731
1977	.4797	1.5261	.9400	1.4785	9.4827	.7024
1978	.3782	1.6452	.8766	2.1559	7.0326	.7112

TABLE XVII

RELATIVE EXPECTED CROP RETURNS PER ACRE IN NORTH CENTRAL CROP REPORTING DISTRICT

Year	Wheat $/acre	Corn $/acre	Sorghum $/acre	Cotton $/acre	Soybeans $/acre
1951	--	--	--	--	--
1952	--	.9432	.6004	2.7209	--
1953	--	2.2732	.4462	14.0637	--
1954	1.0101	0.5155	.4531	2.0739	--
1955	2.2948	.6736	.7242	.7767	--
1956	.5544	1.3819	.4485	3.8738	--
1957	1.8589	.3641	.5670	1.0088	--
1958	1.4796	.8668	.3026	1.1911	--
1959	1.2573	.6961	.7271	1.8466	--
1960	.8792	1.0568	.6121	2.2098	--
1961	1.0741	.9368	.8618	1.1891	--
1962	1.0205	.9003	.7456	1.4628	--
1963	.9565	1.0666	.7918	1.5412	--
1964	.8419	.7817	.8024	2.0930	1.0118
1965	1.4938	.5045	.5670	1.1819	.5626
1966	1.5092	.3991	1.0242	1.1094	.5313
1967	1.2552	.3618	1.5811	1.2462	.5276
1968	1.1068	.7024	1.0524	1.2035	.9409
1969	1.3031	.7600	1.1823	1.1903	.6746
1970	1.3552	.6542	1.3558	1.1037	.7257
1971	1.9985	.5293	1.1217	.7014	.5626
1972	1.5919	1.0174	.9593	.7218	.8430
1973	1.1784	1.5755	.4801	1.2723	1.1531
1974	.9654	1.528	.6570	1.4482	1.1120
1975	.9038	1.3059	.8370	1.1405	1.4304
1976	.9353	1.5507	.9386	1.4056	.9919
1977	1.1673	1.2932	.9657	.6990	1.2338

TABLE XVIII

RELATIVE EXPECTED CROP RETURNS PER ACRE IN CENTRAL CROP REPORTING DISTRICT

Year	Wheat $/acre	Corn $/acre	Sorghum $/acre	Cotton $/acre	Peanuts $/acre	Soybeans $/acre
1951	--	--	--	--	--	--
1952	--	.8926	.3830	2.1770	1.6882	--
1953	--	2.3256	1.7444	1.7122	2.1223	--
1954	.8235	.5130	.5495	2.9893	3.0815	--
1955	1.8719	.5178	.2900	2.9340	1.5889	--
1956	.3966	1.5295	.7096	3.6168	2.1178	--
1957	1.5120	.7082	.5585	1.6812	1.4304	--
1958	.5819	1.3838	.8665	2.6380	1.5342	--
1959	.8360	.8108	.6803	3.2218	1.9624	--
1960	.8277	1.0213	.7324	2.0731	1.7326	--
1961	.7871	.7932	.6856	2.5291	1.7070	--
1962	.8806	.9737	.7413	1.6328	1.9255	--
1963	.7728	1.0691	.8262	1.6025	2.1911	--
1964	.9453	.7904	.6480	2.1276	2.0433	.6066
1965	1.1227	.5406	.5295	1.9946	2.8150	.7653
1966	1.1468	.4546	.4559	2.4163	2.3491	.6406
1967	1.1175	.4643	.5853	1.7411	3.1470	.9277
1968	1.0883	.6764	.6319	1.7353	3.3133	1.0214
1969	.9977	.5706	.6823	1.8580	2.6181	.7978
1970	1.2024	.4892	.5201	2.0886	2.4987	.8435
1971	1.4671	.5902	.5418	1.3542	2.9161	.9544
1972	1.2653	.6784	.5886	1.4139	4.0754	1.0287
1973	1.1026	.8713	.5617	1.7166	3.6185	1.1643
1974	.7705	.9483	.8727	1.5742	3.1651	.9802
1975	.6066	1.1814	.9955	1.5668	3.0239	1.1319
1976	.8844	1.2404	1.0153	.9816	5.3184	1.2886
1977	.7353	1.3013	1.0895	1.1759	3.5174	.9435
1978	.7367	1.1117	.9121	1.3203	3.1734	1.0204

TABLE XIX

RELATIVE EXPECTED CROP RETURNS PER ACRE IN PANHANDLE CROP REPORTING DISTRICT

Year	Wheat $/acre	Corn $/acre	Sorghum $/acre	Cotton $/acre	Soybeans $/acre
1951	--	--	--	--	--
1952	--	.5416	.5487	2.5329	--
1953	--	1.7138	1.9544	7.3814	--
1954	.5094	.3646	.8451	3.9791	--
1955	.6229	.7000	.5570	3.5952	--
1956	.5456	1.7778	.6137	4.0561	--
1957	.6911	.7463	1.1378	1.9346	--
1958	.9051	1.1106	.7377	2.0453	--
1959	1.1577	.8637	.6009	1.7748	--
1960	.6137	.8848	.9136	2.8653	--
1961	.7827	1.2395	.5009	2.7080	--
1962	.8134	1.0945	.8283	1.6994	--
1963	.5043	.9033	1.1142	2.8061	--
1964	.3112	.8997	1.4234	4.5324	--
1965	.6008	.5382	1.1326	2.3635	--
1966	.7686	.5689	1.0063	1.7667	.6713
1967	.6294	.8964	1.6820	1.2261	.9040
1968	.4815	3.6447	1.6888	2.0364	.5962
1969	.4767	3.4282	1.4046	2.5558	.4652
1970	.8509	2.0599	1.0771	1.0931	.7394
1971	.8887	2.3971	1.2377	.6432	1.1397
1972	.9522	3.0097	1.0521	.5430	1.1732
1973	.6716	2.8440	1.0816	1.6208	.7155
1974	.5849	2.6621	1.1755	2.0149	.5945
1975	.3610	5.2644	2.0852	1.9012	1.0286
1976	.5120	3.8738	1.3711	2.1012	.7314
1977	.8052	4.2071	.9434	.9269	--
1978	.6057	3.5181	1.1209	1.6162	.9929

TABLE XX

RELATIVE EXPECTED CROP RETURNS PER ACRE IN SOUTHEAST CROP REPORTING DISTRICT

Year	Wheat $/acre	Corn $/acre	Sorghum $/acre	Cotton $/acre	Peanuts $/acre	Soybeans $/acre
1951	--	--	--	--	--	--
1952	--	.6529	.7414	2.1731	1.5978	--
1953	--	.4230	.6356	3.3725	2.3639	--
1954	1.8724	.2216	.7915	3.8978	4.5129	--
1955	3.5160	.3376	1.3459	3.9322	2.9621	--
1956	.7758	.4449	.4461	2.6926	2.2474	--
1957	1.1408	.6739	.6739	2.6396	1.4839	--
1958	.7338	.6071	.6556	2.3727	1.6471	--
1959	1.2062	.4649	.8190	2.5835	2.1508	--
1960	.8320	.7271	.7036	1.8665	1.3753	--
1961	1.0373	.4495	.7078	2.7767	2.2245	--
1962	1.3665	.4685	.7181	2.8045	2.1344	--
1963	1.8797	.4010	.6175	3.9718	2.4939	--
1964	1.4135	.5742	.5065	4.1161	2.1330	.3378
1965	1.0825	.4118	.5323	2.8378	2.3867	.4910
1966	1.5115	.4842	.8039	2.7921	1.7596	.4852
1967	.9818	.4158	.7265	1.7383	1.9231	.6714
1968	1.0634	.3722	.6176	1.5479	1.6957	.7695
1969	1.0309	.5788	.6209	2.1873	1.7079	.5675
1970	1.4739	.4872	.6276	1.7322	1.2897	.7809
1971	1.2839	.5628	.9568	1.666	1.7550	.7186
1972	1.6097	.3367	.9207	1.8475	2.1802	.7466
1973	.8117	.4651	.5337	1.4672	1.4047	.9449
1974	.7386	.7922	.5589	.90148	1.4470	1.0444
1975	.5709	.5050	.6356	1.1422	1.6349	1.0278
1976	.5869	.4251	.8583	.6182	2.5318	1.5329
1977	.6769	.4072	.9386	1.432	1.3065	1.0301
1978	.7790	.3131	.7048	0	2.1415	3.0312

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