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JOINT ESTIMATION OF U.S. FIELD CROP SUPPLY FUNCTIONS

by

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JOINT ESTIMATION OF U.S. FIELD CROP SUPPLY FUNCTIONS

C. Richard Shumway and Robert C. Green*

Abstract

Jointly-estimated short-run U.S. supply equations are obtained for 13 field crops using a CET-constrained linear supply model. All cross-commodity price relations are estimated, and own-price supply response is derived. A surprisingly large number of the estimated parameters have high t-values suggesting that the statistical performance of the model is quite good. However, half of the cross-commodity price parameters have unexpected signs. The maintained hypothesis of profit maximization is challenged in an ad hoc test, and the parameter estimates are not very robust to changes in model specification. Consequently, the model does not appear generally well-suited for continued use in the estimation of U.S. commodity supply functions.

JOINT ESTIMATION OF U.S. FIELD CROP SUPPLY FUNCTIONS

Introduction

Brandow and George-King have previously conducted comprehensive studies of U.S. demand for food products. A complete set of income elasticities and own and alternative-product price elasticities were estimated or derived in the latter study for 51 products. The very existence of these studies begs a supply sequel. Yet, as production economists have continued to devote much attention to estimation of supply relationships, attention to own-price response has dominated. Until very recently, estimation of alternative-product price effects was almost non-existent.

Just's (1974) analysis of field crop supply response in subregions of California was one of the first studies to include as many as two alternative products prices in an econometric supply equation. Several linear programming studies preceding Just's work included parametric analysis of supply response but to no more than two alternative-product prices (e.g., Colyer and Irwin; Helmers and Lagrone; Dean, Johnson, and Carter).

Only recently has any comprehensive research been undertaken to estimate cross-price supply response for agricultural commodities within the U.S. Econometric estimation of all price parameters in supply systems consisting of as many as six commodities was conducted by Whittaker (1976) for field crops in six regions of the U.S., by Weaver (1977) for food grains, feed grains, and livestock in North and South Dakota, and by Shumway and Chang (1980) for Texas field crops and livestock commodities. Shumway and Chang (1977) derived own and alternative-product price elasticities for a 15-commodity supply system of California field crops and vegetables using linear programming. To date, no study has been reported in which a large

set of potentially relevant product price parameters has been estimated for U.S. agricultural commodities.

The objective of this paper is to begin to fill that void by econometrically estimating the own and alternative-product price parameters of short-run supply for 13 U.S. field crops for the period 1947-1975. Thus, the empirical estimates become the first set of jointly-estimated supply equations for all major field crops in the U.S. The robustness of initial estimates is examined by imposing restrictions on the set of relevant price variables and by redefining one of the non-price proxy variables.

The commodities include barley, corn, cotton, hay, oats, peanuts, rice, rye, sorghum, soybeans, sugar beets, tobacco, and wheat. Together they represent 98% of 1971-75 principal crop harvested acreage and 95% of the principal crop value of production in the U.S. (USDA). The effects of other crop, livestock, and non-agricultural prices on the supply of these 13 commodities is assumed to be negligible.¹

Method of Analysis

Following Whittaker's comparative evaluation of three supply system models, the constant elasticity of transformation (CET) linear supply model was selected for empirical estimation of this supply system. This type of model, developed by Powell and Gruen, was judged by Whittaker to be superior to OLS and restricted (homogeneous of degree zero in prices) least squares models both in the proportion of parameters with signs consistent with theoretical expectations and in predictive accuracy.²

Powell and Gruen's CET linear supply model imposes five assumptions on the k-commodity supply system to obtain estimates of all commodity price parameters while reducing the number requiring explicit estimation from

k^2 to $0.5k(k-1)$. The assumptions include: (a) the industry is comprised of perfectly competitive firms, (b) input level is not a function of product prices in the short-run, (c) industry supply functions are homogeneous of degree zero in product prices, (d) the elasticities of transformation are constant between all pairs of products, and (e) there is a local correspondence at the variable means between the CET production possibilities surface and linear supply functions (i.e., the change in quantity produced of i for a unit change from the mean in the price of j is the same whether measured along the production possibilities surface or measured with a linear supply function).³ Given these assumptions, the symmetrical elasticities of transformation are the parameters of the transformed supply model to be estimated. It is the symmetry and homogeneity conditions that permit the substantive reduction in the number of price parameters requiring estimation. The effect of imposing these restrictions and reducing the number of price parameters requiring estimation is to reduce the collinearity and degrees-of-freedom problem that makes efficiency estimation of the parameters in multi-commodity supply systems so difficult (Kmenta, p. 433).⁴

The Powell and Gruen model is based on a linear commodity supply system in k commodities:

$$(1) \quad y_{i,t} = \sum_{j=1}^k \alpha_{i,j} p_{j,t}^* + s_{i,t} + \mu_{i,t} ,$$

where $y_{i,t}$ is supply of commodity i in year t , $p_{j,t}^*$ is expected price of commodity j in year t , $\alpha_{i,j}$ is the structural parameter measuring response in supply of i to a change in expected price of j , $s_{i,t}$ is a shift function which incorporates the effects of investment and technology, and $\mu_{i,t}$ is the error term. By imposition of the above assumptions on equation (1) Powell and Gruen derive the following system:

$$(2) \quad y_{i,t} = \sum_{j=1}^k \tau_{i,j} z_{i,j,t} + s_{i,t} + \mu_{i,t}, \quad j \neq i,$$

$$(3) \quad \tau_{i,j} \equiv [d(y_i/y_j)](ay_i/ay_j) / [d(ay_i/ay_j)] (y_i/y_j),$$

$$(4) \quad z_{i,j,t} \equiv \bar{y}_i [(p_{j,t}^* / \bar{p}_j^*) - (p_{i,t}^* / \bar{p}_i^*)] / \bar{\omega}_{i,j},$$

$$(5) \quad \bar{\omega}_{i,j} \equiv 1 + \bar{p}_i^* \bar{y}_i / \bar{p}_j^* \bar{y}_j,$$

where $\tau_{i,j}$ is the elasticity of transformation between commodities i and j , $z_{i,j,t}$ is the transformed CET weighted expected price vector, \bar{y}_i is the average supply of commodity i over n years, \bar{p}_i^* is the average expected price of commodity i over n years, and $\bar{\omega}_{i,j}$ is the reciprocal of the average expected share of commodity j in the total revenue of commodities i and j .

Shift Variables

Powell and Gruen accounted for shifts in the production possibilities curve caused by changes over time in technology and aggregate input level by treating them as exogenous and incorporating proxies for such variables in the shift function, s_i . Whittaker expanded the shift function to also account for the effects of government commodity programs. The model is further adapted in this study to permit an ad hoc test of the profit maximization hypothesis (implied by assumption a) and to estimate output rather than acreage response. The adaptations introduced are similar to those made concurrently in the study of Texas field crop supply response (Shumway and Chang, 1980).

Specifically, variables hypothesized to shift the production possibilities surface include (a) input level, (b) technology, (c) government com-

modity programs, and (d) weather. Because data are not available for the total quantity of inputs used in the production of these specific commodities, an index of total inputs used in agriculture is the proxy variable selected. As there is a positive relationship between the level of inputs and the level of production, the coefficient of the first shift variable is expected to be positive.

The second shift variable is technology. Following Powell and Gruen and Shumway and Chang (1980), lagged supply is used as an ad hoc measure of capacity of the system for short-run adjustment. The coefficient of adjustment reflects technological or structural stickiness in the adjustment of supply. The coefficient is expected to be positive.

Agricultural commodity policies directly affect the supply of nearly all commodities included in this study. Following Houck and Ryan, policy effects are captured in two variables (weighted support price and weighted diversion payment). Weighted diversion payment is incorporated in the model as the third shift variable. As diversion payments are inversely related to acres planted, the coefficient is expected to be negative. It is possible for diversion to be required for program participation without diversion payments being made. Thus, improvement in the statistical characteristics of the estimates will be obtained if the effects due to existence verses nonexistence of the policy are partitioned out of the supply response. Therefore, a dummy variable (zero-one) is incorporated as the fourth shift variable to identify years when diversion policy was in effect. The coefficient of this variable is expected to be negative.

Weather is perhaps the most important single variable affecting commodity supply. Proxy variables for weather are not typically included in acreage response studies, but are essential in explaining output response.

Thus, an adaptation of Stalling's weather index (the ratio of actual yield to trended yield for each commodity) is used as the fifth shift variable. The coefficient of this variable is expected to be positive.

Expected Prices

Expected prices are defined following Powell and Gruen as a geometric lag series of past prices, truncated on pragmatic grounds at seven years.

$$(8) \quad p_{i,t}^* = a_i \sum_{\ell=1}^7 \beta_i (1-\beta_i)^{\ell-1} p_{i,t-\ell},$$

where β_i is the coefficient of price expectation for commodity i , and a_i is the weighting factor to adjust the weights on the seven lagged price observations to sum to unity.

The coefficient of price expectation (β_i) is estimated for each commodity independently of all other model parameters. It is selected by minimizing the sum of squares between expected and observed prices over the data period as β_i is parameterized from 0.1 to 1.0 in 0.1 increments.

The larger of expected market price or weighted support price (Houck and Ryan) is included in the supply model as the price assumed relevant for supply decisions. Assuming the market is efficient and all commodities are strictly competitive for a given set of inputs, the CET price variable coefficients (i.e., elasticities of transformation in equation (2)) are expected to be negative.

Test of Profit Maximization

The hypothesis that farmers are profit maximizers, which is implicit in the assumption of perfect competition underlying Powell and Gruen's supply

model, is subjected to an ad hoc test here as in Shumway and Chang (1980). While each element in the decision function may have a risk component, only the risk associated with own-commodity returns per acre is considered. Risk is hypothesized to enter the model as a linear additive component such that it does not affect the CET transformation of the linear supply system. It is introduced simply to permit a tentative test of the profit maximization hypothesis.

The risk variable used in this study for each crop is variance of returns per acre. Following Just (1974), it is defined as a geometric function of past variance:

$$(9) \quad v_{i,t}^* = \phi_i \sum_{\ell=1}^{\infty} (1-\phi_i)^{\ell-1} (r_{i,t-\ell} - r_{i,t-\ell}^*)^2,$$

where ϕ_i is the coefficient of risk expectation for commodity i , r is returns per acre, and r^* is expected returns per acre which is defined as a geometric function of past returns:

$$(10) \quad r_{i,t}^* = \theta_i \sum_{\ell=1}^{\infty} (1-\theta_i)^{\ell-1} r_{i,t-\ell},$$

where θ is the coefficient of return expectation.

Defined in terms of an infinite sum, it is an unobservable variable and must be estimated. As in Just, the infinite sum is partitioned into observable and unobservable parts. The first risk variable, which he labels unobservable, represents the combined impact of all subjective knowledge on the variance of returns held at the beginning of the study period (1947). This variable remains fixed through the study period and is treated as a parameter to be estimated. The second risk variable, observable, represents the combined impact of all subjective knowledge on the variance of returns accumulated during the

study period (1947 to $t-1$). The annual returns per acre data and the parameters ϕ and θ fully define the second risk variable.⁵ Given the hypothesis of profit maximization, the coefficients of both risk variables are expected to be zero. Negative coefficients would imply risk aversion and positive coefficients risk preference.⁶ The coefficients of expectation, ϕ and θ are expected to range from zero to one.

Model Estimation

The assumption of symmetric elasticities of transformation necessitates a simultaneous solution of the commodity supply equations. Specification of the risk component necessitates a nonlinear (two dimensional search) solution of each commodity supply equation. Thus, the estimation of the CET commodity supply system when the profit maximization hypothesis is tested is accomplished in three passes.

The system of equations (2) with the symmetry constraint on the τ 's constitute a case of seemingly unrelated regressions (Kmenta, p.517). Thus, in pass 1, the system of k commodity supply equations (excluding risk) is estimated using generalized least squares (i.e., a two-stage Aitken estimator). This pass results in initial consistent estimates of the elasticities of transformation. It is the only one necessary to estimate the parameters of the supply model when profit maximization is treated as a maintained hypothesis.

In pass 2, the initial estimates of the symmetric elasticities of transformation (obtained in step 1) are treated as known structural constraints in the commodity supply system (including risk). As a result, each supply equation can be re-estimated individually. A two-dimensional search of each reduced supply equation (using ordinary least squares regression) results in conditional maximum likelihood estimates of the risk parameters.

In pass 3, the maximum likelihood estimates of the risk parameters are used to define the risk variables. Revised estimates of all coefficients in the commodity supply system are obtained again using generalized least squares as in pass 1.

Results

CET Supply System

Parameters of the CET supply response system estimated under the maintained hypothesis of profit maximization are reported in Table 1. Except for the input variable and the diversion payment dummy variable, the estimated parameters on the shift variables are basically consistent with a priori expectations. Three-fourths of all shift variable parameters have expected signs, and 86% have t-values ≥ 2.0 suggesting that nearly all of these variables are individually important to the explanation of joint supply response. More than 2/3 have both the expected sign and a t-value ≥ 2.0 . Most of the instances of both unexpected sign and low t-value are limited to the estimated parameters on the input variable and diversion payment dummy variable.

The estimated price parameters are equally divided between expected and unexpected signs. Most (82%) have t-values ≥ 2.0 . There is little difference between the proportion of parameters with expected signs that have high t-values and the proportion of parameters with unexpected signs that have high t-values. Thus, although the statistical evidence suggests that most of these variables are important in the explanation of joint supply response, it provides mixed signals on the structure of U.S. production agriculture.

The expectation of negative price parameters in this model is a strong hypothesis. Since they are estimates of the elasticities of transformation,

negative parameters are required if a concave production possibilities surface is to be implied. Positive elasticities of transformation are not technically impossible, e.g., increasing returns to scale in two technically independent commodities is one situation that generates a positive elasticity of transformation. However, such conditions are expected to occur much less often than the concave production possibilities surface (which is a prerequisite for competitive equilibrium). Thus, although the statistical performance of this complex model appears to be remarkably good, the implications of the estimated price parameters cause it to be suspect.

The remainder of this paper is devoted to an examination of additional implications and performance of this model in order to assess its general suitability for joint estimation of U.S. agricultural commodity supply response. Very short-run supply elasticities (holding input level constant) are derived and evaluated. The profit maximization hypothesis is tested. Finally, alternative specifications of the CET supply model are estimated to permit an evaluation of the robustness of the initial parameter estimates.

Supply Elasticities

Short-run elasticities of commodity supply, derived from the estimated CET commodity supply model, are presented in Table 2. Because each equation is presumed homogeneous of degree zero, the own-price elasticity is derived as the negative sum of the cross elasticities. Since many of the cross elasticities are positive, a negative own-price elasticity may be implied. Half of the cross elasticities are positive; 3 of the 13 own-price elasticities are negative.

Short-run supply response to own price is inelastic for 11 crops. With highest own-price elasticity listed first, the crops are rank ordered

as follows: soybeans, oats, rice, wheat, tobacco, peanuts, hay, corn, barley, sugar beets, cotton, sorghum, and rye. By commodity groups, the elasticities of food grains and soybeans tend to be the highest; 3 of the 4 are above 0.7. The elasticities of the feed grains vary greatly but average 0.2. Tobacco falls in the same range as soybeans and most of the food grains, peanuts and hay are a little lower, and cotton, sorghum, and rye are negative. Elasticity estimates from prior studies also vary greatly (Askari and Cummings), but nearly all the current estimates fall generally within the range of previous estimates. Except for the three negative elasticities, the magnitudes appear to be quite plausible empirical estimates of own-price responsiveness.

Estimated cross elasticities are generally small, but the extremes are wider in both directions than own-price elasticities. Two-fifths of the cross elasticities are between zero and 0.4. More than a third are between zero and -0.4. Seven percent are greater than $|1.0|$ with the largest cross elasticity being 1.9.

If commodities are technically independent with increasing returns to scale in each commodity, their own-price elasticities will be negative and their cross-price elasticities positive when input levels are fixed. The three crops with negative own-price elasticities satisfy these conditions. Consequently, a plausible explanation for the empirical estimates of these crops can be provided. It is not so easy to provide a satisfactory explanation for all the other positive cross-price parameters.

Test of Profit Maximization

Risk parameter estimates from pass 2 ($\hat{\phi}$ and $\hat{\theta}$) and pass 3 (observable and unobservable risk variable parameters) are reported in Table 3. In pass

2, parameters were estimated to define the two risk variables. In pass 3, the impact of these variables on supply response was estimated simultaneously with a re-estimation of other parameters of the supply model.

Twenty (77 percent) of the estimated risk variable coefficients have t -values ≥ 2.0 . More than half of the coefficients are negative, 10 are positive and one rounds to zero. Thirteen of the 15 negative coefficients and seven of the 10 positive coefficients have t -values ≥ 2.0 . The evidence of risk averse behavior is greater than that implying either risk preference or risk neutral behavior. Although this constitutes an imperfect test, the maintained hypothesis of the CET supply model that producers operate as if they were profit maximizers appears suspect. Consequently, the appropriateness of the CET model for estimation of U.S. commodity supply response must be further challenged by this test.

With regard to the robustness of the initial parameter estimates, adding the risk variables had a modest impact on the initial estimates. Most parameter magnitudes changed a little and some (6 percent of the shift parameters and 14 percent of the price parameters) changed sign. Two-thirds of the parameters that changed signs became consistent with a priori expectations.

Alternative Model Specifications

Three alternative model specifications were estimated to further examine the robustness of the initial parameter estimates. Each alternative retained the basic CET model structure already formulated.

In the first, additional a priori restrictions were introduced on the set of price variables in each equation. For alternative crops that did not show some evidence of regional competitiveness with a particular crop, their prices were deleted from the set of independent variables in that equation

and the CET supply model was re-estimated. This restriction reduced the number of price coefficients in the system requiring estimation from 78 to 48.

The use of lagged output as a proxy variable for technology was consistent with the Powell and Gruen formulation. However, the justification for this proxy is perhaps the most tenuous argument in the specification of the original model. There are no proxies that are entirely satisfactory; but time, introduced in linear form, is used in the second alternative model in place of lagged output.

The final model combines the changes imposed in the first two alternatives.

None of these three alternatives produced results more in line with theoretical expectations than the original model. In addition, a large number of the initial parameter estimates changed signs in these alternative specifications. In each alternative, 18 percent of the shift variables changed sign from the initial estimates. Of the price parameters estimated in both models, 27-37 percent changed sign in the alternative specifications. These changes suggest that the initial parameter estimates are not very robust to alternative model specification.

Conclusions

This study apparently represents the first attempt to jointly estimate all relevant price parameters for an agricultural supply system of this size. Because of the large scope, the CET supply model was selected for the express purpose of reducing collinearity problems and conserving degrees of freedom.

The initial model performed very satisfactorily in terms of high *t*-values on most of the 140 parameters estimated. Although most of the shift variable parameters had the expected signs, half of the price parameters did not. All own-price elasticities of supply were consistent with expectations or could be plausibly explained, but many of the cross-price elasticities were not easily explained.

Further evidence in terms of (a) an ad hoc test of the maintained hypothesis of profit maximization and (b) alternative model specifications add further challenge to the general suitability of the model for estimating U.S. commodity supply response. The profit maximizing hypothesis is suspect, and the parameter estimates are not very robust to changes in model specification. Thus, other models need to be explored for the important purpose of jointly estimating the parameters of agricultural supply response. This conclusion is also implied by Shumway and Chang's (1980) empirical findings using a similar model for regional supply response estimation and by Shumway's (1982) discovery of a conceptual problem with the Powell-Gruen CET supply model when applied to systems with more than two products.

Table 1. CET Commodity Supply System Parameter Estimates with Profit Maximization as a Maintained Hypothesis

Commodity	Intercept	Input Level	Lagged Output	Shift Variables		
				Diversion Policy		
				Weighted Payment	Dummy Variable	Weather
Barley	1715981. (234718.)	-16636. (2093.)	0.540 (0.055)	-137407. (108691.)	16211. (15012.)	161035. (29850.)
Corn	7389388. (1051636.)	-95210. (9729.)	0.676 (0.028)	-1707102. (278625.)	-247677. (43934.)	4075782. (141040.)
Cotton	-20807311. (2226765.)	223575. (20905.)	0.025 (0.024)	-18992020. (1245976.)	473858. (84684.)	4238930. (237015.)
Hay	-68661. (21291.)	-515. (173.)	0.646 (0.041)			166217. (8258.)
Oats	-278027. (566835.)	2967. (5328.)	0.252 (0.050)			775782. (84304.)
Peanuts	5346897. (997404.)	-66978. (9591.)	0.417 (0.027)			2927330. (126856.)
Rice	-138032. (42141.)	817. (368.)	0.973 (0.046)			61625. (9671.)
Rye	68246. (29777.)	-1149. (280.)	-0.227 (0.032)			84265. (3144.)
Sorghum	4577240. (405536.)	-43971. (3862.)	0.602 (0.030)	1. (0.)	30306. (17031.)	170045. (29623.)
Soybeans	-528408. (315507.)	82. (2836.)	0.842 (0.026)			671970. (59963.)
Sugar beets	-12091. (10864.)	-91. (105.)	0.927 (0.040)			22899. (1722.)
Tobacco	-4999837. (985201.)	47318. (8837.)	0.863 (0.064)			2927330. (126857.)
Wheat	-1987491. (422117.)	17378. (3857.)	0.248 (0.025)	-46735. (21090.)	-47539. (10957.)	1269621. (47714.)

Table 1. Continued.

Commodity	CET Price Variables												
	Barley	Corn	Cotton	Hay	Oats	Peanuts	Rice	Rye	Sorghum	Soy-beans	Sugar beets	Tobacco	Wheat
Barley		-1.142 ^a (0.121)	0.334 (0.061)	-0.476 (0.081)	1.076 (0.173)	0.111 (0.149)	1.182 (0.126)	-1.566 (0.196)	0.600 (0.082)	0.261 (0.113)	-0.172 (0.099)	-0.373 (0.089)	-0.448 (0.098)
Corn			-0.055 (0.051)	-0.129 (0.035)	-1.199 (0.124)	-0.955 (0.094)	-0.689 (0.109)	1.911 (0.201)	-0.084 (0.095)	-0.873 (0.068)	-0.153 (0.103)	0.619 (0.067)	0.403 (0.051)
Cotton				0.411 (0.036)	0.144 (0.067)	-0.262 (0.050)	0.115 (0.064)	0.144 (0.095)	0.153 (0.077)	0.412 (0.062)	-0.620 (0.057)	-0.468 (0.058)	-0.914 (0.059)
Hay					-0.937 (0.095)	-0.786 (0.095)	-1.263 (0.094)	0.593 (0.146)	0.243 (0.065)	0.379 (0.053)	0.150 (0.075)	-1.097 (0.064)	0.162 (0.045)
Oats						2.278 (0.154)	0.832 (0.149)	-0.799 (0.262)	0.841 (0.102)	-0.420 (0.120)	0.561 (0.119)	-1.052 (0.096)	-0.281 (0.103)
Peanuts							-0.197 (0.110)	-0.337 (0.183)	0.060 (0.064)	0.242 (0.101)	0.618 (0.093)	-0.541 (0.091)	-0.494 (0.090)
Rice								-1.390 (0.177)	0.372 (0.101)	0.147 (0.105)	0.353 (0.095)	0.280 (0.082)	-0.501 (0.106)
Rye									0.278 (0.113)	0.157 (0.201)	0.112 (0.121)	-0.386 (0.152)	1.664 (0.187)
Sorghum										-0.243 (0.103)	-0.567 (0.078)	0.167 (0.079)	-0.990 (0.088)
Soybeans											-0.731 (0.104)	-0.163 (0.080)	-0.180 (0.070)
Sugar beets												0.171 (0.075)	1.115 (0.093)
Tobacco													0.459 (0.067)
Wheat													

^aThe parameters on the CET price variables are estimates of the elasticities of transformation (e.g., -1.142 is the estimated elasticity of transformation between corn and barley). Standard errors are in parentheses.

Table 2. Short Run Elasticities of Supply

Commodity	Elasticity with Respect to the Price of												
	Barley	Corn	Cotton	Hay	Oats	Peanuts	Rice	Rye	Sorghum	Soy-beans	Sugar beets	Tobacco	Wheat
Barley	0.17	-1.06	0.27	-0.41	0.69	0.04	0.54	-0.11	0.39	0.21	-0.07	-0.27	-0.39
Corn	-0.09	0.29	-0.01	-0.04	-0.14	-0.04	-0.05	0.01	-0.01	-0.24	-0.01	0.11	0.12
Cotton	0.06	-0.04	-0.03	0.30	0.04	0	0.20	0	0.05	0.23	-0.09	-0.19	-0.53
Hay	-0.06	-0.08	0.17	0.48	-0.19	-0.07	-0.14	0.01	0.05	0.15	0.01	-0.33	0
Oats	0.38	-1.05	0.10	-0.74	1.10	0.59	0.25	-0.05	0.44	-0.31	0.16	-0.65	-0.22
Peanuts	0.07	-0.91	-0.29	-0.72	1.68	0.62	-0.11	-0.04	0.05	0.21	0.34	-0.45	-0.45
Rice	0.63	-0.64	0.10	-1.13	0.54	-0.08	0.90	-0.13	-0.26	0.13	0.17	0.22	-0.45
Rye	-1.45	1.90	0.14	0.59	-0.78	-0.30	-1.26	-0.63	0.27	0.16	0.10	-0.38	1.64
Sorghum	0.20	-0.07	0.11	0.19	0.40	0.01	0.12	0.01	-0.22	-0.29	-0.13	0.40	-0.73
Soybeans	0.05	-0.64	0.19	0.22	-0.11	0.03	0.03	0	-0.13	1.40	-0.23	-0.10	-0.71
Sugar beets	-0.10	-0.14	-0.53	0.14	0.40	0.28	0.19	0.01	-0.33	-1.49	0.13	0.09	1.35
Tobacco	-0.10	0.50	-0.28	-0.78	-0.41	-0.09	0.07	-0.01	0.28	-0.17	0.02	0.74	0.23
Wheat	-0.06	0.28	-0.38	0	-0.06	-0.05	-0.07	0.02	-0.24	-0.53	0.16	0.11	0.82

Table 3. Risk Parameter Estimates

Commodity	Pass 2 Estimates		Pass 3 Estimates	
	$\hat{\phi}$	$\hat{\theta}$	Unobservable Risk	Observable Risk
Barley	0.1	0.1	-99098.5 (22841.1)	31.5 (6.6)
Corn	0.1	0.1	-1368460.8 (78959.1)	97.4 (3.8)
Cotton	0.3	0.1	-1022888.0 (273527.1)	-42.3 (19.1)
Hay	0.1	0.1	-24703.4 (1976.8)	2.5 (0.4)
Oats	0.1	0.1	31817.9 (77363.0)	-171.5 (55.7)
Peanuts	0.5	0.1	-393943.2 (143184.1)	2.0 (2.6)
Rice	0.1	0.1	8183.1 (4975.6)	0.3 (0.0)
Rye	0.9	0.1	-849749.5 (149737.1)	44.7 (8.0)
Sorghum	0.7	0.1	-1027069.6 (34954.3)	-27.8 (5.7)
Soybeans	0.1	0.1	-440526.8 (29845.6)	18.5 (2.0)
Sugar beets	0.7	0.1	-5885.4 (1288.9)	0.0 (0.0)
Tobacco	0.3	0.3	-139439.4 (90862.7)	-0.1 (0.2)
Wheat	0.9	0.9	-73738024.4 (4450204.5)	153.3 (9.3)

Standard errors are in parentheses.

Footnotes

1. This assumption is admittedly a gross simplification. For example, livestock prices certainly affect feed grain production. However, they do so largely by their effect on feed grain prices. Since feed grain prices are included as independent variables in this analysis, the assumption of separability between field crops and other commodities is imposed without formal test in order to limit the scope of the study.
2. Each equation in the restricted least squares model was constrained to be homogeneous of degree zero in prices and government policy variables.
3. Firm-level supply functions that are homogeneous of degree zero in product prices are implied by assumptions (a) and (b).
4. Alternative modeling approaches not considered at the time this study was initiated have a similar effect on parameter parsimony. Estimation of the system of derivative equations of a second-order Taylor's expansion of the indirect restricted profit function requires the same number of free parameters to be estimated and does not require imposition of the CET assumption. In retrospect, such a model (e.g., Weaver) would typically be preferred for analysis of inter-commodity supply response. Other problems with the Powell-Gruen CET linear supply model became apparent after this study was completed. These problems prevent a clear interpretation of the estimated cross-price parameters in systems of this size. Consequently, the empirical results obtained in this and other studies using the Powell-Gruen CET linear supply model to examine systems with more than two products must be interpreted with caution.
5. The second risk variable is in fact a function of returns data from 1939-75, although the study period is 1947-75. The reader is referred to either Green or Just for elaboration of the variable specification.
6. This test of profit maximization is not completely unambiguous (see Shumway and Chang, 1980).

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