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**ESTIMATION OF A WHEAT ACREAGE
RESPONSE FUNCTION FOR KANSAS**

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JULY 1992

No. 92-18

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by

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Selected Paper Presented at the American Agricultural Economics Association
Annual Meetings, Baltimore, Maryland, August 9-12, 1992

July 2, 1992

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Contribution no. 92-600-D from the Kansas Agricultural Experiment Station.

Estimation of a Wheat Acreage Response Function for Kansas

Abstract

A wheat acreage response function was estimated for Kansas using the Generalized Method of Moments (GMM). The results show that wheat and soybean futures prices and lagged acreage are important factors in the decision to plant wheat acreage, whereas grain sorghum and corn prices are not.

Estimation of a Wheat Acreage Response Function for Kansas

Wheat is the most important crop in Kansas. Twenty six percent of available acreage was used for wheat production in 1990, whereas 6.5% was used for grain sorghum, 4.2% for soybeans, and 3.3% for corn. Wheat production in Kansas totaled 472 million bushels in 1990, which was the historical record. Trends of wheat acreage and yields from 1960 to 1991 have been relatively stable. However, the vulnerability of real prices received by Kansas producers has resulted in high variability in real farm values generated from wheat production.

Incorporation of price expectations has been recognized as crucial to the estimation of crop supply functions, because producers' production decisions usually are based on unobservable, expected, future prices for products. In a static economy in which prices and costs vary in a purely random fashion about fixed equilibrium values and the production technology remains unchanged, the expected value of each stochastic variable could be estimated as the mean of the historical value, and the probability distributions could be estimated from deviations around the means. However, in the dynamic world faced by farmers, the probability distributions of economic variables change over time and decision makers must form expectations about future events. Hence, researchers' estimates of expected values have typically required a priori specification of the farmer's method for projecting past outcomes into the future.

Both static and dynamic models have been used to estimate aggregate supply elasticities for annual crops. The early studies relied on static expectations in single equation models with few variables. Nerlove (1956,

1958) showed that agricultural supply models incorporating adaptive price expectations and/or dynamic adjustments produced larger estimates of supply elasticities for agricultural commodities. These simple, single-equation, Nerlovian-type models have been adapted to a wide range of agricultural supply problems (e.g., Askari and Cummings). However, the adaptive expectations hypothesis is inadequate, not because it implies that the forecast of a particular variable is a distributed lag of its own past values, but because it implies that distributed lag parameters are restricted in an ad hoc way (Fisher). Even though a naive expectations approach can avoid the simultaneity problem because past prices are predetermined, it may also be inadequate for similar reasons. Some common acreage response specifications include moving averages and Nerlove's adaptive expectations models.¹

Aradhyula and Holt state that the rational expectations hypothesis has emerged as a credible alternative to more traditional approaches based on naive expectations. Only in recent years have agricultural economists begun to examine the theoretical and empirical implications of extending the rational expectations hypothesis to a more general model that includes risk-averse behavior. The effects of price uncertainty in a rational expectations setting have been evaluated by Antonovitz and Roe, Antonovitz and Green, and Seale and Shonkwiler. The most common approach is to approximate risk terms with a distributed lag relationship. On the other hand, the rational expectations specification assumes that producers use all currently available

¹ There are two basic criticisms of these approaches: 1) the specified process of forming expectations forever traps the effects of errors made in the past forecasts on the future forecasts, allowing errors to be made systematically; and 2) these approaches tacitly assume that the decision maker is strictly backward looking and, thus, ignore any available information about the future.

information to form expectations about the mean and variance of price. Thus, Aradhyula and Holt extended the rational expectations framework to include price uncertainty.

Recently, duality theory has been applied to static, flexible, functional forms to obtain agricultural supply and input demand functions. These multiple equation systems include a larger set of output and input prices than Nerlovian-type supply functions. Furthermore, considerable structure is imposed on these equations by forcing homogeneity in prices and cross-equation symmetry conditions. However, these systems, have produced only a few reasonable estimates of supply elasticities for individual crops (Tegene, Huffman, and Miranowski).

The objective of this paper is to estimate Kansas wheat acreage response function using annual data from 1970 to 1991. The Generalized Method of Moments developed by Hansen is used to estimate the regional wheat acreage response function under the assumption that producers hold rational expectations.

This paper proceeds according to the following plan. The next section discusses the theoretical framework and empirical model development. The third section presents the data. Empirical results are presented in section four. The last section contains a brief review of the analysis, and offers concluding remarks.

Empirical Model Development

The rational expectations model specified in this study relates wheat acreage to expected levels of its determinants. Wheat acreage rather than

production is used as the dependent variable.²

The problem facing the Kansas wheat producers is:³

$$\begin{aligned} \text{Max } \pi^e_{t+1} &= \sum_{i=1}^4 P^e_{i,t+1} Q^e_{i,t+1} - \sum_{i=1}^4 \sum_{j=1}^m w_{ij,t} x_{ij,t} \\ \text{s. t. } \sum_{i=1}^4 A_i &= \bar{L} \end{aligned} \quad (1)$$

where π^e_{t+1} is expected profit in time $t+1$, i is index of crops, j denotes index of inputs, $P^e_{i,t+1}$ represents expected output price of crop i in time $t+1$, $Q^e_{i,t+1}$ is expected production function of crop i in time period $t+1$, $w_{ij,t}$ is price of input j used in production of crop i in time t , $x_{ij,t}$ is amount of input j used in production of crop i in time $t+1$, and L represents total planted acres of the four crops.

To estimate the wheat acreage response function, the expected production function, $Q^e_{i,t+1}$, should be represented as a function of planted acres and expected yields of crops as follows:

$$Q_{i,t+1}^e = A_{i,t} * Y_{i,t+1}^e = A_{i,t} * g_i^e(x_{i1,t}, x_{i2,t}, \dots, x_{ij,t}) \quad (2)$$

where $A_{i,t}$ is acres of crop i in time t and $Y^e_{i,t+1}$ ($g_i^e(\cdot)$) represents per acre expected production function of crop i planted in time t . Solving the first

² There may not be any preharvest date at which a farmer can irrevocably make a decision about the planned output. Even after the crop is planted, planned output can be revised and actions taken accordingly in fertilization, pest control, and other practices, such as plowing under a crop or using it for forage. However, the main production decisions are the choices of acreage and technologies to follow planting.

³ Kansas wheat producers are assumed to be faced with a production decision involving only wheat, corn, soybeans, and sorghum, because acres of the other crops (oats, barley, etc) make up small portions of total acreage.

order conditions gives the following wheat acreage response function:

$$A_w = f(PW_{t+1}^e, PC_{t+1}^e, PS_{t+1}^e, PSG_{t+1}^e, w_1, w_2, \dots, w_m, \bar{L}) \quad (3)$$

The model specified in this study relates expected wheat acres to expected producer prices for wheat, corn, grain sorghum, and soybeans; a lagged dependent variable; a time trend; and a dummy variable that represents wheat acreage allotment program. This relationship can be expressed using the following function:

$$AW_t = f(RPW_{t+1}^e, RPC_{t+1}^e, RPS_{t+1}^e, RPSG_{t+1}^e, RIOCI, WA_{t-1}, T, D) \quad (4)$$

where WA_t ; RPW_{t+1}^e , RPC_{t+1}^e , RPS_{t+1}^e , and $RPSG_{t+1}^e$; $RIOCI$; T ; and D are wheat acres; expected real prices for wheat, corn, soybeans, and grain sorghum; index of agricultural production expenses; time trend; and dummy variable, respectively.

The expected prices are generally unobservable. An appropriate price for supply analysis is the post-harvest price expected by producers at the time production decisions are made. Information concerning futures prices can be found in the futures markets.⁴ However, the futures prices are aggregate (or group) judgements on expected prices, so they may not appropriately reflect expectations of future localized prices to which Kansas farmers respond. Also, the timing of the futures contracts may not coincide with the

⁴ Lance and Helmreich conclude that futures prices provide the primary source of market information for their sample of corn and soybean producers. On the basis of extensive empirical analysis, Telser argues that the futures price can be regarded as the market expectation of subsequent cash prices. Gardner and Just and Rausser argue in favor of futures prices in supply analysis, indicating that they forecast relatively well compared to econometric forecasts and suggesting that acreage decisions could be based on futures prices.

timing of planting or harvest decisions of Kansas farmers. Thus, the prices of a futures contract may not totally reflect expected local prices of Kansas farmers.⁵

The instrumental variables techniques developed by Hansen and Sargent, MaCallum, Cumby et al., Hansen, and Hansen and Singleton are used in this study to project expected prices. The instrumental variables techniques consistently represent expected values of endogenous variables in rational expectations models. With this approach, parameters of rational expectations models are estimated by projecting ex-post realizations of endogenous variables on a set of relevant instruments drawn from the agents' information set. Rational expectations require that the difference between the expected value of a variable and its eventual realization, i.e., the estimation errors, be uncorrelated with relevant information contained in the information set at the time expectations are formulated. This fact forms the basis of the Generalized Method of Moments (GMM) estimator, developed by Hansen and Singleton.

The GMM estimator exploits the property that rational expectations are conditional expectations of sample moments. The GMM estimator minimizes a sample error of objective function by applying instrumental variables estimation techniques directly to the orthogonality condition implied by rational expectations. The use of instrumental variables in evaluating the determinants of wheat acreage provides a consistent and straightforward means for incorporating expectations and overcomes any biases resulting from the

⁵ Empirical work by Tomek and Gray and by Stein raises questions about whether futures prices are appropriate price forecasts. Stein states that "prior to four months to maturity, the futures price is a biased and worthless estimate of price maturity."

fact that wheat acreage and those factors that influence wheat acreage may be jointly determined. Furthermore, the careful use of lagged values of the endogenous variables as instruments provides a straightforward means of incorporating dynamics.

The empirical relationships given by equation (3) is assumed to represent the equilibrium determination of wheat acreage through the collective actions of optimizing buyers and sellers in the wheat market. Thus, we can replace the expected acres with their realizations and define an error function in implicit as:

$$e_{t+1}(\gamma) = WA_t - f(RPW^e_{t+1}, RPC^e_{t+1}, RPS^e_{t+1}, RPSG^e_{t+1}, RIOC_{1,t}, WA_{t-1}, D, T) \quad (5)$$

where γ are parameters implicit in $f(\cdot)$ that relate expected wheat acres to their theoretical determinants. Rational expectations require that the error function be uncorrelated with any variables in the information set that could be used by optimizing agents to forecast WA^e_t . A suitable vector of instruments, z_t , drawn from the information set, can be used to form the orthogonality condition:

$$E_t[e_t(\gamma^0)z_t] \quad (6)$$

where γ^0 are the true (but unknown) values of the parameters, and E_t is the conditional expectations operator. The law of iterative projections (Sargent) implies that:

$$E E_t[e_t(\gamma^0)z_t] = 0 \quad (7)$$

where E is the unconditional expectations operator. Thus, we can define a random variable, m_t , using this orthogonality condition as:

$$m_t = [e_t(\gamma^0) \otimes z_t]. \quad (8)$$

Rational expectations tell us that the first moment of this variable is zero. Thus, we can use GMM procedures to estimate the parameters relating wheat

acreage and its determinants by forcing the sample mean of m_t (given by $1/n \sum_{t=1}^n m_t$) to its population moment of zero, as given by equation (5).

The specific analytical model used to relate wheat acreage to its determinants is a log-linear representation of equation (3):

$$LWA_t = \alpha + \beta_1 LRPW_{t+1}^e + \beta_2 LRPC_{t+1}^e + \beta_3 LRPS_{t+1}^e + \beta_4 LRPSG_{t+1}^e + \beta_5 D + \beta_6 LWA_{t-1} \quad (9)$$

The estimation proceeds by replacing the expected variables by their futures prices and selecting instruments to form the orthogonality condition implied by equation (7). Instruments should be predetermined and useful to agents in formulating expectations of the endogenous variables. In this analysis, lagged values of the endogenous variables and an index of agricultural production expenses, a dummy, and a time trend variable are used as instruments to obtain the orthogonality given by (7) and to purge the parameter estimates of equation (9) of simultaneity. Specifically, the following instrument set is used in the empirical applications of the GMM procedures:

$$z_t = (1, LRFW_t, LRFPC_t, LRFPS_t, LRFPSG_t, LRIOC_{t-1}, LWA_{t-1}, D, T) \quad (10)$$

The use of lagged dependent variable incorporates dynamics into the determination of equilibrium wheat acres. The use of an index of agricultural production expenses and time trend variable implicitly incorporates the effects of production costs and technological changes on wheat acres in the model. Four models are specified for comparisons. Model 1 incorporates three price variables (corn is not included)⁶, a lagged dependent variable, and a dummy variable. Model 2 is like model I, but sorghum price is eliminated. Model 3 does not include prices of any substitutes for wheat price. All four

⁶ Corn usually is grown on irrigated land in Kansas whereas wheat, soybeans, and grain sorghum are grown mainly on dry or summer fallow land. This implies that corn may not be a substitute for wheat in terms of use of land.

prices are included in model 4.

Data Development

Averages of the Chicago weekly contract prices for wheat and corn from September through November 10th for the next July are used.⁷ Contract prices of soybeans during the wheat planting time period were not available, so they are calculated by adding 3-month T-bill interest to May contract prices.⁸ Because sorghum contract prices were not available, the next July prices received by Kansas producers are used as proxies. The weekly contract prices of wheat, corn, and soybeans are obtained from the Grain and Feed Market News (USDA). The sorghum prices are obtained from the Agricultural Prices (USDA). Wheat acreage, producer prices, and index of agricultural production expenses are obtained from the Kansas Farm Facts (Kansas State Board of Agriculture). All price variables are deflated by the Consumer Price Index. The 3-month T-bill rates and the CPI are obtained from the Economic Indicators (Council of Economic Indicators).

Empirical Results

The GMM procedures were applied to the annual data from 1970 through 1990. Table 1 shows the results for the four wheat acreage response functions. In models 1 and 2, the wheat price variable has a correct sign and is significant at the 5 percent level. Soybean price is significant at the 5 percent level except in model 4. Thus, soybeans can be interpreted as a

⁷ Kansas wheat is planted from September through the middle of November and harvested from June and July of the next year (Kansas Farm Facts).

⁸ The expected product prices that Kansas wheat producers consider in their planting decisions are assumed to be the prices at wheat harvest (the next July). This assumption may be appropriate because wheat is the dominant crop in Kansas.

substitute for wheat in Kansas. The results show that corn and grain sorghum prices are not important variables in Kansas producers' decisions on wheat acreage. The two price variables have incorrect signs and parameter estimates are not significantly different from zero. This may be due to the current government program restrictions, which do not allow shifting between wheat and sorghum or corn production.

The "best" results are obtained with model 1. The estimated equation explains 83% of the variation in Kansas wheat acreage, and all variables except sorghum price have the anticipated signs and are significant at the 5% level. As expected, acreage reduction programs reduced Kansas wheat acres, though not by a statistically significant amount. This is mainly because wheat is the dominant crop.

In the log-linear function, parameter estimates are elasticities. In model 1, the results shows that a one percent increase in real futures price for wheat induces a 0.467 percent increase in wheat acreage. The cross soybean-price elasticity of wheat acreage is -0.522. This means that a one percent increase in real soybean futures price will cause wheat acreage to decrease by 0.522 percent. Thus, wheat and soybeans are substitutes in terms of land utilization. The elasticity of grain sorghum price is very low, 0.094. This implies that wheat producers respond less to changes in grain sorghum price than to those in wheat and soybeans prices. When acreage reduction programs were implemented, wheat acreage in Kansas was reduced by roughly 5%. The lagged dependent variable is significant as in most supply function analysis, representing partial adjustment.

Summary and Conclusions

Wheat acreage response functions were estimated for Kansas by using the GMM procedure. The results with model 1 show that wheat and soybean real futures prices and lagged dependent variable are important factors in the wheat acreage decision of Kansas farmers. Soybeans was a substitute in terms of land use; however, grain sorghum and corn prices were not significant in the wheat acreage decision. As expected, acreage reduction programs had reduced Kansas wheat acres, but not by a statistically significant amount.

Implications from this study suggest that policies affecting corn and grain sorghum prices probably are not important factors in the wheat acreage decision. Policies that affect the price of soybeans are much more important in determining wheat acreage. The response to changes in expected wheat price is inelastic, suggesting that a 30% change in expected wheat price will increase acreage planted by roughly 15%. Given the changes in wheat and soybean prices in the last year and assuming that no other major changes will occur, the results from this paper suggest that wheat acreage in Kansas probably will increase on the order to 10 to 15% in Kansas during the 1993 crop year.

The U.S. wheat production sector is highly subsidized by government policies, which affect farmers' decision making about production, marketing, input use, etc. Together with the futures prices, other price data, such as target prices and price received, may be considered. Futures other than Chicago futures prices, as well as resource and weather constraints and demand conditions not included in this study, may be needed to explain the wheat acreage response of Kansas farmers.

Table 1 Estimation Results of Wheat Acreage Response Functions

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	1.522(0.001)	2.128(0.004)	0.761(0.050)	0.185(0.043)
Wheat Price	0.467(0.01)	0.449(0.013)	0.030(0.517)	0.185(0.616)
Corn Price				0.389(0.291)
Soybean Price	-0.522(0.011)	-0.486(0.013)		-0.634(0.055)
Sorghum Price	0.094(0.111)			0.025(0.819)
Dummy	-0.054(0.085)	-1.382(0.189)	-1.244(0.231)	-0.062(0.208)
Lagged Wheat Acreage	0.570(0.000)	0.356(0.200)	5.099(0.000)	0.677(.0005)
R^2	0.831	0.812	0.658	0.601
\bar{R}^2	0.771	0.745	0.594	0.417
D.W	1.954	2.102	1.962	1.842
F	13.802	12.108	10.272	3.26
DF	20	20	20	20

Note: Figures in () are probability values for the estimated parameters.

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