EFFECTS OF GOVERNMENT PROGRAMS ON CORN, SOYBEANS, AND WHEAT PRODUCTION IN THE U.S.

Won W. Koo
and
James R. Lehman

Department of Agricultural Economics
North Dakota Agricultural Experiment Station
North Dakota State University
Fargo, North Dakota 58105

Preface

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Highlights

The main objective of this study was to evaluate the impact of government programs and crop prices on the acreage response of corn, wheat, and soybeans.

The theoretical model used in this study was a combination of Nerlove's partial adjustment model and the finite arithmetic lag distribution with prices. By utilizing Nerlove's model, a dynamic acreage response model for each commodity under study was developed to determine the effect of government programs and crop prices on acreage planted. The finite arithmetic lag model is also used to incorporate the current monthly crop prices in time t in addition to the crop price lagged one year.

The system estimation technique was applied to the corn, soybean, and wheat models to alleviate the problem of inherent correlation among their error terms. The estimation technique used is the three-step Gauss-Newton procedure developed by Wong et al.

Data for the period 1964-1982 were used to estimate acreage response equations. All data used in this study were time series data obtained from various secondary sources. Prices used in each model, including the effective support price and maximum deficiency payment, were deflated by the index of prices paid for all production items (1967 = 100). The feed grain price index was also deflated by the index of prices paid for all production items (1967 = 100).

Methodologically, this study found that the system estimation technique provides asymptotically more efficient parameter estimates of the wheat, corn, and soybean models as compared to the single equation estimation technique.

Most studies in the past utilized only price lagged one time period (P_{t-1}) as the parameter for crop price. However, implementation of the finite arithmetic lag distribution, combining P_{t-1} with the current monthly crop prices, results in more efficient parameter estimates for the corn, wheat, and soybean acreage response models.

This study reveals that all government programs are highly significant in the corn and wheat acreage response models. Corn and wheat producers have been responding actively to government programs during the time periods. All government programs have been effective in controlling production, although producers response to programs is somewhat different for corn and wheat. Wheat producers exhibit a high sensitivity to the expected deficiency payment while corn producers are highly sensitive to the effective support price.

The price elasticity of soybeans is much higher than those of corn and wheat. The reason for this is that corn and wheat acreage responses to crop prices have been tempered by government programs, while soybean acreage response is highly sensitive to crop prices due to the lack of government programs which directly affect soybean acreage planted.

Effects of Government Programs on Corn, Soybeans, and Wheat Production in the U.S.

by

Won W. Koo and James R. Lehman*

A major problem faced by producers throughout the United States agricultural sector is uncertainty which comes mainly from the supply side of commodities in both importing countries and the United States. Other sources of uncertainty include changes in monetary and fiscal policy, and trade restrictions imposed by trading countries.

Because of the uncertainty faced by producers, there has been persistent government intervention in the crop-producing sector of agriculture since World War II. Price supports and various subsidy programs have served, in the past, to reduce the risks farmers face and to lower the costs of farming relative to other types of businesses further than otherwise would have occurred.

Since World War II, government programs for crops have been altered to reflect changing short-run views of economic conditions. In addition, the philosophy characterizing programs was altered somewhat from administration to administration and from Congress to Congress to reflect changing political views of farm problems and their solutions.

A central problem in supply analysis since World War II has been to account for and somehow measure the impact of changing government programs. A major transition in program philosophy occurred in 1964 when program participation changed from mandatory to voluntary. This transition has altered producers' response to programs. An analysis of commodity supply

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*Koo is professor and Lehman is former graduate research assistant, Department of Agricultural Economics, North Dakota State University, Fargo.

response will yield considerable implications for policymakers since much of the past and present farm policy debate centers around the question of how responsive crop output is to program changes. If the impact of government programs on commodity supply response can be estimated, then forecasting and analyzing alternative policies for the affected agricultural products can be improved.

To determine the effect of government programs and commodity prices on commodity supply response, a dynamic model is introduced. The dynamics of agricultural supply was first discussed by Bradford B. Smith (36) in his study of cotton in 1925. John M. Cassels (5) was also among the first economists to recognize the dynamic nature of agricultural supply. His discussions in 1933 recognized both that supply adjustments are not achieved instantaneously and that expansion and contraction of agricultural output are not identically opposite processes.

During the time period of the late 1930s to the mid 1950s there was considerable debate in the political arena concerning policy options and programs to stabilize farm output and prices. The truth as to whether or not agricultural output is virtually unresponsive to price changes has important implications for the impacts of policies and programs proposed during that time. The process of estimating policy and program impacts is essentially a dynamic one, yet the dynamics of the agricultural sector had not been tested empirically at that time.

In a pioneering effort to develop a theory for the dynamics of agricultural supply, Marc Nerlove (32, 33) developed the partial adjustment model which resulted in a distributed lag specification. He employed this distributed lag model to estimate farmers' response to price changes in the production of corn, cotton, and wheat. He argued that when "static models are used to estimate elasticities of demand or supply under conditions in which it takes the decision maker longer than one period to adjust to changed conditions, then statistical relationships among observations on the relevant variables, each of which is taken at the same time, tell us little about the long-run elasticity or any of the short-run elasticities" (33). Nerlove asserted that the distributed lag model provided a solution to this problem.

The concept of distributed lags was not new, although Nerlove's utilization in estimation problems for agricultural supply was new to the field of agricultural economics in 1956. The first to use and discuss the concept of a distributed lag was Irving Fisher (8) in 1925. His approach was to assume a general form for the distribution of lag and estimate the parameters by defining the exact distribution. This approach has been followed by several others, including L. M. Koyck (26), who in 1954 developed a procedure which transformed a geometric lag distribution into a workable hypothesis, and Philip Cagan (4), who in 1956 developed the adaptive expectations model.

Nerlove combined the conceptual aspects of both the adaptive expectation and partial adjustment models so that the desired value of the dependent variable is determined by the expected or desired value of the independent variable. The Nerlove model has become widely used over the past two decades to estimate agricultural supply. A 1977 survey cites 190 studies that have employed this model and several adaptations of it in agricultural supply studies.

Most of these studies done in the past did not recognize inherent correlation among error terms of individual crop models and used a single equation estimation technique in estimating acreage response equations for each crop. If there are inherent correlations among error terms of individual equations to be estimated, a system estimation technique is more efficient than a single equation estimation. However, application of a system estimation technique in estimating supply response has been neglected up to now. Another issue which is virtually ignored in most supply response studies is specification of the price variable. Because of availability of the data, only season average crop prices lagged one year have been used in supply response models. Farmers' planting decisions could be more influenced by recent monthly prices available at planting time than by prices lagged one year. This is especially true for those crops which are planted in spring.

The objective of this study, therefore, is twofold: (1) to reformulate acreage response models for corn, soybeans, and wheat with recognition of the inherent correlation among crops and inclusion of most recent monthly prices available in time t as well as the average yearly lagged crop prices, and (2) to evaluate the impact of government programs and crop prices on the acreage response of corn, soybeans, and wheat. The following section briefly discusses major government programs for the last 35 years from 1948 to 1982. Then, methodology used to estimate acreage responses for the crops and estimation procedure are presented. Empirical results and conclusions then follow.

Review of Major Government Programs

This section reviews major governmental programs related to wheat, corn, and soybeans from 1948 to 1982. Although this review does not include each specific program involved, it does contain those which are important in the development of this study.

The major programs analyzed are acreage allotment, set-aside and average diversion, price and income support, and farmer-owned reserve programs. Each program is presented in a separate section explaining how it operates, its purpose, and the years it was in force.

Acreage Allotment

The national acreage allotment is the number of harvested acres of a commodity, based on estimated average yield, that would provide a supply equal to a normal year's domestic consumption and exports, plus an allowance for reserve. States, counties, and farms are apportioned the national allotment based on past production and some other factors. Compliance with allotments was usually required as a condition for obtaining price supports, but penalties were not imposed for noncompliance unless marketing quotas were in effect.

Each year the Secretary of Agriculture would proclaim allotments for specified crops unless he suspended the program under emergency powers. The main purpose for using this program was to control the output of specific commodities.

Acreage allotments, not accompanied by marketing quotas, were imposed on wheat and corn in 1950 for the first time since World War II. Allotments were discontinued for the 1951-1953 crop years due to the Korean War emergency. Beginning in 1954, allotments were reimposed on both commodities. However, only the wheat allotment was accompanied by marketing quotas. When marketing quotas apply, producers who exceed their allotment are penalized with fines and a reduction in future allotment acres.

From 1954 through 1959, corn acreage allotments without marketing quotas were in effect. Under new legislation in 1959, the authorization for corn acreage allotments was terminated. Instead of using allotments to control output and allocate governmental payments, a feed grain base from historical planting practices was instituted.

Wheat acreage allotments with marketing quotas were in effect from 1954 through 1963. Quotas were voted out in 1964, but the allotment program was continued through the 1970 crop year.

Under the Agricultural Act of 1970, national acreage allotments for wheat were suspended for the 1971-1973 crop years. An allotment for domestic food use only was specified for those years to compute set-aside acreage requirements and marketing certificate payments.

The Agriculture and Consumer Protection Act of 1973 brought about a change in the national acreage allotment program. Wheat acreage allotments were reinstated for the 1974-1977 crop years. However, they did not restrict the wheat acreage a farmer could produce on his land. They were used only to determine payments to a producer in the event they were due.

Another change brought about by the Act of 1973 was that the term *feed grain base* for corn was to no longer be used. Instead the term *allotment* was used so the terminology of the feed grain program coincided with the wheat program. Allotments were reimposed for the 1974-1977 corn crop years and were used solely for determining payments and not for restricting planted acreage.

A second change in terminology came about under the Food and Agriculture Act of 1977. The national acreage allotment was renamed national program acreages for wheat and corn. National program acreages were in effect for the 1978-1982 crop years for both commodities.

Set-Aside and Acreage Diversion

Acreage withdrawn from crop production and devoted to approved conservation practices under production adjustment programs is termed *set-aside*. Program participants have been required to meet set-aside requirements to become eligible for price support loans and program payments.

Acreage diversion also has involved withdrawing acreage from crop production and devoting it to conserving uses for producers to be eligible for price support loans and program payments. Although these programs appear to be similar, a major difference is that the diversion program limited allotment acres while the set-aside program idled acres from total cropland on the farm as a unit (24). The main purpose of both programs, when used, was to reduce the supply of specific commodities by reducing acreage planted.

The acreage diversion program was in effect for the 1961-1970 corn crop years. The amount of land diverted each year was based on a percentage of a farm's base acreage, which was determined from historical planting practices. To induce compliance, an acreage diversion payment was made to farmers for idling this land.

The acreage diversion program for wheat was enacted in 1962. Acreage to be diverted was based on a percentage of a farm's allotment. Payments to farmers were made to induce program compliance. In 1967 and 1968 the program was discontinued to stimulate wheat output. However, the program was reinstated for 1969 and 1970 in order to reduce acreage planted.

Under the Agricultural Act of 1970, marketing quotas, acreage allotments, and base acreages for wheat and corn were suspended and replaced with the set-aside program for the 1971-1973 crop years. Acreage idled for wheat was based on a percentage of the domestic allotment for that year while corn acreage idled was based on a percentage of the farm's base acreage in 1959 and 1960.

Both corn and wheat producers could divert additional acreage in 1972 and 1973 crop years on a voluntary basis. They were eligible for payments on this additional acreage diverted.

Under the Agriculture and Consumer Protection Act of 1973, the corn and wheat set-aside and acreage diversion programs were discontinued for the 1974-1977 crop years.

The Food and Agriculture Act of 1977 reinstated the set-aside program for corn and wheat for the 1978-1979 crop years. Compliance, although on a voluntary basis, was required of producers to be eligible for price support loans and payments. After 1979 the set-aside program was discontinued for the 1980-1982 corn and wheat crop years.

Price and Income Support Program

Commodity loans have been made to farmers by the government to provide floors under market prices. Because of this, loans have served as a market price support program for commodities.

Loans are secured by storing a commodity in an approved facility, either on or off the farm. Loans typically perform several functions: 1) they provide farmers a cash return for the commodity at the support level, 2) they strengthen market prices of the commodity through withdrawal of supplies from the market, especially at harvest, and 3) they tend to even out marketing because farmers who obtain loans on their crop at harvest time can market the crop over the season (7).

The target price concept is an income support program, utilized by the government under the Agriculture and Consumer Protection Act of 1973, which provided farmers with a guaranteed return on the portion of the crop produced on his allotment acres. This guaranteed return is called a deficiency payment. If the national weighted average market price received by farmers is below the target price for the first five months of the marketing year, deficiency payments are made to eligible producers. The payment rate is the difference between the established target price and the higher of the five month weighted national average price received by farmers or the national loan level. A target price was established each year for corn and wheat during 1974-1982 crop years. There was no target price for soybeans during this time.

The primary means of supporting wheat, corn, and soybean prices during the 1948-1962 crop years was nonrecourse loans. In most years loan rates were set at the minimum legal level.

Support of soybean prices by means of nonrecourse loans was continued during the 1963-1974 and 1976-1982 crop years. There was no national loan rate to support soybean prices in 1975.

The loan rate for corn and wheat was lowered slightly in 1963. To make up for the loss in income this reduction could cause, a price support direct payment was offered to participants increasing the level of total support.

This combination of a price support loan with a price support direct payment was continued through the 1970 corn crop year. However, in 1964 the wheat program made some significant changes in the method of supporting prices. The price support payment was eliminated and replaced by a domestic certificate payment and an export certificate payment. These two payments along with a price support loan were continued through the 1970 wheat crop year.

Support of corn prices during the 1971-1973 crop years was accomplished by using a price support loan in combination with a set-aside payment. Wheat prices during the 1971-1973 crop years were supported by a price support loan along with a domestic certificate payment.

Price support loans continued to be a part of the wheat and corn program during the 1974-1982 crop years. However, the corn set-aside payment and wheat domestic certificate payment were discontinued as a price support mechanism.

Farmer-Owned Reserve Program

The most notable innovation in farm policy in the late 1970s was the development and implementation of the farmer-owned reserve program. The farmer-owned reserve (FOR) was designed to stabilize prices and provide increased supply assurance to domestic and foreign customers.

The FOR is, in essence, an extended loan program covering a period of up to three years. In return for placing commodities in the FOR, farmers receive a higher loan rate than the regular price support loan. This loan can be interest free, during the first year, with the possibility of interest in subsequent years being waived. A payment approximating the average cost of storage is also provided by USDA. In return for the higher reserve entry price, interest subsidy, and storage payment, a farmer agrees not to market the grain until the market price reaches a specified level referred to as the release price. At the release price a farmer is free to sell his FOR grain.

The farmer-owned reserve program was developed under the Food and Agriculture Act of 1977. FOR was first implemented during the 1978 crop year for corn and wheat. Its use was continued through the 1979-1982 crop years for both commodities. FOR was not used as a price support mechanism for soybeans during this time period.

Summary

The wheat and corn industry, since 1948, has experienced marked changes in governmental programs. However, even with these changes the overall goal of the programs tends to remain the same; contribute to economic stability of the food supply of domestic markets and protect farmers from potential income loss due to economic difficulties or from rapid increases in supply (14).

The post-1948 period can be divided into two separate periods. The first, 1948-1963, was characterized by war in Korea and then by a time of mounting surpluses. Marketing quotas were in effect and participation in government programs was mandatory.

The second period covers the years 1964-1982. During this period participation in government programs was voluntary, since in 1963 farmers voted down mandatory controls over wheat and corn. Loan levels were set low, and the primary inducement to participation was direct payments.

While there have been a variety of programs affecting the corn and wheat industry, the only program used in the soybean industry has been the national loan rate. No other programs have been utilized for soybeans.

Methodology

The model used in this study is Nerlove's partial adjustment model based on the assumption that producers anticipate production of a particular crop in acres desired at the given crop prices (33). The desired acres must be adjusted with the aggregate acreage actually planted because planted acres are not necessarily equal to the desired level.

Specification of the annual acreage response model begins with the assumption that producers anticipate a certain level of acreage planted at given prices. This relationship can be expressed as

$$A_t^* = \alpha + \beta_1 P_t + \beta_2 P_{t-1} + \sum_{i=1}^{n} \gamma_i G_{it} \qquad (1)$$

where A_t^* is the desired acreage in year t, P_t is an average price of the monthly prices available in time t, P_{t-1} is season average prices lagged one time period, and G_{it} with i=1,2,...n is the government policy instrument and other relevant exogeneous variables.

Equation 1 includes dynamic adjustment of the desired acres to actual acres planted as follows:

$$A_t - A_{t-1} = \delta(A_t^* - A_{t-1}) + U_t \qquad (2)$$

where A_t is the actual acres planted in year t, U_t is a disturbance term, and δ is the coefficient of acreage adjustment with $0 < \delta < 1$. This adjustment coefficient equation indicates that the actual changes in acres planted in year t is a fraction of the difference between desired and planted acres.

Combining Equations 1 and 2 gives the first order difference equation in dependent variable as

$$A_t = \delta\alpha + \delta\beta_1 P_t + \delta\beta_2 P_{t-1} + \delta \sum_{i=1}^{n} \gamma_i G_{it} + (1 - \delta)A_{t-1} + U_t \qquad (3)$$

Most supply response models have been specified as a function of P_{t-1} because season average crop prices for time t are not available to farmers at the planting time based on the price reporting system by the USDA (Figure 1). However, some monthly prices for each crop in time t are known at planting time although crop year is defined differently for crops and regions. For instance, October, November, December, January, and February prices in time t are generally available for corn at its planting season. Similarly, monthly soybean prices in time t available at the planting time are those from September through February. While wheat prices for two months are available for winter wheat at planting time, those for eight months are available for spring wheat. These available monthly prices might influence more farmers' decisions than season average price lagged one year (P_{t-1}). However, a potential problem in including P_t in equation 3 is a high degree of multicollinearity between P_t and P_{t-1}. To avoid this problem, these two prices are aggregated under the assumption that P_t and P_{t-1} influence farmers' planting decisions with the arithmetic lag distribution incorporating higher

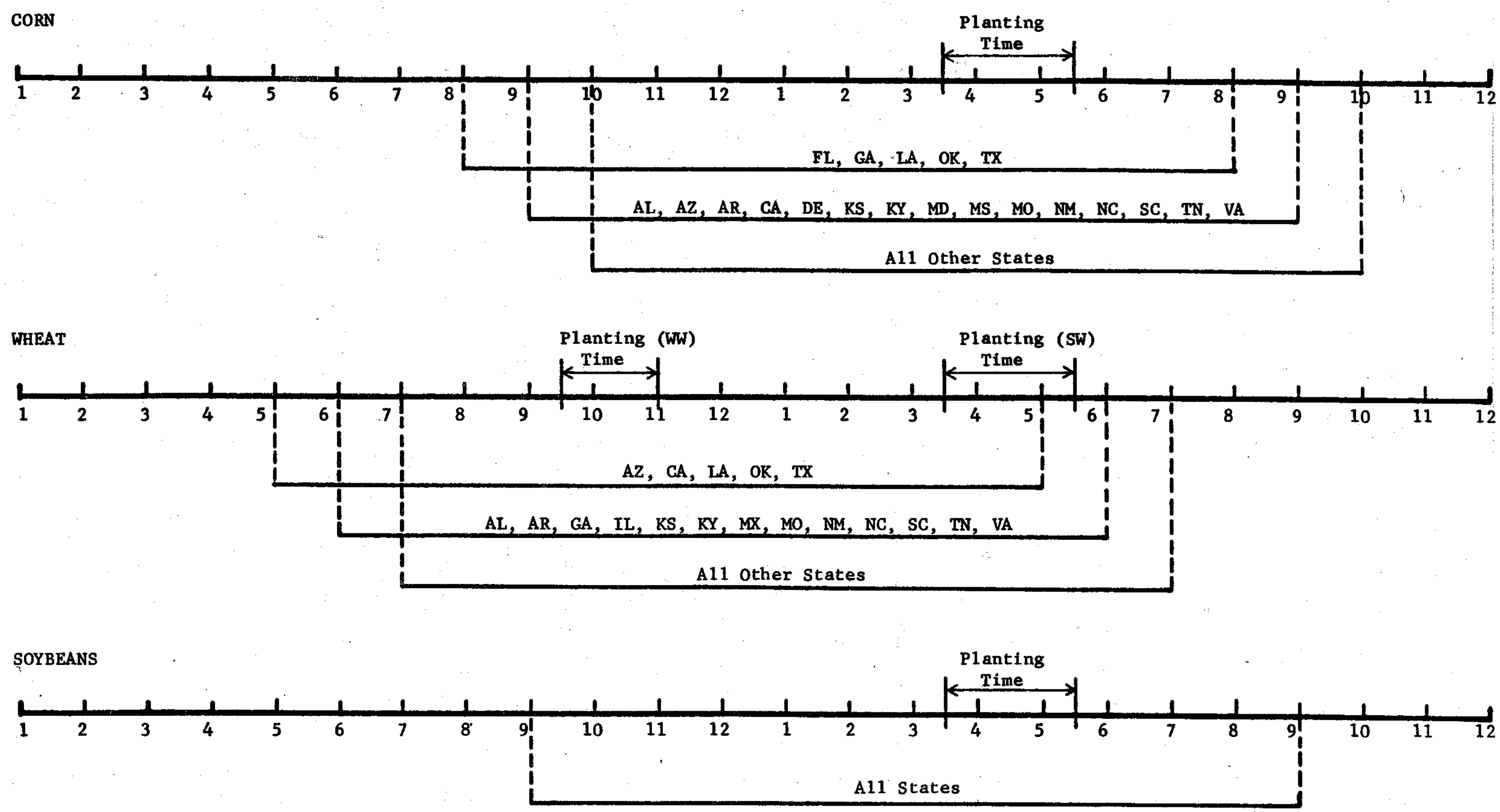

Figure 1. Relationship Between Crop Years and Planting Time

weight on P_t than on P_{t-1}. In general, effects of P_{t-i} are assumed as

$$\beta_i = (K + 1 - i)\beta \tag{4}$$

Substituting Equation 4 into Equation 3 gives

$$A_t = \delta\alpha + \delta\beta \sum_{i=0}^{k} (K + 1 - i)P_{t-i} + \delta \sum_{i=1}^{n} \gamma_i G_{it} + (1 - \delta)A_{t-1} + U_t \tag{5}$$

This equation can be written as

$$A_t = \delta\alpha + \delta\beta CP_t + \delta \sum_{i=1}^{n} \gamma_i G_{it} + (1 - \delta)A_{t-1} + U_t \tag{6}$$

where $CP_t = \sum_{i=0}^{k} (K+1-i)P_{t-i}$. Since K is 1 in equation 6, $CP_t = \sum_{i=0}^{1} (2-i)P_{t-i}$.

It is also recognized that error terms are contemporaneously correlated among corn, soybeans, and wheat acreage equations. Seemingly unrelated regression techniques, therefore, are used to improve the efficiency of the estimates.

Specification of the Empirical Model

There are numerous programs utilized by the government which can affect the acreage of a commodity planted. However, only the major acreage influencing programs will be analyzed in this study.

J. P. Houck and M. E. Ryan (18) and J. P. Houck, et al. (19) used the support price of corn as the government program variable affecting the acres of corn planted in the U.S. In this study, the corn support price is also analyzed along with the set-aside and acreage diversion programs to determine their effect on corn acreage.

Studies by Won W. Koo (25) and by Russell Lidman and D. Lee Bawden (28) on the impact of government programs on wheat acreage serve as a reference for determining the appropriate programs which affect wheat acreage. Lidman and Bawden specified the wheat acreage allotment and the announced loan rate as their acreage-influencing programs while Koo estimated wheat acreage response to acreage allotment, set-aside, acreage diversion, and farmer-owned reserve programs.

In this study, wheat and corn acreage response models include two major acreage control programs: set-aside and additional diversion. In addition, while expected deficiency payments are specified in the wheat acreage model, support prices are included in the corn acreage model. Since target prices are set much higher for wheat than for corn, wheat farmers are more sensitive to deficiency payments, while corn farmers are more sensitive to support prices.

Since World War II, the price of soybeans has been supported by a national loan rate, with no acreage restrictions attached to these supports. However, in all but one year the average crop price has been above the support level set by the loan rate. This indicates a lack of significance for the loan rate as an independent variable which affects soybean acres planted. Because acreage restrictions and marketing quotas have not been imposed on soybeans, and since the loan rate has played a relatively insignificant role in supporting prices, this study will not specify any governmental programs in the soybean acreage response model.

In addition to governmental programs, there are other exogenous variables which can affect the supply of a commodity. These independent variables include the futures price of a crop, a variable representing irreversibilities in supply, and the price of competing crops.

The question of using futures prices in supply response is a controversial issue; evidence dealing with their quality as forecasts is somewhat mixed. Bruce L. Gardner (11) and R. E. Just and G. C. Rausser (22) argued in favor of using futures prices in supply response, indicating that they forecast relatively well compared to econometric forecasts and suggesting that acreage decisions could be based on futures prices.

On the other hand, empirical work by W. G. Tomek and R. W. Gray (38) and by J. L. Stein (37) raises questions about whether futures prices are price forecasts. Stein states that "prior to four months to maturity, the futures price is a biased and worthless estimate of the price of maturity."

Jean-Paul Chavas, Rulon D. Pope, and Robert S. Kao (6) performed an analysis of the role of futures prices in acreage response models. They concluded that although the futures price appears to be a good substitute for the crop price lagged one year in supply analysis, their results raised some questions about the informational efficiency of futures prices. In particular, futures prices do not reflect the effects of governmental decisions, implying that using futures prices as a proxy for expected prices in supply response appears to be justified only in the absence of government programs.

Based on those discussions, futures prices were not specified as an independent variable for the price that producers base their decisions on.

The notion of irreversibilities with respect to supply response has been presented since the work of Cassels in 1933. This response concept is based on the hypothesis that when the price changes, there are likely to be correlated changes in supply shifters. In particular, when the price increases, new techniques of production are more likely to be introduced. Once adopted, these improved production practices usually are retained even though the price of the commodity subsequently decreases.

When static supply response models were used to estimate commodity acreage, analysts were unable to account for the irreversibility phenomena. Houck (20), in 1977, attempted to specify and estimate nonreversible functions consistent with the Wolffram technique developed in 1971. Oscar R. Burt and Jeffrey T. LaFrance (27), in 1983, found that the irreversibility phenomena is inherently specified within dynamic supply models. Because of Burt and LaFrances' conclusion, an independent variable to account for supply irreversibility was not specified in this study.

The final exogenous variable analyzed is the price of competing crops being introduced into the acreage response models. Most crops tend to compete with one another for acreage at planting time. Soybeans compete with corn, and corn with soybeans, for production resources since corn land is also desirable for growing soybeans and vice versa. Since the decision of producing corn or soybeans is made at planting time, the substitute crop price is lagged one year to correspond with the producers decision.

Although wheat does not compete solely with any one main commodity in the U.S., it does compete with the feed grains in various parts of the country. In the Midwest wheat competes with corn while in the Upper Midwest it competes with barley and oats. Because of this competition, it is hypothesized that wheat acreage is inversely related to the feed grain price index.

Data

Data for the period 1964-1982 were used to estimate the acreage response equations. Corn, soybean, and wheat prices used in this study are seasonal average prices received by producers lagged one year (P_{t-1}) and averages of monthly prices available in time t prior to planting season for these crops. All price variables were deflated to 1967 dollars using the index of prices paid for all production items (41).

Data for corn and wheat set-aside and additional diversion acres were available on a national basis through the Agricultural Stabilization and Conservation Service (ASCS) for the time period under study (1).

It has been hypothesized that wheat producers are sensitive to the expected deficiency payment available to them while corn producers are sensitive to their effective support price. The expected deficiency payment available to wheat producers was calculated for 1974-1982 as follows:

$$EDP_t = TP_t - CP_t$$

where: EDP_t = maximum wheat deficiency payment at time t

TP_t = wheat target price at time t

CP_t = average crop price at time t

Prior to 1974 a value of zero was assigned to the EDP_t variable. Also, if CP_t was greater than TP_t, a value of zero was assigned to the EDP_t variable for that year.

A study by J. P. Houck, et al. (19) serves as a reference for calculating the effective support price of corn. For the 1948-1973 crop years the effective support price variable was calculated as follows:

$$SPC_t = [1/2\ (\frac{A\ min}{A_0} + \frac{A\ max}{A_0})]\ LR_t$$

where: LR_t = announced corn loan rate at time t

A_0 = base acreage for corn

A min = minimum corn acreage allowable under price program

A max = maximum corn acreage allowable under price program

SPC_t = effective support price of corn at time t

After 1973, with the advent of the target price concept, farmers were eligible for a direct payment if the five-month average market price was below the target price. The general form of computation for 1974-1982 crop years was as follows:

$$SPC_t = LR_t + \frac{A_a}{A_0}\ (DPC_t)$$

where: LR_t = announced corn loan rate at time t

A_a = total corn acreage allotment

A_0 = corn base acres

DPC_t = estimated direct payment rate at time t

SPC_t = effective support price of corn at time t

Both the maximum wheat deficiency payment and the effective support price of corn were deflated to 1967 dollars using the index of prices paid for all production items.

Empirical Results

Due to the inherent correlation among the error terms of the corn, soybean, and wheat equations, a system estimation technique is used to estimate the equations in the system. The efficient estimation of seemingly unrelated regressions with independent errors has been suggested by Zellner (46). However, it was found from the preliminary estimates that the individual equations have autocorrelated residuals. Zellner's estimator therefore is not consistent for the parameters of model 6. To avoid the inconsistency of parameter estimates, the procedure developed by Kmenta and and Gilbert (23) has been widely used to estimate the models in a system. Recently, asymptotically more efficient procedures for equation 6 were proposed by Hatanaka (15) and by Wang, Hirdiroglon, and Fuller (43). The estimator developed by Wang et al. was used in this study and the detailed estimation steps are presented in the mathematical appendix.

The estimated equations are presented in Table 1. Most coefficients of the corn, soybean, and wheat acreage response equations are statistically significant.

Table 2 presents the system estimates of corn, soybean, and wheat acreage models with season average wheat prices lagged one period (P_{t-1}). The

TABLE 1. SYSTEM ESTIMATES OF CORN, SOYBEANS, AND WHEAT ACREAGE RESPONSE MODELS WITH THE ARITHMETIC LAG PRICE (T-VALUE IN PARENTHESIS)

Variable	Corn	Soybeans	Wheat
Constant	56.244	8.795	60.893
	(6.183)	(1.119)	(2.712)
A_{t-1}	0.290	0.887	0.484
	(3.097)	(7.558)	(2.698)
CP_t	2.813	5.504	20.716
	(1.011)	(4.732)	(2.838)
X_1	7.781		
	(1.890)		
X_2			-6.093
			(0.332)
X_3	-0.516		-0.311
	(6.304)		(0.962)
X_4	-0.718		-2.337
	(6.058)		(1.893)
Z_1	-2.268		
	(2.068)		
Z_2		-13.724	
		(4.703)	
Z_3			-37.687
			(2.025)

Weighted R^2 for the system = 0.9986.
Weighted standard error = 1.284.
A_{t-1} = acres planted in millions in year t-1.
CP_t = arithmetic crop price deflated by farm input price index in year t (dollars per bushel).
X_1 = effective support price deflated by farm input price index in year t (dollars per bushel).
X_2 = expected deficiency payment deflated by farm input price index in year t (dollar per bushel).
X_3 = set-aside acres in millions.
X_4 = acreage diversion acres in millions.
Z_1 = soybean price, used as competing price in corn model, deflated by farm input price index in year t-1 (dollars per bushel).
Z_2 = corn price, used as competing price in soybean model, deflated by farm input price index in year t-1 (dollars per bushel).
Z_3 = feed grain price index, used as competing price in wheat model, deflated by farm input price index in year t-1 (dollars per bushel).
R^2 = coefficient of multiple determination.

models with the arithmetic lag price variables are asymptotically more efficient than those with P_{t-1} although estimated parameters are similar in

TABLE 2. SYSTEM ESTIMATES OF CORN, SOYBEANS, AND WHEAT ACREAGE RESPONSE MODELS WITH SEASON AVERAGE PRICE LAGGED ONE YEAR (t-VALUE IN PARENTHESIS)

Variable	Corn	Soybeans	Wheat
Constant	57.345 (5.629)	8.572 (1.682)	47.696 (2.039)
A_{t-1}	0.265 (0.298)	0.878 (12.553)	0.481 (2.401)
P_{t-1}	3.192 (1.006)	7.538 (5.266)	19.033 (1.850)
X_1	9.433 (2.242)		
X_2			-1.459 (0.064)
X_3	-0.534 (6.426)		-0.406 (1.192)
X_4	-0.758 (5.859)		-3.065 (2.090)
Z_1	-2.577 (2.183)		
Z_2		-18.428 (5.789)	
Z_3			-38.572 (1.545)

Weighted R^2 for the system = 0.999.
Weighted standard error for the system = 1.690.
A_{t-1} = acres planted in millions in year t-1.
P_{t-1} = season average prices deflated by farm input price index in time t-1.
X_1 = effective support price deflated by farm input price index in year t (dollars per bushel).
X_2 = expected deficiency payment deflated by farm input price index in year t (dollar per bushel).
X_3 = set-aside acres in millions.
X_4 = acreage diversion acres in millions.
Z_1 = soybean price, used as competing price in corn model, deflated by farm input price index in year t-1 (dollars per bushel).
Z_2 = corn price, used as competing price in soybean model, deflated by farm input price index in year t-1 (dollars per bushel).
Z_3 = feed grain price index, used as competing price in wheat model, deflated by farm input price index in year t-1 (dollars per bushel).

magnitude in both cases. The weighted average standard error for the system with the arithmetic lag is 1.284 while that with P_{t-1} is 1.690.

The system estimates of corn, soybean, and wheat models are also compared with single equation estimates of those models. All models in both cases are specified with the arithmetic lag prices. The estimation technique used for the single equation estimates is Hatanaka's two-step efficient procedure which is equivalent to maximum likelihood estimates. This procedure is identical to the first two steps of the three-step Gauss-Newton procedure. The parameters estimated by the single equation estimator are presented in Table 3. Most estimated parameters are statistically significant, but they are less efficient than those parameters estimated by the system estimation technique. Standard errors in corn, soybeans, and wheat equations are 1.621, 2.242, and 5.002, respectively, which are larger than the weighted average standard error for the system estimates.

Effects of Government Programs

Corn acres planted has a negative relationship with the set-aside and acreage diversion programs, while there is a positive relationship between planted acres and the effective support price of corn as shown in Table 1. The acreage diversion program is slightly more effective at controlling corn acres planted than the set-aside program.

The positive relationship between the effective support price and corn acres planted indicates that a 10 cent increase in the effective support price from one year to the next will result in a subsequent 0.78 million increase in corn acres planted. All three government program variables in the corn acreage response equation are significant at the 99 percent probability level.

Wheat acres planted has a negative relationship with the expected wheat deficiency payment. Expected deficiency payments have a dual effect on producers when other government programs, such as the set-aside and acreage diversion programs are in effect. The deficiency payment serves as an

TABLE 3. SINGLE EQUATION ESTIMATION OF CORN, SOYBEAN, AND WHEAT ACREAGE RESPONSE MODELS WITH THE ARITHMETIC LAG PRICES (t-VALUE IN PARENTHESES)

Variable	Corn	Soybeans	Wheat
Constant	60.265 (6.362)	8.329 (1.682)	55.566 (2.039)
A_{t-1}	0.259 (2.673)	0.893 (7.56)	0.478 (2.560)
CP_t	2.366 (0.831)	5.530 (4.74)	18.006 (2.37)
X_{1t}	-2.416 (2.101)		
X_{2t}			2.232 (0.12)
X_{3t}	-0.542 (6.511)		-0.342 (1.04)
X_{4t}	-0.791 (6.370)		-2.340 (1.81)
Z_{1t-1}	-2.416 (2.100)		
Z_{2t-2}			
Z_{3t-3}			-31.873 (1.64)
R^2	0.9995	0.992	0.9947
SE	1.621	2.242	5.002

A_{t-1} = acres planted in millions in year t-1.
CP_t = arithmetic crop price deflated by farm input price index in year t (dollars per bushel).
X_1 = effective support price deflated by farm input price index in year t (dollars per bushel).
X_2 = expected deficiency payment deflated by farm input price index in year t (dollar per bushel).
X_3 = set-aside acres in millions.
X_4 = acreage diversion acres in millions.
Z_1 = soybean price, used as competing price in corn model, deflated by farm input price index in year t-1 (dollars per bushel).
Z_2 = corn price, used as competing price in soybean model, deflated by farm input price index in year t-1 (dollars per bushel).
Z_3 = feed grain price index, used as competing price in wheat model, deflated by farm input price index in year t-1 (dollars per bushel).

incentive for producers to participate in these programs. On the other hand, a deficiency program provides income protection to producers from adverse changes in market prices, resulting in more acres planted. A negative relationship between wheat acres planted and the expected deficiency payment indicates that a deficiency payment program serves as an incentive for producers to participate in acreage reduction programs rather than as income protection. Due to these two effects on a deficiency payment program, however, the variable is not statistically significant.

Wheat acres planted has a negative relationship with the set-aside and acreage diversion programs. The acreage diversion program is more effective at controlling wheat acres planted than the set-aside program.

All governmental program variables in the corn and wheat acreage response equations were tested simultaneously with a null hypothesis that the estimated coefficient associated with each government program is equal to zero. The traditional F-test with the sum of square errors obtained from restricted and unrestricted models was used to test the null hypothesis.

The unrestricted corn and wheat models are identical to the equations presented in Table 1. The corn and wheat restricted models were developed by eliminating all relevant goverment program variables from the equations presented in Table 1.

The error sum of squares obtained from restricted and unrestricted models and the F-values calculated from them for both corn and wheat acreage response equations are presented in Table 4.

The calculated F-values of the corn and wheat acreage response models indicate that government programs are significant at the 99 percent confidence level, resulting in rejection of the null hypothesis that the estimated coefficient associated with each government program is equal to zero. This illustrates the important role government programs have as a whole in controlling corn and wheat acres.

TABLE 4. SUM OF SQUARE ERRORS AND F-VALUES FOR CORN AND WHEAT ACREAGE RESPONSE MODELS TO TEST SIGNIFICANCE OF GOVERNMENT PROGRAMS FOR 1964-1982 TIME PERIOD

	Corn Model	Wheat Model
SSE_{UR}	18.550	55.072
SSE_R	344.433	625.802
F-Value*	46.843	12.436

$$*F_{r,n-k} = \frac{(SSE_R - SSE_{UR})/r}{SSE_{UR}/n-k}$$

where: SSE_R = sum of square errors in the restricted model
SSE_{UR} = sum of square errors in the unrestricted model
r = degrees of freedom for the numerator
$n-k$ = degrees of freedom for the unrestricted model

Effects of Crop Prices

Corn acreage planted is positively related to the corn price and negatively related to the soybean price in the corn acreage response equation as shown in Table 1. The corn price is significant at the 80 percent probability level in the corn acreage model, while the soybean price is significant at the 90 percent probability level.

The positive relationship between the corn price and acres planted indicates that a 10 cent increase in the corn price from one year to the next results in a 0.281 million increase in corn acres planted, while the negative coefficient for the soybean price implies that a 10 cent increase in the soybean price from one year to the next results in a 0.226 million decrease in corn acres planted. This negative coefficient for the soybean price in the corn model indicates that soybeans compete with corn at planting time and are considered a viable alternative crop.

Soybean acreage planted is positively related to the soybean price and negatively related to the corn price in the soybean acreage response equation as shown in Table 1. Both the soybean and corn prices are significant at the 99 percent probability level, illustrating the key role prices play in determining soybean acreage planted due to the lack of any direct governmental program influence.

The positive coefficient for the soybean price indicates that a 10 cent increase in the soybean price from one year to the next results in a 0.504 million increase in soybean acres planted, while the negative coefficient for the corn price implies that a 10 cent increase in the corn price from one year to the next results in a 1.372 million decrease in soybean acres planted. This negative coefficient for the corn price in the soybean model, again, represents the competition which takes place between soybeans and corn for acreage at planting time.

Wheat acreage planted is positively related to the wheat price and negatively related to the feed grain price index in the wheat acreage response equation as shown in Table 1. The wheat price is significant at the 99 percent probability level, while the feed grain price index is significant at the 90 percent probability level. These high significance levels indicate the key role prices play when wheat producers are making planting decisions.

The positive coefficient for the wheat price indicates that a 10 cent increase in the wheat price results in a 2.072 million increase in wheat acres planted, while the negative coefficient for the feed grain price index implies that a 10 percent increase in the feed grain price index from one year to the next results in a 3.769 million decrease in wheat acres planted. This negative coefficient for the feed grain price index in the wheat model once again illustrates the competition which takes place between wheat and many feed grains at planting time.

Estimated very short-run, short-run, and long-run price and cross price elasticities of the corn, soybean, and wheat acreage response equations are presented in Table 5.

TABLE 5. ESTIMATED PRICE AND CROSS PRICE ELASTICITIES OF CORN, WHEAT, AND SOYBEAN ACREAGE RESPONSE MODELS FOR 1964-1982 TIME PERIOD

	Corn Model	Wheat Model	Soybean Model
Price Elasticity			
Very Short-Run	0.028	0.307	0.198
Short-Run	0.043	0.465	0.299
Long-Run	0.061	0.901	1.751
Cross Price Elasticity			
Short-Run	-0.087	-0.555	-0.317
Long-Run	-0.123	-1.075	-2.804

Very short-run price elasticity estimates were calculated for each crop under study to isolate the effect of the current crop year price because short-run elasticities show producers' response to both last year's seasonal average price received by producers and the current crop price. In the very short-run producers have less time to respond to market changes as compared to the short-run. Because of the limited time in the very short-run, the very short-run price elasticities of corn, wheat, and soybean are all more inelastic than the short-run elasticity estimates.

The short-run price and cross price elasticities of the corn, wheat, and soybean acreage response models are all in the inelastic range, with corn acreage response to prices much more inelastic than that of wheat and soybeans. The low elasticities of the corn model indicate that corn acreage response is not very sensitive to market prices, in the short-run, at planting time. Instead, the influence of governmental programs, although voluntary in nature for the time period, are strong in determining corn acreage planted.

While wheat and soybeans exhibit a higher sensitivity to market prices in the short-run, it is surprising to see wheat having the most elastic short-run price and cross price elasticity estimates. This indicates that wheat production, although restricted by various governmental programs, is highly sensitive to market prices at planting time as compared to corn and soybeans.

The long-run price and cross price elasticities of acreage response models reflect dynamic adjustments of producers with prices over time. Long-run price and cross price elasticity estimates of the corn acreage response model are in the inelastic range, while the long-run price elasticity of the wheat acreage response model is inelastic yet its long-run cross price elasticity is slightly elastic. These higher long-run elasticity estimates of the wheat model as compared to the corn model again depict the higher sensitivity of wheat producers to market prices in the long run as compared to corn producers.

It is not surprising to see that the soybean long-run price and cross price elasticities are extremely elastic. The reason for the higher elasticity estimates of the soybean acreage response model is due to the effect of governmental programs. Since there are no governmental programs which directly affect soybeans, soybean acreage is much more sensitive to market prices in the long run as compared to the corn and wheat acreage response models.

Price elasticity estimates of the corn and soybean acreage response model are similar to those elasticity estimates reported by James P. Houck

(19) in 1976. No studies in the past have calculated cross price elasticity estimates making comparison of this studies' estimates difficult. Price elasticity estimates of the wheat acreage response model are comparable with price elasticity estimates of a wheat acreage response model developed by Marc Nerlove (32) in 1956.

Conclusions

Methodologically, this study found that the system estimation technique provides asymptotically more efficient parameter estimates of the corn, soybean, and wheat models as compared to the single equation estimation technique.

Most studies in the past utilized only price lagged one time period (P_{t-1}) as the parameter for crop price. However, implementation of the finite arithmetic lag distribution, combining P_{t-1} with the current monthly crop prices, resulted in more efficient parameter estimates for the corn, wheat, and soybean acreage response models.

This study revealed that all government programs are highly significant in the corn and wheat acreage response models. Corn and wheat producers have been responding actively to government programs during the time periods. All government programs have been effective in controlling production, although producers response to programs is somewhat different for corn and wheat. Wheat producers exhibit a high sensitivity to the expected deficiency payment while corn producers are highly sensitive to the effective support price.

The price elasticity of soybeans is much higher than those of corn and wheat. The reason for this is that corn and wheat acreage responses to crop prices have been tempered by government programs, while soybean acreage response is highly sensitive to crop prices due to the lack of government programs which directly affect soybean acreage planted. This indicates that changes in government programs could alter elasticities of corn and wheat acreage response model. For instance, market oriented government programs could make the price elasticities more elastic.

Mathematical Appendix

The Estimation Technique of Seemingly Unrelated Regression With Lagged Dependent Variables and Autocorrelated Errors

Consider a system of acreage response regression equations of the following forms:

$$A_i = X_i \beta_i + A_{i-1} \gamma_i + U_i \quad i = 1, 2, \ldots, m \tag{A1}$$

Where A_i is an N X 1 vector of observations on ith dependent variables: X_i is N X (K_{i-1}) nonstochastic matrix of observations on (K_{i-1}) regressors; β_i is a (K_{i-1}) vector of regression coefficients; A_{i-1} is the N X 1 vector of observations on the ith dependent variable lagged one period and γ_i is the regression coefficient of A_{i-1}. It is assumed that all γ_i are less than one in absolute value, i = 1, 2, . . ., m.

The system of equation can be expressed in matrix form as

$$A = Z\delta + U \tag{A2}$$

Where A is Nm X 1 vector of observations on dependent variables; Z is the Nm X $(\sum_{i=1}^{m} K_i)$ block diagonal matrix of observations on regressors [i.e., Z = block diag $(Z_1, Z_2, \ldots Z_m)$ and $Z_i = (X_i, A_{i-1})$]; and $\delta' = (\delta'_1, \delta'_2, \ldots \delta'_m)$ is the $(\sum_{i=1}^{m} K_i)$ X 1 row vector of coefficients and $\delta'_i = (\beta'_i, \delta'_i)$.

The assumed error structure for model A2 is

$$U_{it} = \rho_i U_{it-1} + E_{it} \qquad i = 1, 2, \ldots, m$$

Where the parameters $|\rho_i| < 1$ for i = 1, 2, . . . m.

Furthermore, we assume that the vector $E_t = (E_{1t}, E_{2t}, \ldots E_{mt})$, t = 1, 2, . . . n, are independently distributed as multivariate normal with zero mean vector and nonsingular covariance matrix $\Sigma = (\sigma_{ij})$.

The three-step Gauss-Newton procedure consists of following steps:

First, use method of instrumental variable technique to obtain consistent estimates. The set of instrumental variables are X_i, X_{i-1}. Using these preliminary estimates, the residuals are

$$\hat{U}_i = A_i - Z_i \hat{\delta}_i \qquad (A3)$$

Where $\hat{\delta}_i$ are the instrumental variable estimates.

The autocorrelation coefficients are estimated by:

$$\hat{\rho}_i = \frac{\sum_{t=1}^{N} \hat{U}_{it} \hat{U}_{it-1}}{\sum_{t=1}^{N} \hat{U}_{it-1}} \quad i = 1, 2, \ldots m \qquad (A4)$$

Second, expanding the ith equation in a Taylor series expansion about $(\hat{\delta}_i, \hat{\rho}_i)$ and rearranging the terms yields.

$$(1 - \hat{\rho}_i^2)^{1/2} A_{it} = \sum_{r=1}^{K_i-1} (1 - \hat{\rho}_i^2)^{1/2} A_{i\,t-1}\, \gamma_i + E_{it} \qquad t=1$$

$$A_{it} - \hat{\rho}_i A_{it-1} = \sum_{r=1}^{K_i-1} (X_{itr} - \hat{\rho}_i X_{i\,t-1\,r})\, \beta_{i\gamma} + (A_{it-1} - \hat{\rho}_i A_{it-2})\, \gamma_i +$$

$$\Delta\rho_i \hat{U}_{i\,t-1} + E_{it} \qquad t = 2, 3, \ldots, N \qquad (A5)$$

Where $\hat{U}_{i\,t-1}$ is estimated residuals of equation i defined in model 6, lagged one period with $\hat{U}_{i\,0} = 0$. Using the estimated E_{it}, which we denote by $\hat{E}_{it}$, i = 1, 2, . . ., m; t = 1, 2, . . ., N; estimate the elements of the covariance matrix Σ by

$$\hat{\delta}_{ij} = \frac{\sum_{t=1}^{N} \hat{E}_{it} \hat{E}_{jt}}{(N-K_i)^{1/2} (N-K_j)^{1/2}} \quad i, j = 1, 2, \ldots, m \qquad (A6)$$

Where $\hat{E}_{it} = \hat{U}_{it} - \hat{\rho}_i \hat{U}_{it-1}$

Third, an adaption of Aitken generalized least square is applied to the system of regressions (A5). The system of equations in (A5) can be written in matrix form:

$$\tilde{T}A = \tilde{H}W + E$$

Where

$\tilde{H}$ = Block diag $(\tilde{H}_1, \tilde{H}_2, \ldots, \tilde{H}_m)$; $\tilde{H}_i = (\tilde{T}_i X_i, \tilde{T}_i A_{i-1}, \tilde{U}_{i-1})$

$\tilde{T}$ = Block diag $(\tilde{T}_1, \tilde{T}_2, \ldots, \tilde{T}_m)$

$\tilde{T}_i$ is T_i of (A7) evaluated at $\rho_i = \tilde{\rho}_i$

$$T_i = \begin{bmatrix} (1-\rho_i)^{1/2} & 0 & 0 & \ldots & 0 & 0 & 0 \\ -\rho_i & 1 & 0 & \ldots & 0 & 0 & 0 \\ \vdots & & & & & & \\ 0 & 0 & 0 & \ldots & -\rho_i & 1 & 0 \\ 0 & 0 & 0 & \ldots & 0 & -\rho_i & 1 \end{bmatrix} \qquad \text{(A7)}$$

$W' = (\delta'_1, \Delta\rho_1, \delta'_2, \Delta\ell_2, \ldots, \ell'_m, \Delta\ell_m)$

$\Delta\rho_i = \rho_i - \hat{\rho}_i$

$E' = (E'_1, E'_2, \ldots E'_m)$

The final estimator of $(W'_1, W'_2, \ldots W'_m)$ is given by

$$\tilde{W} = (\tilde{H}\hat{\Omega}^{-1}\hat{H})^{-1}\tilde{H}\hat{\Omega}^{-1}\tilde{T}A$$

Where $\hat{\Omega}^{-1} = \hat{\Sigma} \times I$, and elements of $\hat{\Sigma}$ are defined in equation A6. The estimator of ρi is $\tilde{\rho} i$ $(= \tilde{\rho} i + \tilde{\Delta\rho} i)$ where $\tilde{\Delta\rho} i$ is the coefficient of $\hat{U}_{i-1}$.

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