STRUCTURE OF SOUTH CENTRAL AGRICULTURAL PRODUCTION

Rudolph A. Polson and C. Richard Shumway

Abstract

Using a dual economic specification of a multiproduct technology, the structure of agricultural production was tested for five South Central states (Texas, Oklahoma, Arkansas, Mississippi, and Louisiana). A comprehensive set of output supplies and input demands comprised the estimation equations in each state. Evidence of nonjoint production in a subset of commodities was detected in four of the five states. Several commodities also satisfied sufficient conditions for consistent aggregation. However, the specific outputs satisfying each structural property varied by state. Sufficient conditions for consistent geographic aggregation across the states were not satisfied. These results provide empirical guidance and important cautions for legitimately simplifying state-level model specifications of southern agricultural production.

Key words: dual models, geographic aggregation, nonjointness, separability

When modeling complex production relationships such as the production of multiple outputs by a single firm or industry, one of the most difficult challenges facing the analyst is striking an appropriate balance between desirable detail and necessary abstraction in the model design. The theory of production is a firm-level theory because the firm level is where production and allocation decisions are made. However, it is not generally possible to econometrically examine production relationships at the most disaggregated level conceivable. Data limitations, high collinearity that exists within the data, computational burden, interest in deriving aggregate inferences, and the difficulty of drawing aggregate inferences from highly disaggregated data and analyses all combine to encourage data aggregation and simplification of economic models.

No general theory exists that permits the analyst to know prior to examining the data just how much model simplification is legitimate for a particular purpose. Theoretically-derived sufficient conditions for certain types of model simplification (e.g., production independence, output and input aggregation, geographic aggregation) have been developed. Whether or not they are satisfied is an empirical question for each dataset, and no general rules of simplification independent of the data have been discovered that apply across a wide variety of production situations. One method of dealing with this problem is to determine the extent of output independence in production and the extent of justifiable output, input, and geographic aggregation for the particular data of interest.

Tests of structural production hypotheses that are important both for model building and estimation can be performed. For example, nonjointness reduces the amount of information required of the data since alternative output relationships need not be investigated. Consistent output and/or input aggregation and two-stage choice are possible for separable output and/or input subsets which permit the analyst to use fewer economic variables in each stage of the optimization (Lau 1978; Shumway; Ball; Pope and Hallam; Weaver 1983). The existence of identical production technologies permits legitimate geographic aggregation of data prior to economic analysis.

These important structural properties have not been adequately investigated prior to modeling multiproduct relationships. A recent study by Shumway and Alexander, for example, developed output supply and input demand parameter estimates assuming a quadratic production technology for all ten USDA farm production regions but did not investigate technological differences among regions. Ball assumed consistent aggregation for five output and seven input categories in analyzing aggregate U.S.

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Agricultural production. While Ball and Shumway and Alexander rejected production independence (*i.e.*, short-run nonjointness) of all outputs in most geographic units, tests of independence within subsets of outputs were not conducted. Lopez (1984, p. 359) utilized aggregate indices for Canadian agriculture but cautioned that "... this might not be a plausible assumption... since it does not allow measurement of the interdependence among outputs and the differential effects of various outputs on factor demands." In none of these studies, nor in most others, have any comprehensive tests of the technology been conducted as a basis for modeling multiproduct production.

The primary purpose of this study, therefore, is to address some of the important modeling and aggregation issues inherent in estimating multiproduct relationships. Tests of structural relationships were performed to determine legitimate analytical simplifications for modeling crop production relationships in the five South Central states (Texas, Oklahoma, Arkansas, Louisiana, and Mississippi) comprising two USDA farm production regions (Southern Plains and Delta States). Tests were conducted to determine empirical support for (1) short-run output independence, (2) consistent output and input aggregation, and (3) consistent geographic aggregation. While the tests used are not new, this study reports their most comprehensive application to date.[1]

TECHNOLOGY TESTS

Because the true functional form of a production technology is unknown and because computational burdens are greatly increased for large models when hypothesis tests require nonlinear restrictions, these tests emphasize simplicity and approximation. Following Shumway, dual tests of various hypotheses concerning production structure were conducted by means of linear restrictions. Alternative second-order Taylor-series expansions (locally flexible functional forms) were used to approximate the unknown functional form of the true restricted profit function. Assuming competitive behavior, exogenous prices, and standard regularity conditions (including twice-continuous differentiability) on an aggregate multiple-output state-level production technology, the restricted profit function is finite, nonnegative, monotonic, linear homogeneous, convex, and twice-differentiable in netput prices.[2] The tests of the production structure hypotheses were carried out in a sequential fashion. Because of the sequential nature of subset selection for the nonjointness and homothetic separability tests, no assurance can be given that the results are invariant to the order of these tests.

Nonjointness

If production of one output, say $x_{\iota+1}$, is independent of decisions about the production of all other outputs, say $x_{\iota+2},...,x_m$, production of $x_{\iota+1}$ is nonjoint in inputs and there is no need to incorporate information about quantities or prices of the outputs in modeling the supply response of $x_{\iota+1}$. The assumption of nonjointness is the theoretical justification for any single-commodity model which excludes alternative output prices and quantities from its specification. The necessary and sufficient conditions for short-run nonjointness in inputs of output x_i, $i = \iota + 1,...,m$ (Lau 1972; Shumway *et al.*) are (1)

$$(1) \quad \frac{\partial^2 \tilde{\pi}}{\partial \tilde{p}_i \partial \tilde{p}_j} = 0, \text{ for } j = \iota + 1,...,m, \; j \neq i,$$

where $\tilde{\pi} = \frac{\pi}{p_0}$ is normalized restricted profit, π is returns in excess of variable costs, $\tilde{p}_i = \frac{p_i}{p_0}$ is the normalized price of netput i, $p_0,...,p_\iota$ are variable input prices, and $p_{\iota+1},...,p_m$ are output prices. Tests for short-run nonjointness were conducted through linear restrictions on the parameters of the normalized quadratic specification of the restricted profit function,

[1] As noted by one of the anonymous reviewers, the underlying reasons why certain aggregations of data are legitimate, and the circumstances under which highly disaggregated estimations are required, relate to why and how producers react as decision makers to economic forces. It is these decision makers (producers, farmers, managers) who should ideally form the basic units for which testing of output independence and aggregation begins. Unfortunately, our data do not permit such tests to be conducted at the firm level.

[2] The assumption of price-taking competitive behavior in state-level agricultural production data has recently been subjected to nonparametric testing by Lim. He found that measurement errors of less than 2 percent in the quantity data would have been sufficient to render complete consistency with price-taking competitive behavior in each of the five South Central states analyzed here during the period 1956-1982. Thus, this behavioral assumption is treated along with each of the regularity conditions as a maintained hypothesis.

$$\tilde{\pi} = b_0 + \sum_{i=1}^{m} b_i \tilde{p}_i + \sum_{i=m+1}^{n} b_i x_i$$

$$(2) \quad + .5\left(\sum_{i=1}^{m} \sum_{j=1}^{m} b_{ij} \tilde{p}_i \tilde{p}_j + \sum_{i=m+1}^{n} \sum_{j=m+1}^{n} b_{ij} x_i x_j\right)$$

$$+ \sum_{i=1}^{m} \sum_{j=m+1}^{n} b_{ij} \tilde{p}_i x_j,$$

where $x_{m+1},...,x_n$ are exogeneous variables other than output and variable input prices (*i.e.*, fixed input quantities, government policy variables, weather and time), and b_0, b_i, and b_{ij}, are parameters of the system to be estimated.

The first derivatives of $\tilde{\pi}$ in $\tilde{p}_i$ are the vector of netput equations (positive output supplies and negative variable input demands), and the parametric test for nonjoint production of outputs within a subset N is

$$(3) \quad b_{ij} = 0, \text{ for all } i \in N \text{ and for all } j = \iota + 1,...,m; j \neq i.$$

Short-run nonjointness in inputs was tested for a variety of output subsets in each state. The subsets were selected beginning with the output having the lowest maximum t-statistic on estimated cross-output price parameters in the estimated netput equation. That is, the first output selected for the short-run nonjointness test had the lowest t-statistic on the most significant alternative output price parameter. The second output selected had the next lowest t-statistic, etc. Additional outputs were included in successively larger subsets using the same criterion until all outputs were included. The netput equations were estimated as a system using procedures outlined in the Estimation section.

Homothetic Separability

A technology for which all variables in a subset of netputs are weakly separable from other variables permits aggregation of the subset and consistent two-stage choice. The technology is weakly separable in quantities of a subset of netputs if the normalized profit function is homothetically separable in normalized prices of the same subset. The normalized profit function is homothetically separable in a subset if the function is weakly separable in the subset and if the aggregator function is homothetic in all elements of the subset (Lau 1978). Optimization with the aggregated model gives the same aggregate results as with the disaggregated model, and optimal allocations within the separable subset can be determined independently of variables outside the subset.

Determination of consistent aggregation in each state focused on tests both of weak separability and homotheticity in various input and output subsets. Tests were sequential; the test for homotheticity was conducted first, and if not rejected, it was followed by the test for weak separability. Although constant returns to scale is not a maintained hypothesis in this study, Hall's impossibility theorem on nonjointness and weakly separable technology under constant returns to scale was used as a heuristic guide for selecting the order of subsets to test for consistent aggregation.

The ratios of partial derivatives within a homothetic subset are all homogeneous of degree zero. Because global homotheticity requires either nonlinear restrictions on the normalized quadratic or elimination of the second-order terms within the subset, homotheticity was tested using the translog form of the restricted profit function,

$$1n\tilde{\pi} = c_0 + \sum_{i=1}^{m} c_i 1n\tilde{p}_i + \sum_{i=m+1}^{n} c_i 1nx_i$$

$$(4) \quad + .5\left(\sum_{i=1}^{m} \sum_{j=1}^{m} c_{ij} 1n\tilde{p}_i 1n\tilde{p}_j + \sum_{i=m+1}^{n} \sum_{j=m+1}^{n} c_{ij} 1nx_i 1nx_j\right)$$

$$+ \sum_{i=m}^{n} \sum_{j=m+1}^{n} c_{ij} 1n\tilde{p}_i 1nx_j,$$

where c_0, c_i, and c_{ij} are parameters.

A sufficient test of homotheticity of an aggregator function in a subset is homotheticity of $\tilde{\pi}$ in the subset (Lau 1978). The parametric test for homotheticity of $\tilde{\pi}$ in a subset H is the set of linear restrictions,

$$(5) \quad \Sigma_{j \in H} \; c_{ij} = 0, \text{ for all } i \in H.$$

The normalized profit function is weakly separable in a subset if all the ratios of partial derivatives in that subset are independent of other normalized prices and quantities not included in the subset. Global tests of weak separability using any second-order Taylor-series expansion require nonlinear restrictions (Pope and Hallam). Because the ratio of partial derivatives of the normalized profit function is equivalent to netput ratios by Hotelling's lemma, a global approximate test for weak separability in a subset S using linear restrictions was constructed using linear equations of netput quantity ratios (Shumway):

$$(6) \quad \frac{x_i}{x_j} = d_0 + \sum_{r=1}^{m} d_{ijr} \tilde{p}_r + \sum_{r=m+1}^{n} d_{ijr} x_r, \quad \text{for all } i, j \in S, i \neq j.$$

Although these linear netput ratio equations cannot be derived from an explicit form of the profit function, they are locally consistent with an unknown restricted profit function.[3] A subset S is weakly separable if

(7) $d_{ijk} = 0$, for all $i, j \in S, i \neq j$, and for all $k \in S$.

In addition to the ordered tests in successively larger subsets, the largest subset of outputs satisfying the nonjointness restrictions and the largest subsets of outputs and inputs satisfying the homothetic separability restrictions in one state were tested for satisfaction of the same restrictions in all other states.

Identical Technologies

Because information derived from state-level production relationships is state-specific, one limitation of estimating state-level functions is the inability to generalize policy inferences to a regional or national level, especially when similar variables are not exogenous in both specifications. Conversely, one may be unable to draw state-level inferences when employing regional or national data without distorting the effects of important policies affecting producers in the various states. Although it is a critical maintained hypothesis underlying the large number of regional and national agricultural production studies, little empirical attention has been given to the appropriateness of the identical technologies assumption.

Evidence of identical technologies across states would provide a legitimate basis for constructing regional price and quantity indices for outputs and inputs and for estimating a regional model. It would imply that agricultural policies have similar effects on producers across states. If technology is not identical across states, then regional aggregation of prices and quantities is not valid (Chambers, p. 188).

The normalized quadratic functional form was used to conduct pairwise tests of identical technologies for the five states comprising the Southern Plains and Delta States farm production regions. The test procedure thus appended the auxiliary hypothesis of a quadratic technology in each state to the set of maintained hypotheses. Subject to a quadratic functional form, identical technologies would imply that the slope coefficients on output and input prices and on all fixed input quantities are similar across states. The tests were conducted on a per-acre basis in order to remove potential distortions caused by large differences in the land endowment among states. The hypothesis was tested in a pairwise, sequential manner such that ten independent models were constructed and estimated for the five states. The unrestricted model for any pair of states was

$$\tilde{\pi} = b_0 + \sum_{i=1}^{m} \sum_{k=1}^{2} b_{ik}\tilde{p}_{ik} + \sum_{i=m+1}^{n} \sum_{k=1}^{2} b_{ik}x_{ik}$$

$$(8) \quad + .5\Big(\sum_{i=1}^{m} \sum_{j=1}^{m} \sum_{k=1}^{2} b_{ijk}\tilde{p}_{ik}\tilde{p}_{jk} + \sum_{i=m+1}^{n} \sum_{j=m+1}^{n} \sum_{k=1}^{2} b_{ijk}x_{ik}x_{jk}\Big)$$

$$+ \sum_{i=1}^{m} \sum_{j=m+1}^{n} \sum_{k=1}^{2} b_{ijk}\tilde{p}_{ik}x_{jk},$$

where k= 1,2 are states, and x is the netput quantity used per acre.

The null hypothesis of identical technologies for a pair of states was tested by the linear restrictions

(9) $b_{ij1} = b_{ij2}$, for all i,j.

VARIABLE CONSTRUCTION AND DATA

Annual data for Texas, Oklahoma, Arkansas, Louisiana, and Mississippi for the period 1951 to 1982 were used in this study. Exogenous variables included in the systems of supply and demand (share) equations and the netput quantity ratio equations were expected output prices, variable input prices, quantities of fixed inputs, and other exogenous variables. The expected output prices were weighted averages of lagged market prices and effective support prices for each of the major farm program crops (*i.e.*, corn, cotton, rice [not in Oklahoma], sorghum, soybeans, and wheat [not in Louisiana]). They were lagged market prices for an "other crops" aggregate and a livestock aggregate.

[3] Equation (6) can also be obtained as the set of first derivatives of the normalized quadratic restricted profit function specified per unit x_j. Because such a formulation would treat x_j as exogenous, this conceptualization is not carried further.

Variable input prices were market prices for fertilizer, hired labor, and miscellaneous variable inputs. All output and variable input prices were normalized (divided) by the price of a fourth input category, capital operating inputs. Fixed input quantities were the amount of family and operator labor, service flows from capital stocks, and land.[4] Other exogenous variables were temperature, precipitation, time, and effective diversion payments.

All price and quantity data for outputs and variable inputs and quantity data for fixed inputs were compiled by Robert Evenson and his associates. Fertilizer quantities were annual estimates of nitrogen, potassium, and phosphate used in each state. Because state-level fertilizer price data were not available, it was assumed that little diversity existed in fertilizer composition within a multi-state USDA farm production region; a quantity-weighted index of fertilizer price was estimated for each region by dividing total regional fertilizer expenditures by the total combined quantity of these three nutrients. Fertilizer data were from *State Farm Income and Balance Sheet Statistics.*

Total expenditures on hired labor included all cash and non-cash perquisites such as room and board on farms where employed. Since workers who receive non-cash benefits typically also receive lower cash wages, the cash value of these perquisites was included in total labor expenditures. Labor expenditures in each state were divided by the wage rate, exclusive of social security contributions for workers receiving only cash wages, to obtain an estimate of hired labor quantity. Labor expenditure data were from *Farm Labor* and *State Farm Income and Balance Sheet Statistics.*

Expenditures on repairs and operation of machinery and buildings (excluding operators' dwellings) were divided by a composite of two national indices (the index of the price of building and fencing supplies and the index of the price of farm and motor supplies) to obtain an estimate of capital operating input quantity. These data were from *Agricultural Prices.* The miscellaneous inputs category was a catch-all for other variable inputs such as pesticides, feed, and seed. The miscellaneous input category was aggregated using the Tornqvist index.

State-level estimates of unpaid operator and other family labor used on farms were from *Farm Labor.* Land measured as the sum of all land in farms was from *Agricultural Statistics* and, for 1981 and 1982, from *Farm Real Estate Market Development.* Service flows from capital stocks included depreciation and investment charges on service structures, farm equipment and on-farm automobiles. Data were from *State Farm Income and Balance Sheet Statistics.*

Price and quantity data for all outputs were annual state-level data from various sources including *Agricultural Statistics, Agricultural Prices, and Field Crop Production, Disposition and Value.* All output prices for individual commodities were season-average prices received by farmers. For all commodities, quantity data were for the harvest of the production year. The "other crops" category included the remaining commercial crops not included in the individual supply equations. The livestock category included cattle and calves, hogs and pigs, sheep and lambs, chickens and eggs, and milk. Both the other crop and the livestock categories were aggregated using the Tornqvist index.

The effects of government policy on supply were addressed very simply in order to conserve degrees of freedom. Following Houck *et al.*, two variables were specified—effective support price and effective diversion payments. The effective support price accounted for announced support prices, loan rates, and associated acreage restrictions. Expected output prices were then computed as weighted averages of lagged market prices and effective support prices with the weights dependent on their relative magnitudes (Romain). Diversion payment programs were available in some of the observation years for corn, cotton, sorghum, and wheat. Computed effective diversion payments for a crop were included in the respective supply equation in each state. Data were from various sources including *Commodity Fact Sheets, Situation Reports,* and Cochrane and Ryan.

Weather variables were state averages of temperature and precipitation for critical growing months, with individual weather station data weighted by the total acreage of harvested cropland. These data were from Weiss *et al.* Time was included in all equations as a proxy for disembodied technological change.

[4] The division of inputs into variable and fixed categories in a static model is partially arbitrary since some adjustment may be possible in all input quantities during a single production period. Those inputs designated as fixed are the most difficult for producers to change rapidly. An underlying assumption of the restricted profit function is that first-order conditions for profit maximization are satisfied for all variable inputs and outputs. No comparable behavioral assumption is applied to the fixed inputs. Therefore, in the spirit of maintaining fewer rather than more hypotheses in the analysis, all major inputs that cannot be fully consumed by the production process in a single period were treated as fixed inputs.

ESTIMATION

Eight output supply (share) equations for corn, cotton, rice, sorghum, soybeans, wheat, other crops, and livestock, and three variable input demand (share) equations for fertilizer, hired labor, and miscellaneous inputs comprised the systems of equations used to test for nonjointness and homotheticity in each state except Oklahoma and Louisiana. Production and market price information for rice in Oklahoma and wheat in Louisiana were incomplete over the estimation period. These commodities were, therefore, aggregated into the "other crops" category of the respective states. For the identical technologies hypothesis test, wheat and rice were aggregated into the "other crops" category in every state, resulting in six output supply equations being estimated for each pair of states for this test. The equations estimated for the nonjointness, identical technologies, and homotheticity tests were the respective systems of first-order derivative equations of (2), (8), and (4) with respect to normalized prices (or the logarithms of prices). The netput quantity ratios, (6), were used to test the hypothesis of weak separability in various subsets of inputs and outputs.

Several properties of the profit function were implied by the conceptual model. These include homogeneity, symmetry, convexity, and monotonicity in prices. Homogeneity was maintained by normalization in all estimation equations. Symmetry was maintained by linear cross-equation restrictions on the estimation equations when conducting tests of nonjointness, homotheticity, and identical technologies. Symmetry could not be maintained in the weak separability tests using the netput quantity ratios. Convexity and monotonicity were not maintained in any estimation. Maintaining convexity and monotonicity require nonlinear inequality restrictions and would therefore greatly increase the computational burden. Further, the asymptotic distributions of the test statistics are unaffected by the inequality restrictions, when valid, thus making it unnecessary with large samples to repeat the structural tests with convexity maintained (Jorgensen and Lau, pp. 71-72; Rothenberg, pp.49-58).

Weather variables were included only in the output supply and the output quantity ratio equations. To preserve degrees of freedom, effective diversion payment variables were included only in own-output supply equations of program commodities and only for the system estimations.

Because the quantity ratio equations were not formally derived from an explicit representation of the profit function, the tests for weak separability were conducted equation-by-equation. Since these test conclusions are not invariant to ratio inversion, the tests were repeated with the netput quantity ratios in the dependent variables inverted. Rejection of weak separability in any ratio within a subset therefore implies rejection of weak separability for the entire subset.

Due to severe collinearity, neither the numeraire equation nor the profit function, (2), (4), or (8), were included in estimating the systems of output supplies and variable input demands. Disturbance terms associated with the systems of equations and with the netput quantity ratio equations were assumed to be normally and independently distributed. Because of the interrelatedness of production decisions, contemporaneous correlation among the supply and demand (share) equation disturbance terms were accounted for. However, independence was assumed across states. The three sets of seemingly unrelated regression systems of input demand and output supply (or share) equations were estimated by iterative generalized least squares (GLS), which is asymptotically equivalent to maximum likelihood. Iterative GLS assures invariance of the share equation estimates to the equation deleted (capital operating inputs). Consistent parameter es-

Table 1. Pairwise Tests of Identical Technologies in Five Southern States

State	F-Statistics[a] for Identical Technologies in: All netputs[b]	Variable netputs[c]
Texas - Oklahoma	7.68	6.73
Texas - Arkansas	7.79	6.27
Texas - Mississippi	8.71	7.30
Texas - Louisiana	8.71	6.00
Oklahoma - Arkansas	6.24	6.77
Oklahoma - Mississippi	7.14	6.00
Oklahoma - Louisiana	8.25	6.50
Arkansas - Mississippi	5.60	4.24
Arkansas - Louisiana	6.58	3.98
Mississippi - Louisiana	6.78	7.67

[a]Computed at the first iteration. In all cases examined, the statistic at the final iteration was larger.

[b]Critical value: $F^{.01}_{63,384} = 1.47$

[c]Critical value: $F^{.01}_{45,384} = 1.57$.

Table 2. Short-Run Nonjointness Test Results

Outputs	State				
	TX	OK	AR	LA	MS
Wheat	NR[a]		R		
Wheat, Livestock	NR	R	R	-[b]	R
Wheat, Livestock, Rice	R				
Wheat, Livestock, Rice, Cotton	R				
Wheat, Livestock, Rice, Cotton, Soybeans	R		R		
Wheat, Livestock, Rice, Cotton, Soybeans, Corn	R		R		
All Outputs	R	R	R	NR	R
Other Crops		NR		NR	
Other Crops, Wheat		NR			
Other Crops, Wheat, Soybeans		NR			
Other Crops, Wheat, Soybeans, Cotton		NR			
Other Crops, Wheat, Soybeans, Cotton, Corn	R	NR	R	-[b]	R
Wheat, Soybeans			R		
Wheat, Soybeans, Cotton			R		
Wheat, Soybeans, Cotton, Rice			R		
Other Crops, Soybeans				NR	R
Other Crops, Soybeans, Cotton				NR	
Other Crops, Soybeans, Cotton, Rice				NR	
Other Crops, Soybeans, Cotton, Rice, Corn				NR	
Soybeans	R	NR	R	NR	NR
Soybeans, Other Crops, Cotton					R
Soybeans, Other Crops, Cotton, Corn					R
Soybeans, Other Crops, Cotton, Corn, Rice					R
Soybeans, Other Crops, Cotton, Corn, Rice, Sorghum					R

[a]R means the test is rejected at .01 level of significance; NR means the test is not rejected.

[b]These tests could not be performed in Louisiana because data series for wheat were incomplete.

timates for the netput quantity ratios were obtained using ordinary least squares (OLS).

EMPIRICAL RESULTS

Because of the large number of models estimated and the number of tests conducted, individual parameter estimates and most test statistics are not reported in this paper. Both the data used and the specific empirical results obtained are available upon request from the junior author.

Consistent Geographic Aggregation

The results of pairwise identical technologies tests are reported in Table 1. The hypothesis of identical

Table 3. Homothetic Separability Test Results

Outputs or Inputs	State: TX		OK		AR		LA		MS	
	Hom[a]	Sep	Hom	Sep	Hom	Sep	Hom	Sep	Hom	Sep
Fertilizer, Hired Labor	R[b]		R		R		R		R	
Fertilizer, Misc. Inputs	R		NR	R	R		NR	NR	R	
Hired Labor, Misc. Inputs	R		NR	R	R		R		NR	R
Hired Labor, Fertilizer, Misc. Inputs	R		R		R		R		R	
Soybeans, Other Crops	NR	NR								
Soybeans, Other Crops, Rice	NR	NR	-[c]	-[c]	NR	R	NR	R	NR	R
Soybeans, Other Crops, Rice, Corn	R									
Soybean, Other Crops, Rice, Corn, Cotton	R									
Soybeans, Other Crops, Rice, Corn, Cotton, Sorghum	R									
Soybeans, Other Crops, Rice, Corn, Cotton, Sorghum, Wheat	R									
All Outputs	R		NR	R	R		R			
Sorghum, Livestock	R		NR	NR	NR	NR	NR	NR	NR	NR
Sorghum, Livestock, Corn	R		NR	NR	R	NR			R	
Sorghum, Livestock, Corn, Cotton			NR	R						
Sorghum, Livestock, Corn, Cotton, Soybeans	R		NR	NR	NR	R	R		R	
Sorghum, Livestock, Corn, Cotton, Soybeans, Wheat			NR	R						
Sorghum, Livestock, Corn, Other Crops					R					
Sorghum, Livestock, Corn, Other Crops, Rice					NR	R				
Sorghum, Livestock, Corn, Other Crops, Rice, Cotton					NR	R				
Sorghum, Livestock, Corn, Other Crops, Rice, Cotton, Soybeans					R					
Sorghum, Rice								R		
Sorghum, Rice, Corn								R		
Sorghum, Rice, Corn, Livestock	R		-[c]	-[c]	R		NR	NR	R	
Sorghum, Rice, Corn, Livestock, Cotton								NR	R	R
Sorghum, Rice, Corn, Livestock, Cotton, Soybeans								R		
Sorghum, Rice, Corn, Livestock, Cotton, Wheat									R	
Sorghum, Rice, Corn, Livestock, Cotton, Wheat, Soybeans									R	

[a]Hom refers to the homotheticity test; Sep refers to the weak separability test.

[b]R means the test is rejected at the .01 level of significance for each test statistic; NR means the test is not rejected.

[c]These tests could not be performed in Oklahoma because there were no data for rice.

technologies in all netputs was rejected at the .01 level for all pairs of the five states. The hypothesis of identical technologies only in the subset of variable netputs was also tested and rejected in all pairs of states. Whether these test results were primarily due to fundamental differences in the applied technology or to differences in heterogenous soils and climate, no evidence was found to support construction of aggregate multi-state models of agricultural production in either of these two farm production regions. Consequently, the remaining tests of production structure were conducted for each individual state.

The results of the nonjointness, homotheticity, and weak separability tests conducted independently for each of the five states are reported in Tables 2 and 3. All individual tests were conducted at the .01 level of significance by computing F-statistics at the final iteration. By Bonferroni's inequality, the probability of rejecting a true null hypothesis would be at most the sum of the probabilities of rejecting each individual hypothesis. For example, the probability of rejecting a true hypothesis of homothetic separability of fertilizer and hired labor under this criterion would be at most .05 since there is one homotheticity test statistic and four weak separability test statistics.

Production Independence

Short-run nonjointness of all outputs in inputs was rejected in all states except Louisiana (Table 2). Nonjoint production was not rejected for (1) wheat and livestock in Texas, (2) other crops, wheat, soybeans, cotton, and corn in Oklahoma, and (3) soybeans in Mississippi. These results indicate that it would be valid to model all outputs in Louisiana and specific output subsets in three of the four remaining states independent of prices and quantities of all other outputs. No alternative cross-output price interactions would need to be included in these equations. Thus, the information required of the data would be greatly reduced since fewer relationships would need to be estimated in each state. There was no evidence of complete consistency across states in the outcomes of any of these tests. Nonjoint production of each of the four output categories tested in every state was rejected in at least one state and not rejected in at least one other state. The most consistent evidence of nonjoint production was found for soybeans; the hypothesis of short-run nonjoint production of this crop was not rejected in three of the five states. Short-run nonjoint production was rejected for every output category tested in Arkansas.

Consistent Commodity-Wise Aggregation

Three variable inputs (fertilizer, hired labor, and miscellaneous inputs) and all subsets of them were tested for consistent aggregation in each state. These tests covered all variable inputs except the numeraire (capital operating inputs). Homotheticity of the restricted profit function in these three variable inputs and in the two-input subset, fertilizer and hired labor, was rejected in every state. Homotheticity in both of the other two-input subsets was rejected in three states. Weak separability was tested in each subset for which homotheticity was not rejected. Among the input subsets, neither homotheticity nor weak separability was rejected for only one subset (fertilizer and miscellaneous inputs) in only one state (Louisiana). Thus, based on the empirical evidence for the data period 1951-1982, only for the fertilizer and miscellaneous input subset in Louisiana can quantity and price variables be legitimately aggregated and consistent two-stage choice analysis conducted for inputs.

Sequential tests of homotheticity and weak separability were also conducted for output subsets in each state beginning with outputs that did not register evidence of short-run nonjointness. Neither homotheticity nor weak separability was rejected in (1) the soybeans, other crops, and rice subset in Texas, (2) the sorghum, livestock, corn, cotton, and soybeans (and two smaller) subsets in Oklahoma, (3) the sorghum and livestock subset in Arkansas and Mississippi, and (4) the sorghum, rice, corn, and livestock (and one smaller) subsets in Louisiana. For all other output categories examined, either homotheticity or weak separability was rejected. It appears legitimate to aggregate both quantity and price variables and conduct consistent two-state choice analysis for at least one output subset in each state. The most consistent evidence of homothetic separability was found for the sorghum and livestock subset. For this category neither homotheticity nor weak separability was rejected in four of the five states.

Implications

The results of these various tests imply that over the data period, (1) it was not legitimate to construct aggregate multi-state models in these two farm production regions, (2) the structure of production varied substantially across states even within the same farm production region, and (3) one cannot expect government farm programs to affect producers in different states in these production regions in similar ways.

Although model specification and data used in this study differ somewhat from previous studies, several qualitative conclusions are consistent with earlier findings. For example, in a study of six Texas field crops using 1957-1979 data, Shumway also rejected homothetic separability in inputs and failed to reject short-run nonjoint production in wheat. Short-run nonjointness in livestock was a maintained hypothesis in the earlier study and was not rejected in the current study. Although the specific outputs differed, homothetic separability in a three-output category was not rejected in either study. Using regional data, Shumway and Alexander rejected short-run nonjoint production of all outputs in the Delta States and Southern Plains farm production regions just as this study does for four of the five states in these regions. Ball, using national data, also rejected nonjoint production of all outputs. In his study of North and South Dakota, Weaver (1977) did not reject separability in one subset of two inputs, as this study does, for two inputs in Louisiana.

CONCLUSIONS

A dual economic specification of a multiproduct technology was used to test the structure of agricultural production in five South Central states comprising two USDA farm production regions—the Delta States and the Southern Plains. Tests were conducted for short-run nonjoint production in inputs, for homothetic separability in output and input subsets, and for identical technologies across states. These results, if valid, indicate that considerable simplification of models describing multiproduct production relationships is possible in each of these states. However, the simplified models vary greatly among states.

Modeling of short-run production decisions without regard to output interrelationships is supported by the data (*i.e.*, nonjointness not rejected) for each output in Louisiana, for each of five outputs in Oklahoma, for two outputs in Texas, and for one in Mississippi. Only in Arkansas is there an absence of support for independent modeling or production for every output. Thus, continued independent analysis of individual output supplies and their policy implications, as has been the norm in the agricultural economics literature, remains justified for an average of 2/5 of the commodities produced in these five states.

Consistent aggregation and two-stage choice is supported by the data (*i.e.*,homothetic separability not rejected) for only two variable inputs in only one state, Louisiana. A higher degree of aggregation is supported by the data for outputs than for inputs. Although the specific crops vary, consistent aggregation is supported for five outputs in Oklahoma, four in Louisiana, three in Texas, and two each in Arkansas and Mississippi. On average, legitimate policy analysis can be conducted using two-state choice models for slightly more than 2/5 of the outputs. However, consistent aggregation of price and quantity data for all outputs is clearly rejected by these parametric tests in each of the five states. Thus, another common practice in production modeling of aggregating all outputs into a single index lacks support.

Expansion paths are straight lines in several output subsets in all states, but these homothetic subsets do not all satisfy the separability restrictions nor are the homothetic subsets the same in all states. In addition, differences in technology and/or heterogenous resources across states imply that state-level models of agricultural production are more reliable for drawing policy inferences than are regional models. There was no empirical basis for consistent geographic aggregation across states in either of these two production regions.

The results of these structural tests shed important light on production model specification. Suggestions for potentially legitimate *a priori* simplification of econometric models have been identified. However, because the test results varied so greatly among states, no generalizations can be drawn either to other states or to different data periods. Further, because the tests relied on linear restrictions, each relates to a different approximation of the true functional form. Although comprehensive in test coverage of South Central states and a wide variety of output and input subsets, these test conclusions should be treated cautiously. Only if they are corroborated by further test results can they be maintained with considerable confidence in model specification.

The need to determine whether these findings are corroborated under alternative equally plausible modeling conditions suggests a clear opportunity for further research. Both parametric and nonparametric test procedures should be considered. Exact parametric tests can be conducted using the often nonlinear restrictions for a range of potentially relevant functional forms. Nonparametric tests can be conducted without maintaining any functional form. Another opportunity would be to estimate the fully disaggregated, interrelated models and contrast their results with those of the aggregated and independent models. A comparison of important inferences relevant for policy analysis and the additional costs (computational, research time, and data burden) of estimating the more disaggregated and interrelated models could make a useful contribution.

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