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PRODUCTION RELATIONSHIPS IN SOUTH CENTRAL AGRICULTURE

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Abstract

Output supplies and input demands were estimated for each of five South Central states. The model structure in each state was based on prior parametric tests of homothetic separability, and estimates were generally consistent with a competitive, profit-maximizing industry. Considerable diversity among states was evident in selected production relationships. These results further document the non-uniform ways in which producers respond to government farm programs and market information.

Key words: competitive behavior, consistent aggregation, output supplies

Intervention in agricultural output and input markets is pervasive at all levels of government. Policy changes are often implemented with little notion of their likely impact on voluntary production decisions. Because of the prevalence of multiple-output producers and the ease with which output mixes can often be adjusted, only measuring direct production consequences (i.e., impacts on the commodity directly affected) of the policy change is inadequate. It is also necessary to anticipate indirect effects on other commodities. Because of differences in agroclimatic conditions and other resource endowments among states, distributional effects of policy changes can also vary substantially across geographical units.

The purpose of this study was to provide empirical estimates relevant for simulating the impact of changes in the economic and political environment in each of five South-Central states (Arkansas, Louisiana, Mississippi, Oklahoma, and Texas). Price and policy responses were estimated for six major program commodities. Cross-price as well as own-price responses were estimated for each output and for four input categories. Elasticities were derived and the impact of decoupling farm program benefits from production decisions was examined in each state. These objectives were facilitated by estimating two-stage optimization models consistent with prior statistical test results. Methodologically, when production structure is homothetically separable in a subset of outputs and/or inputs, both prices and quantities of the subset can be consistently aggregated into one price and one quantity index. Two-stage optimization can then be consistently performed.

Production structure is homothetically separable in a subset if (a) the marginal rate of substitution among all pairs of elements (commodities and/or inputs) in the subset is independent of the level of all elements not in the subset, and (b) the index (aggregator function) is homothetic in all elements in the subset. The ability legitimately to conduct two-stage optimization analyses of production relationships is particularly important in empirical work in agriculture because of the large number of commodities produced and the diverse inputs used. The advantage of two-stage optimization is that less information is demanded from the limited and imperfect data, because the analyst needs to consider only subsets of decision variables in each stage. Commodity-level implications from legitimate two-stage optimization are the same as those obtained from a single fully disaggregated model.

Despite the analytic importance of consistent aggregation and the frequency with which it is implicitly regarded as a valid assumption in empirical analysis, separability tests have been conducted infrequently in agriculture. Their implications have been fully exploited even less frequently. Such tests have been conducted by Shumway; Ball; Pope and Hallam; and Polson and Shumway. After failing to reject homothetic separability in a subset of outputs, Shumway estimated an aggregate model for Texas field crops consistent with this structural hypothesis. But he misspecified the second-stage suboptimization model (by failing to include an aggregate quantity index as a regressor and by normalizing with a price outside the subset), and he did not derive policy-relevant inferences from either model. Ball tested and rejected separability in all outputs for his

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five-output U.S. model, but he did not test this important structural hypothesis in any subset of inputs or outputs. Pope and Hallam did not reject separability of a two-input subset in the production of Westside California cotton, but this result was not utilized for further model design.

This paper builds on previous work by exploiting the homothetic separability test results of Polson and Shumway. They failed to reject consistent aggregation for selected output subsets in each of five South Central states and for an input subset in one state. Evidence was found to support consistent aggregation of (a) sorghum and livestock in Arkansas and Mississippi, (b) corn, rice, sorghum, and livestock in Louisiana, (c) corn, cotton, sorghum, soybeans, and livestock in Oklahoma, (d) rice, soybeans, and other crops (a residual output category) in Texas, and (e) fertilizer and miscellaneous inputs (a residual input category) in Louisiana. Two-stage optimization models were developed and estimated in this study for each of the five states consistent with the earlier findings.

MODEL SPECIFICATIONS

Each state was modeled as a perfectly competitive industry facing exogenous prices for inputs and outputs with a twice-continuously-differentiable and strictly concave transformation function.[1] For each state, maximum profit was modeled in the first stage as a function of output and variable input prices (including those for aggregated subsets), fixed input quantities, and other exogenous variables (i.e., weather, government policies, and technology). The aggregate (first-stage) state-level restricted profit function was modeled using the normalized quadratic functional form (Lau; Huffman and Evenson):[2]

$$(1)\ \Pi = A + P'B + Z'C + P'DZ + .5P'EP + .5Z'FZ,$$

where Π is normalized restricted profit (profit divided by the numeraire price), P is an n-row vector of normalized prices including those for aggregated subsets, and Z is an m-row vector of fixed inputs and other exogenous regressors. The parameter matrices have the following dimensions: A is a scalar, B is n x 1, C is m x 1, D is n x m, E is n x n and F is m x m. Following the netput convention, output quantities were measured positively, and variable input quantities were measured negatively.

One property of this restricted profit function is that its gradient vector, taken with respect to netput prices, is the vector of n output supply and input demand equations (Hotelling's lemma):

$$(2)\ X = \bar{v}_p\Pi = B + DZ + EP,$$

where X is the n-row vector of linear netput equations. The numeraire equation can also be extracted from the restricted profit function by subtracting the n linear-in-price-ratios supply and demand equations from normalized restricted profit. The numeraire equation,

$$(3)\ x_0 = \Pi - P'X = A + Z'C - .5P'EP + .5Z'FZ,$$

is a quadratic function of normalized prices and fixed inputs.

When production is separable in a subset, data within the subset can be consistently aggregated, and optimization can be conducted by stages. Assuming the same functional form as for the aggregate model, the normalized quadratic suboptimization (second-stage) model for the separable subset, s, can be written as

$$(4)\quad \begin{aligned} \pi_s = {} & A_s + P'_sB_s + Z'_sC_s + P'_sD_sZ_s + .5P'_sE_sP_s \\ & + .5Z'_sF_sZ_s + Q'_sG_s + P'_sH_sQ_s + Z'_sI_sQ_s \\ & + .5Q'_sJ_sQ_s, \end{aligned}$$

where π_s is normalized profit for the subset, P_s is the ν-row vector of normalized prices of individual netputs in the separable subset, Z_s is the μ-row vector of exogenous variables not included in the weak separability tests (i.e., weather, government diversion payments, and time), and Q_s is the aggregate netput quantity index of the separable subset. The parameter matrices of the suboptimization model have the following dimensions: A_s, G_s, and J_s are scalars, B_s is ν x 1, C_s is μ x 1, D_s is ν x μ, E_s is ν x ν, F_s is μ x μ, H_s is ν x 1, and I_s is μ x 1. One of the prices within the subset is used to normalize subset profit and all other prices within the subset.

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[1] This maintained hypothesis was not subjected to a full range of parametric tests. However, in nonparametric tests of the joint hypothesis of competitive behavior, concave transformation function, and nonregressive technical change, Lim found that minor measurement errors (less than 2 percent) could have accounted for all departures from the joint hypothesis in each of these five states.

[2] Functional form was not subjected to a specification test using these data. However, a recent empirical test of functional form using U.S. data concluded that the normalized quadratic was preferred to either the generalized Leontief or translog (Ornelas et al.).

Equation (4) is a constrained optimization model that includes the aggregate subset quantity (Q_s) as an exogenous variable. This specification is analogous to a cost function, where output level appears as one of the regressors when the behavioral objective is to minimize costs.

Applying Hotelling's lemma to the suboptimization problem (4) yields the system of linear-in-price-ratios allocation equations

$$(5)\ X_s = \bar{v}_p\pi_s = B_s + D_sZ_s + E_sP_s + H_sQ_s,$$

where X_s is a ν-row vector of allocation equations for the suboptimization model. The vector of estimation equations is a linear function of price ratios within the separable subset, the aggregate quantity index, and the quantity of exogenous variables not included in the weak separability tests. Subtracting (5) from (4) yields the numeraire equation,

$$(6)\ x_v = \pi_s - P'_sX_s = A_s + Z'_sC_s - .5P'_sE_sP_s + .5Z'_sF_sZ_s + Q'_sG_s + Z'_sI_sQ_s + .5Q'_sJ_sQ_s,$$

which is quadratic in normalized prices, the aggregate quantity index, and other exogenous variables. The theory of competitive behavior imposes several restrictions both on the restricted profit function (1) and on the suboptimization model (4). These restrictions include (a) linear homogeneity in prices, (b) monotonicity (increasing in output prices and decreasing in input prices), and (c) convexity in prices. Twice-continuous-differentiability of the transformation function and of the suboptimization model implies cross-price symmetry of parameters within (2) and (5).

Disaggregated elasticities can be derived from parameter estimates of both the aggregate and suboptimization models. From (2), (3), (5), and (6), the elasticity of a netput quantity within the separable subset with respect to a price within that subset is derived as

$$(7)\ \varepsilon_{ij} = \xi_{ij} + \xi_{iq}\eta_{qp}s_j, \quad \text{for all i, j in } X_s \text{ and } x_v,$$

where ξ_{ij} is the partial elasticity from (5) or (6) of the ith netput quantity in the separable subset with respect to the jth price in the subset, ξ_{iq} is the elasticity from (5) or (6) of the ith netput within the separable subset with respect to the aggregate quantity (Q_s), η_{qp} is the elasticity from (2) of the aggregate quantity index with respect to the aggregate price index of the separable subset, and s_j is the jth netput's share of the separable subset revenue (expenditure).

The elasticity of the ith netput within the separable subset with respect to a price outside of the subset is

$$(8)\ \varepsilon_{ik} = \xi_{iq}\eta_{qk}, \quad \text{for all i in } X_s \text{ and k not in } X_s \text{ or } x_v,$$

where η_{qk} is the elasticity of the aggregate quantity index with respect to the price of the kth netput outside the subset.

The elasticity of a netput outside the separable subset with respect to any price within the separable subset is

$$(9)\ \varepsilon_{kj} = \eta_{kp}s_j, \quad \text{for all j in } X_s \text{ and } x_v \text{ and k not in either } X_s \text{ or } x_v,$$

where η_{kp} is the elasticity of the kth netput outside the subset with respect to the aggregate price index for the subset.

VARIABLE SPECIFICATION AND DATA

Annual state-level data for the period 1951-1982 were used in this study. Exogenous variables for the system of estimation equations in each state included expected output prices, variable input prices, quantities of fixed inputs, subset aggregate quantity index (for suboptimization models only), government policy variables, weather, and time.

At the most disaggregated level of analysis, expected output prices were included for each of the major farm program crops (i.e., corn, cotton, sorghum, soybeans, rice [except in Oklahoma], and wheat [except in Louisiana]) as well as for aggregates of other crops and livestock. Two government policy variables were constructed using data from McIntosh following the procedures of Houck et al. An "effective support price" variable was computed accounting for announced support prices and associated acreage restrictions. Expected prices of farm program commodities were then formed as weighted averages of market price expectations and effective support prices, with the weights dependent on their relative magnitudes (Romain). A separate "effective diversion payment" variable was also computed for those crops (corn, cotton, sorghum, and wheat) subject to such programs during a portion of the estimation period. The effective diversion payment variable for a crop was included only in its respective supply equation.

Lagged market prices were used as expected price proxies for the "other crops" and livestock aggregates. Current market prices were used as expected variable input prices for fertilizer, hired labor, and a "miscellaneous inputs" aggregate. All prices in the aggregate models were normalized by the price of a fourth variable input category, machinery operating inputs. Even at the most disaggregated level, considerable output and input data were combined in the three aggregate categories (miscellaneous inputs, other crops, and livestock). Preliminary aggregation of data into these residual categories was necessary to retain enough degrees of freedom to focus the analysis on farm program crops. Higher levels of aggregation were maintained for the aggregate (first-stage) models in this study only for those categories for which homothetic separability was not rejected. Full disaggregation to the levels noted above were achieved in the suboptimization (second-stage) models. All aggregation was accomplished using the Tornqvist Index.

Land, family labor, and service flows from capital stocks were assumed to be exogenously determined over the estimation period in each state. Hence, first-order conditions were not assumed to be satisfied for these variables which were treated as though they were fixed inputs (Taylor and Kalaitzandonakes).

The price and quantity data for outputs and variable inputs and quantity data for fixed inputs were compiled by Robert Evenson and his associates. Details of the data construction and sources were reported in Polson and Shumway. Weather variables were state averages of temperature and precipitation for critical growing months, weighted by the total acreage of harvested cropland. Data for these variables were taken from Weiss, Whittington, and Teigen. They were included in each output supply equation as *ex post* output-influencing measures rather than as *ex ante* decision variables. Time was included in all equations as a proxy for disembodied technological change.[3]

ESTIMATION PROCEDURE

Two-stage analysis of production was conducted for input and output subsets satisfying the sufficient homothetic separability conditions for consistent aggregation. The same data were used in these estimations as were used in the homothetic separability tests.

Output supply equations estimated for the aggregated models included (a) corn, cotton, rice, soybeans, wheat, other crops, and a sorghum- livestock aggregate in Arkansas, (b) cotton, soybeans, other crops, and a corn-rice-sorghum-livestock aggregate in Louisiana, (c) corn, cotton, rice, soybeans, wheat, other crops, and a sorghum-livestock aggregate in Mississippi, (d) wheat, other crops, and a corn-cotton-sorghum-soybeans-livestock aggregate in Oklahoma, and (e) corn, cotton, sorghum, wheat, livestock, and a rice-soybeans-other crops aggregate in Texas.

A variable input demand aggregate was included in the aggregate model only in Louisiana. It combined fertilizer and miscellaneous inputs. In all other states, separate demand equations were specified in the aggregate models for fertilizer, hired labor, miscellaneous inputs, and machinery operating inputs.

The suboptimization models estimated for output subsets included individual equations for sorghum and livestock in Arkansas, corn, rice, sorghum, and livestock in Louisiana, sorghum and livestock in Mississippi, corn, cotton, sorghum, soybeans, and livestock in Oklahoma, and rice, soybeans, and other crops in Texas. Suboptimization models estimated for the input subset included fertilizer and miscellaneous inputs in Louisiana.

Each system of stacked linear and quadratic output supply and/or input demand equations-(2) and (3) for the aggregate models, (5) and (6) for the suboptimization models-for the two-stage optimization process was estimated for each state independently of other states.[4] Estimation of the two-stage process was accomplished subject to linear homogeneity, symmetry, and convexity of the profit function in prices. Monotonicity was not maintained but was checked at every observation following estimation.

Disturbance terms were assumed to be normally and independently distributed with mean zero and constant contemporaneous covariance matrix for each system. Estimation was accomplished using

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[3] To determine whether a deterministic time trend was needed in the specification as a proxy for disembodied technical change, Dickey-Fuller tests of trend nonstationarity were conducted for all outputs and variable inputs. Trend nonstationarity was rejected at the .10 level for more than half of the output and input series. Except for hired labor, it was rejected in at least two states for every series. Rather than selectively including the time variable in an output supply or input demand equation in one state and not including it in another state, it was included in all equations in all states. It should be noted, however, that the test procedure used here was the minimum recommended by Nelson and Kang. Clark and Youngblood offer a more thorough procedure for determining the appropriate time series representation of variables. If the input and output quantity data were not in fact stationary around the linear deterministic time trend and if any independent variables (other than time) were not stationary, the R2 values of the estimated equations and the t- statistics of estimated parameters would be inflated (Nelson and Kang).

[4] The restricted profit function (1) was not included in the estimation system for the aggregate models. All parameters in (1) were estimated by the system, (2) and (3). Likewise, the subset profit function (4) was not included in the estimation system for the suboptimization models.

constrained nonlinear least squares. A reduced gradient nonlinear program (Talpaz, Alexander, and Shumway) was employed using algorithm code MINOS version 5.1 (Murtagh and Saunders) to obtain generalized least squares estimates for each system of output supplies and/or input demands.[5] Due to high collinearity, the interaction terms were not estimated among fixed inputs and among fixed inputs and aggregate quantity indexes. Because the specification of each estimated model was based on nonrejected homothetic separability tests, significance levels reported throughout this paper are conditional on the estimated model specification being the "true" model specification.

EMPIRICAL RESULTS

Because of space limitations and the large number of models estimated, parameter estimates are not reported, but are available upon request. All statistical test results reported in this section use a significance level of .05.

Aggregate Models

Summary statistics for the aggregate model estimates are reported in Table 1. As gauged by the approximation test of Talpaz et al., curvature properties were not significantly violated in any of the states. Monotonicity violations were also not significant in any state. Empirical estimates were consistent with the theory of a perfectly competitive industry facing exogenous prices.

There was evidence of considerable collinearity among the regressors. Condition indices for the systems ranged from 515 in LA to 2508 in TX. Although large, these condition indices are similar in range to those previously reported for some comparable-sized production systems (e.g., Shumway and Alexander). Despite the evidence of collinearity, a substantial proportion (40 to 52 percent) of all estimated parameters were significant in each state.

Because curvature properties were maintained in the estimation, all estimated own-price parameters were positive. Significant own-price input demand parameters were estimated for miscellaneous inputs in MS and OK, for fertilizer in AR, MS, OK, and TX, for the fertilizer-miscellaneous inputs aggregate in LA, and for hired labor in AR, LA, MS, and TX. The input category that included fertilizer yielded a significant own-price response in every state. Hired labor yielded a significant own-price response in four of the five states. Significant own-price output parameters were estimated for corn in AR, for cotton in AR, LA, MS, and TX, for rice in AR and MS, for other crops in OK, for soybeans in AR and MS, for wheat in AR, MS, and TX, for livestock in TX, for the sorghum-livestock aggregate in AR and MS, and for the corn-cotton-sorghum-soybean-livestock aggregate in OK. The output categories that included cotton and livestock yielded significant own-price responses in all five and in four states, respectively. AR and MS had the largest proportion of significant own-price parameters (73 percent), followed by OK (57 percent), TX (50 percent), and LA (43 percent).

Significant competitive relationships between pairs of variable inputs were estimated for miscellaneous inputs and hired labor in MS, and for the fertilizer-miscellaneous inputs aggregate and hired labor in LA. Significant competitive relationships between variable and fixed inputs were estimated for hired labor and land in AR and for fertilizer and family labor in LA. The only significant complementary variable input relationship was for fertilizer and hired labor in AR. All others were between variable and fixed inputs. They included miscellaneous inputs and capital services in AR, OK, and TX, miscellaneous inputs and family labor in AR, OK, and TX, miscellaneous inputs and land in AR, MS, and TX, fertilizer and capital services in TX, fertilizer and land in MS and TX, the fertilizer- miscellaneous inputs aggregate and land in LA, and hired labor and family labor in AR, LA, OK, and TX. The complementary relationships between hired and family labor and between land and the input category containing miscellaneous inputs were both significant in four of the five states.

Significant competitive output-output relationships included soybeans and wheat in AR and MS, cotton and wheat in MS and TX, other crops and wheat in OK, the sorghum-livestock aggregate and wheat in MS, cotton and corn in TX, the sorghum-livestock aggregate and corn in AR, the sorghum-livestock aggregate and cotton in MS, soybeans and rice in MS, and the sorghum- livestock aggregate and rice in AR. The only significant complementary relationships were between wheat and livestock in TX and between the sorghum-livestock aggregate and soybeans in MS. There were no significant relationships among pairs of outputs in LA, the only state for which short-run nonjoint production had not been rejected for all outputs (Polson and Shumway).

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[5] Because it is difficult to optimize a nonlinear system subject to nonlinear inequality constraints, the employed procedure reparameterized the system to linearize such constraints by means of the Cholesky decomposition. For the Cholesky decomposition, the sum squared error of the symmetric, positive definite matrix of price parameters was minimized and then substituted into a nonlinear objective function, which was iterated to convergence.

Table 1. Summary Statistics of Estimated Aggregate Models

State	Number of Equations Estimated	Convexity, F-Statistics[a]	Monotonicity: Number of Violations[b]	Monotonicity: χ^2 Statistic[a]	Condition Index	Percent of Parameters Significant (.05 level)
Arkansas	11	0.21	11	8.99	636	42
Louisiana	7	0.26	6	5.42	515	42
Mississippi	11	0.47	9	3.42	675	52
Oklahoma	7	0.33	0	-	663	43
Texas	10	0.47	1	0.15	2508	40

[a] None of the test statistics for convexity or monotonicity was significant at the .05 level.

[b] Number of violations of monotonicity from a possible total of 32 x number of equations estimated in the respective model.

A considerable number of significant output-input relationships were estimated. When individual variable input prices rose, the number of outputs whose supplies decreased significantly was 60 percent larger than the number that increased significantly. When individual fixed input quantities increased, twice as many outputs experienced significantly increased supplies as the number that experienced decreased supplies. These results were consistent with expectations because output levels generally move in the same direction as input levels. Under single-output production within the economic region of production, expected output is always positively correlated with input level. There is no such implication for multiple-output production; changing an input level can alter comparative advantage among outputs such that one output level is increased so much that another may actually be decreased (Moschini).

Diversion payment parameters were significant for cotton in AR, LA, and MS, wheat in AR, and sorghum in TX. Except for wheat, each reflected a negative supply response, as expected, to a change in the effective diversion payment.

Temporal parameters for all input demands except the numeraire variable input were generally significant in all states and indicated a positive temporal response, as expected. Temporal parameters for half of the output supplies were significant. More than 80 percent of the significant output supply relationships reflected an increase, as expected, in commodity supplies over the estimation period.

The number of significant weather variables in supply equations varied greatly by state, from one in OK to ten in MS. Except for a positive relationship between rainfall and the supplies of corn and rice in MS and sorghum and wheat in TX, all other significant rainfall and temperature parameters indicated that an increase in either weather variable resulted in decreased individual output supplies. The consistently negative output response to temperature during critical growing months supported the hypothesis that hot Southern summers typically exceed optimal growth temperatures for both animals and plants. The frequently negative output response to rainfall (2/3 of the significant cases) also reflected the notion that rainfall in most of these states typically exceeds optimal growth requirements for some commodities.

Suboptimization Models

Summary statistics for the six subset optimization models are reported in Table 2. Suboptimization models were estimated for five output subsets and one input subset. Convexity was not rejected for any of the suboptimization models in any state. Monotonicity was significantly violated only for the Texas output allocation model (for five observations early in the data period). Although lower than for the aggregate models, condition indices calculated for each suboptimization system reflected moderate-to-serious collinearity in the data. Condition indices ranged from 33 for the input allocations to 321 for the output allocations in LA. The suboptimization models consistently had a lower percentage of significant parameters than did the corresponding state's aggregate model.

Significant own-price relationships were estimated for fertilizer, rice, and corn in LA and for cotton and soybeans in OK. Because curvature properties were maintained, all own-price parameters were positive. The only significant cross-price relationships were between sorghum, cotton, and soybeans in OK.

The aggregate output quantity index parameter was significant in at least half of the allocation equations in each model. The effective diversion payment parameter was significant for sorghum in

Table 2. Summary Statistics of Estimated Suboptimization Models

				Monotonicity			
State	Allocation	Number of Equations Estimated	Convexity, F-Statistic	Number of Violations[a]	χ^2 Statistics	Condition Index	Percent of Parameters Significant (.05 level)
Arkansas	Output	2	[b]	1	.01	172	20
Louisiana	Output	4	0.29	7	1.38	321	35
	Input	2	[b]	0	-	33	43
Mississippi	Output	2	0.03	3	6.02	227	20
Oklahoma	Output	5	0.11	2	.02	198	42
Texas	Output	3	[b]	5	68.69**	189	38

**Significant at the .01 level.

[a] Number of violations of monotonicity from a possible total of 32 x number of equations estimated in the respective model.

[b] Convexity was satisfied by the unconstrained estimates.

AR, LA, and OK, and for corn in LA. Temporal parameters were significant in at least half the equations in the output allocation models in LA, MS, and OK. None were significant in the other three models. The only significant weather parameters were a positive rainfall parameter for OK sorghum supply and negative temperature parameters for OK soybean and TX rice supplies.

Disaggregated Price Elasticities

Equations (7) - (9) were used to derive the full matrix of disaggregated elasticities in each state from parameter estimates of (2), (3), (5), and (6). These elasticities are reported at the data means in Appendix Tables A.1-A.5. Own-price elasticities for all states are repeated in Table 3. Approximate standard errors are also reported for each elasticity. Standard errors were computed based on first-order Taylor- series expansions of the elasticity equations (Miller et al.).

Own-price disaggregated output supply elasticities varied considerably across states as well as across commodities and input categories. Twelve of the 58 estimated own-price elasticities were elastic. For no input or output, however, were they elastic in all states. Corn and wheat supplies were elastic in three states, machinery operating input demand in two, hired labor demand and cotton, sorghum, and soybean supplies in one. All other estimated own-price responses were inelastic. The largest number of elastic estimates was five in Arkansas. No elastic demands or supplies were estimated in Oklahoma.

The smallest range of own-price elasticities across states was obtained for livestock supplies (.11 to .34). For half the input demands and half the output supplies, the elasticities varied by more than a magnitude of 1.0 across the five states.

More than half of the estimated own-price elasticities and a quarter of all (own- and cross-) price elasticities were significant at the .05 level. A larger portion of input demand than output supply own-price elasticities were significant. Across states, own-price elasticities for fertilizer, hired labor, and miscellaneous input demands and for cotton, rice, and livestock supplies were generally significantly different from zero. All five of the fertilizer, cotton, and livestock own-price elasticities were significant. None of the sorghum own-price elasticities was significant.

Among the significant elasticities, the range of elasticities across states was generally narrower, but still quite large for several commodities and input categories. For example, significant hired labor demand elasticities ranged from -.64 to -2.27, and cotton supply elasticities ranged from .59 to 1.64. The narrowest range of significant elasticities was for livestock supply, .11 to .34. The three largest elasticities (those greater than 3.0) were all non-significant.

Examination of cross-price elasticities, reported in the Appendix Tables, revealed a similar result. High variability was evident across states, but the degree of variability often decreased substantially when the comparison was limited to statistically significant estimates. Like the own-price elasticieelasticities, all of the very large cross-price elasticities (those greater than 3.0) were non-significant.

In addition to examining the range of these estimated elasticities across states, it may be informative to compare the own-price elasticities to other recent estimates for similar outputs and inputs. The most complete sets of prior estimates for these geographic units were elasticities for Texas (Shumway; Shumway, Alexander, and Talpaz) and elasticities for the

Table 3. Mean Own-Price Elasticities

Commodity or Input	State				
	Arkansas	Louisiana	Mississippi	Oklahoma	Texas
Fertilizer	-0.426	-0.370	-0.293	-0.678	-0.762
	(0.145)[a]	(0.076)	(0.093)	(0.256)	(0.260)
Hired Labor	-2.274	-0.679	-0.643	-0.353	-0.958
	(0.414)	(0.250)	(0.119)	(0.426)	(0.256)
Machinery Oper.	-2.848	-0.349	-0.473	-0.479	-1.020
	(0.800)	(0.467)	(0.594)	(0.432)	(0.877)
Misc. Inputs	-0.184	-0.579	-0.227	-0.377	-0.211
	(0.131)	(0.078)	(0.100)	(0.120)	(0.136)
Corn	3.252	1.772	0.637	0.091	1.429
	(2.866)	(0.738)	(0.508)	(0.765)	(1.388)
Cotton	0.592	0.809	0.651	0.893	1.643
	(0.161)	(0.243)	(0.146)	(0.264)	(0.255)
Rice	0.471	0.382	0.944	-	0.311
	(0.192)	(0.117)	(0.422)		(0.171)
Sorghum	0.015	1.740	0.159	0.392	0.130
	(0.463)	(4.448)	(0.447)	(0.229)	(0.447)
Soybeans	1.020	0.425	0.544	0.600	0.280
	(0.237)	(0.434)	(0.237)	(0.342)	(0.620)
Wheat	5.101	-	7.727	0.186	1.948
	(4.229)		(6.421)	(0.219)	(0.690)
Other Crops	0.539	0.064	0.252	0.583	0.242
	(0.323)	(0.094)	(0.146)	(0.284)	(0.108)
Livestock	0.343	0.250	0.259	0.284	0.110
	(0.118)	(0.095)	(0.062)	(0.057)	(0.051)

[a] Approximate standard errors are in parentheses.

Southern Plains and Delta regions (Shumway and Alexander). All five of the fertilizer elasticities from the current study were within the range of the estimates for the most similar input category (-.21 to -.85) from the other studies. Four each of the hired labor and other crops elasticities were within the ranges of the closest categories (-.01 to -1.42, and .10 to .60, respectively) from the other studies. Three each of the machinery operating and sorghum elasticities were within the ranges of the closest categories (-.25 to -.93, and .06 to .65, respectively)from the other studies. Two of the corn elasticities and one each of the cotton, rice, soybean, and livestock elasticities were within the range of the closest categories (.06 to .65, .25 to .60, .40 to .76, .15 to .34, and .11 to .15, respectively) from the other studies. None of the miscellaneous inputs or wheat elasticities were within the ranges of the closest categories (-.04 to -.14, and .27 to .51, respectively) from the other studies. Thus, fewer than half the own-price elasticity estimates from the current study lay within the range of these prior estimates. Differences are due to the period, source, and construction of data as well as to geographic unit, model specification, and estimation method. The same functional form was used in all cases.

Although these five states are contiguous, they contain a lot of space and their agroclimatic conditions vary considerably. The hypothesis of identical agricultural technologies was previously rejected for each pair of these states (Polson and Shumway). Thus, it is not surprising to find evidence of varying rates of output and input responsiveness to changes in the economic environment. Collinearity among the regressors also contributed to some of this variability, although it is unclear how much. High collinearity was evident from the high condition indices. Yet, particularly in the aggregate models, a large portion of the parameter estimates were statistically significant. Collinearity certainly biased some of the standard errors upward, but not enough to keep many of the parameter estimates from being significant.

There are no absolutes against which one can judge the quality of these elasticity estimates. However, in addition to evaluations of them with respect to prior estimates, some relative comparisons about their economic reasonableness can be made. Considering only significant elasticity estimates and those inputs and outputs with at least two significant own-price elasticities in the five states, the following will focus on their relative magnitudes.

Among the inputs, the hired labor own-price demand elasticity was consistently larger than the elasticity for either fertilizer or miscellaneous inputs in the same state. Larger own-price elasticities are expected for inputs with more close substitutes and for inputs that account for a larger share of total expenditures. Hired labor expenditures exceeded fertilizer expenditures in nearly all years of the data period in all states. In addition, there are several close substitutes for hired labor, including family labor, machinery, and pesticides. The significant cross- price elasticities between hired labor demand and the prices of machinery operating and miscellaneous inputs (including pesticides) consistently supported this assertion. On the other hand, land is frequently regarded as the only close substitute for fertilizer. The miscellaneous input category includes rental charges on necessary farm stocks (such as seed and breeding herds) that are used in further production. It is unlikely that such stocks would adjust rapidly to year-to-year price fluctuations because their substitutes are highly limited. Because labor has more close substitutes, it was not surprising that the hired labor demand elasticities exceeded those for fertilizer and miscellaneous inputs.

Among outputs, the cotton own-price elasticity was consistently larger than the other crops supply elasticity, and the cotton, rice, soybeans, and other crops supply elasticities were consistently larger than the livestock supply elasticity in the same state. Cotton is a single commodity (consisting of two major varieties) while the other crops category is an aggregate of many crops ranging from hay to orchard crops. Cotton is an annual crop while several commodities in the other crops category are perennials. Because the elasticities represent annual response rates, it is likely that an annual crop would adjust more rapidly than would a perennial to price changes. The same economic logic applies to the comparison of individual crop elasticities for cotton, rice, and soybeans relative to livestock. The livestock category is an aggregate of all animal production, much of which has a production period longer than 12 months. Based on both the length of the production period and number of competitive enterprises for a single output versus an aggregate of many outputs, one would expect the crop supply elasticities to be larger than the livestock elasticity. In addition, livestock activities such as cattle, sheep, and goats represent the only viable agricultural use for much of the rangeland in these states. Wildlife and sporting uses are often complementary to livestock production (Stuth and Sheffield). Thus, it was not surprising that the other crops aggregate supply elasticities were greater than the livestock aggregate elasticities. Nor was it surprising that crop elasticities varied more among states than did aggregate livestock elasticities.

To summarize the assessment about the quality of these elasticity estimates, two cautions are noted-high collinearity was evident, and a substantial portion of the estimates lay outside the range of prior estimates. Three positive attributes about them are also noted—a substantial portion of the elasticity estimates was statistically significant, the variation in agroclimatic conditions among states is consistent with at least some of the observed differences in responsiveness among states, and the relative magnitudes of significant input and output elasticities were economically reasonable. Thus, while they must be interpreted with caution because there is some ambiguity about their quality, many of the elasticity estimates seem defensible.

Diversion Payment Elasticities

Because expected output prices are weighted averages of expected market prices and effective support prices, some of the variability across states in producers' response to government programs is evident from the range of estimated price elasticities already reported. Farm programs are available to farmers with an historical base in production of a particular commodity in all states, but the differences in resource endowment, comparative advantage, and production experiences cause producers in different states to respond differently to changes in relative incentives.

To discern the distributional effects of supply control programs on South Central agriculture, output elasticities with respect to effective diversion payments were estimated for affected program commodities (corn, cotton, sorghum, and wheat) in each state. These elasticities, computed at the data means, are reported along with approximate standard errors (based on first-order Taylor-series expansions of the elasticity equations) in Table 4. All diversion payment responses were inelastic. Elasticities ranged from -.11 to .09 in AR, -.59 to .12 in LA, -.04 to .09 in MS, to -.03 to .05 in OK, and -.03 to .01 in TX.

While nine of the 19 estimated supply response parameters with respect to diversion payment were significant, only six elasticity estimates were significant. All three significant elasticities for cotton were negative as expected. All were small, ranging from -.03 to -.07, implying a relatively modest response of commodity output levels to changes in the diversion program. The two significant elasticities for

Table 4. Mean Supply Elasticities with Respect to Diversion Payments

	State				
Commodity	Arkansas	Louisiana	Mississippi	Oklahoma	Texas
Corn	-0.072 (0.157)[a]	0.118 (0.054)	0.065 (0.057)	-0.019 (0.066)	0.013 (0.078)
Cotton	-0.074 (0.011)	-0.033 (0.009)	-0.048 (0.009)	-0.009 (0.010)	0.002 (0.009)
Sorghum	-0.113 (0.067)	-0.586 (0.903)	-0.007 (0.019)	0.045 (0.021)	-0.031 (0.015)
Wheat	0.093 (0.083)	[b]	0.093 (0.102)	-0.026 (0.018)	0.003 (0.026)

[a]Approximate standard errors are in parentheses.
[b]Wheat supply was not estimated in Louisiana.

sorghum were also small, one negative (-.03) and one positive (.05). The largest significant elasticity was for corn (.12).

The findings of both negative and positive supply response to effective diversion payment and relatively few significant elasticities were consistent with prior research findings for California (McIntosh and Shumway). In that study, elasticity estimates ranged from -.10 to .06; only the negative elasticity for cotton was significantly different from zero at the .10 level. Shumway and Alexander also found both negative and positive supply responses in the Delta and Southern Plains farm production regions that ranged from -.10 to .15; only the output category that included cotton was estimated to have a negative response in both regions. Thus, the current state-level estimates of response to effective diversion payment were largely consistent with prior estimates.

Impacts of Decoupling

One of the frequently debated methods for removing resource and output distorting effects of current farm programs is to decouple benefits from production decisions. Under this alternative, farmers would receive direct payments based on their historical base acreage rather than on their decisions about what and how much to produce. The market would be left to determine prices for motivating decisions about future production and equilibrium prices for allocating produced output.

The approach of this study in examining the possible effects of decoupling followed that of McIntosh and Shumway. The short-run impact of removing both price support and diversion payments together with their associated acreage restrictions was examined. Long-run effects of industry entry and exit decisions were ignored.

The predicted impacts of decoupling on each of the variable input demands and commodity supplies are reported in Table 5 as percentage changes from mean levels for each state. Approximate standard errors were computed using first-order Taylor-series expansions. The estimated impacts ranged from -56 percent to 36 percent. Neither of those extreme estimates was significant, however. Of all the estimated impacts, 2/5 were negative, 3/5 were positive, and only 1/6 were significant. No estimated impacts were significant in either Oklahoma or Texas. Significant impacts ranged from -6.7 percent to 12.0 percent with 4/5 of the estimates positive.

The range of estimated significant impacts, the preponderance of positive impacts, and the frequency of significant cotton impacts (of which all of the significant ones were positive and similar in magnitude) were all consistent with prior findings of McIntosh and Shumway for California. Although many of the estimates were not significant, the overriding inference from the significant estimates is that decoupling benefits from production decisions could be expected to increase total output of program commodities and increase demand for most variable inputs.

CONCLUSIONS

A full set of parameters was econometrically estimated for multiple-output production relationships in five contiguous South Central states comprising two USDA farm production regions. These estimates were generally consistent with two-stage choice and the theory of a perfectly competitive industry facing exogenous prices at the state level. Most of the implied properties were maintained in the estimation. Monotonicity was checked at every observation and was significantly violated only for the Texas allocation model (and only for early observations in the data period). Convexity of the unconstrained estimates was also tested and not rejected for any model.

Table 5. Mean Impacts of Decoupling

	Predicted Percent Quantity Change from Withdrawing Price Supports and Diversion Payments				
Commodity or Input	Arkansas	Louisiana	Mississippi	Oklahoma	Texas
Fertilizer	4.33 (3.20)[a]	4.45 (1.12)	-1.57 (1.97)	0.12 (1.90)	4.42 (3.99)
Hired Labor	-2.91 (3.71)	-6.70 (2.52)	5.06 (2.22)	2.39 (2.47)	-0.82 (2.97)
Machinery Oper.	6.86 (4.01)	5.46 (2.27)	3.34 (3.82)	0.68 (1.44)	1.84 (4.84)
Misc. Inputs	-0.82 (1.23)	3.35 (0.76)	1.47 (1.01)	-0.33 (0.69)	-0.19 (1.20)
Corn	36.28 (45.25)	4.64 (11.46)	-2.91 (10.87)	3.51 (11.32)	4.80 (20.23)
Cotton	12.03 (2.69)	9.01 (2.84)	10.51 (1.96)	1.79 (1.81)	-1.31 (2.13)
Rice	5.93 (3.29)	3.58 (1.52)	16.70 (9.61)	- -	3.69 (2.37)
Sorghum	4.53 (8.45)	-23.94 (148.56)	1.19 (4.42)	-5.57 (3.27)	2.95 (5.30)
Soybeans	2.09 (2.90)	3.15 (3.96)	1.45 (3.07)	3.64 (4.40)	-0.28 (10.48)
Wheat	-7.47 (43.37)	- -	-55.95 (70.35)	4.05 (2.51)	5.82 (8.35)
Other Crops	-5.19 (4.35)	-0.92 (1.33)	-3.45 (2.43)	-3.08 (1.67)	-0.79 (1.81)
Livestock	-3.05 (1.05)	-1.43 (1.13)	-0.76 (0.81)	-0.00 (0.33)	0.05 (0.60)

[a] Approximate standard errors are in parentheses.

Fertilizer demand and cotton and livestock supplies were the most consistently significantly responsive to changes in own price. Most of the significant input-input cross-price relationships were complementary. Output-output cross-price relationships, on the other hand, were generally competitive, suggesting that the relative impact on short-run supplies of constraining allocatable inputs and decreasing returns to size (Moschini; Leathers) exceeded that of technical interdependence. Output supply responses to weather variables revealed that hot and wet Southern summers typically exceeded optimal temperatures and moisture levels for many commodities.

Cotton supplies exhibited the largest number of significant state-level responses to changes in the effective diversion payment, all of which were negative as expected. They also exhibited the largest number of significant responses to decoupling farm program benefits from production decisions, suggesting that decoupling would generally increase output of program commodities.

Output supply and variable input demand elasticities revealed highly diverse production relationships both across and within these five South Central states.[6] Elasticities varied considerably among commodities, among input categories, and among states. Most were inelastic. Less diversity across states was evident among the statistically significant elasticities for several outputs and inputs. Nevertheless, for some, the diversity was both significant and substantial.

For example, the greatest diversity among significant output relationships was found for cotton. Significant own-price elasticities were estimated in all states for this crop. In addition, three of its diversion payment elasticities and a considerable number of its cross-price elasticities were significant. The large number of significant parameters in these equations in each state together with the large differences among states in several of the policy-relevant elas-

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[6] High collinearity may have contributed also to this apparent diversity. Collinearity among regressors in these types of models constitutes a serious potential limitation to reliable estimation of individual relationships. The sensitivity of policy-relevant supply and demand implications to ill-conditioned data is a viable question for further research.

Table A.1. Disaggregated Output Supply and Input Demand Elasticities, Arkansas

	Elasticity with Respect to the Price of											
Quantity	Fertilizer	Hired Labor	Mach. Oper.	Misc. Inputs	Corn	Cotton	Rice	Sorghum	Soy-beans	Wheat	Other Crops	Live-stock
Fertilizer	-0.429	-0.432	0.017	0.110	0.009	0.480	0.128	0.001	-0.354	0.264	0.069	0.133
	(0.145)[a]	(0.201)	(0.301)	(0.276)	(0.126)	(0.170)	(0.127)	(0.003)	(0.182)	(0.221)	(0.182)	(0.277)
Hired	-0.209	-2.274	2.534	0.348	0.126	-0.343	0.205	-0.001	-0.593	0.213	0.133	-0.139
Labor	(0.100)	(0.414)	(0.485)	(0.255)	(0.142)	(0.185)	(0.154)	(0.003)	(0.225).	(0.238)	(0.170)	(0.277)
Mach.	0.007	2.134	-2.848	0.023	0.084	0.363	-0.035	-0.000	0.334	0.079	-0.106	-0.035
Oper.	(0.123)	(0.430)	(0.800)	(0.305)	(0.179)	(0.201)	(0.158)	(0.003)	(0.223)	(0.257)	(0.206)	(0.299)
Misc.	0.013	0.085	0.007	-0.184	-0.093	0.043	-0.051	0.002	0.151	-0.157	0.017	0.166
Inputs	(0.033)	(0.062)	(0.089)	(0.131)	(0.041)	(0.064)	(0.050)	(0.001)	(0.072)	(0.094)	(0.060)	(0.120)
Corn	-0.046	-1.346	-1.068	4.013	3.252	-2.200	1.471	-0.047	-0.843	0.358	0.906	-4.451
	(0.649)	(1.783)	(2.384)	(3.379)	(2.866)	(1.960)	(1.422)	(0.040)	(1.412)	(1.667)	(1.368)	(3.745)
Cotton	-0.124	0.183	-0.230	-0.093	-0.110	0.592	0.079	-0.002	-0.118	0.131	-0.100	-0.207
	(0.044)	(0.097)	(0.125)	(0.140)	(0.059)	(0.161)	(0.107)	(0.002)	(0.137)	(0.137)	(0.089)	(0.154)
Rice	-0.042	-0.141	0.029	0.141	0.095	0.101	0.471	-0.005	-0.269	0.084	0.022	-0.485
	(0.043)	(0.106)	(0.128)	(0.141)	(0.063)	(0.139)	(0.192)	(0.002)	(0.193)	(0.154)	(0.092)	(0.196)
Sorghum	-0.026	0.055	0.016	-0.269	-0.166	-0.154	-0.281	0.015	0.062	-0.140	0.127	0.760
	(0.057)	(0.117)	(0.142)	(0.281)	(0.145)	(0.163)	(0.236)	(0.463)	(0.146)	(0.206)	(0.142)	(0.785)
Soybeans	0.077	0.268	-0.179	-0.278	-0.036	-0.100	-0.177	0.001	1.020	-0.561	-0.105	0.070
	(0.040)	(0.100)	(0.118)	(0.137)	(0.054)	(0.116)	(0.125)	(0.002)	(0.237)	(0.155)	(0.080)	(0.158)
Wheat	-0.501	-0.835	-0.369	2.505	0.132	0.961	0.479	-0.015	-4.876	5.101	-1.203	-1.381
	(-0.559)	(1.114)	(1.228)	(2.390)	(0.615)	(1.234)	(0.949)	(0.022)	(3.825)	(4.229)	(1.300)	(2.031)
Other	-0.045	-0.181	0.170	-0.096	0.115	-0.254	0.043	0.005	-0.314	-0.415	0.539	0.432
Crops	(0.119)	(0.230)	(0.331)	(0.329)	(0.154)	(0.227)	(0.182)	(0.004)	(0.240)	(0.331)	(0.323)	(0.364)
Livestock	-0.011	0.025	0.007	-0.120	-0.074	-0.069	-0.126	0.004	0.028	-0.063	0.057	0.343
	(0.024)	(0.049)	(0.063)	(0.087)	(0.033)	(0.051)	(0.046)	(0.006)	(0.062)	(0.079)	(0.047)	(0.118)

[a] Approximate standard errors are in parentheses.

Table A.2. Disaggregated Output Supply and Input Demand Elasticities, Louisiana

	Elasticity with Respect to the Price of										
Quantity	Fertilizer	Hired Labor	Mach. Oper.	Misc. Inputs	Corn	Cotton	Rice	Sorghum	Soy-beans	Other Crops	Live-stock
Fertilizer	-0.370	0.452	-0.252	-0.501	0.014	0.216	0.108	0.001	0.164	-0.078	0.246
	(0.076)[a]	(0.111)	(0.110)	(0.180)	(0.005)	(0.087)	(0.040)	(0.000)	(0.093)	(0.054)	(0.091)
Hired	0.216	-0.679	0.379	1.094	-0.020	-0.325	-0.162	-0.002	-0.248	0.117	-0.370
Labor	(0.037)	(0.250)	(0.248)	(0.190)	(0.009)	(0.204)	(0.072)	(0.001)	(0.213)	(0.128)	(0.165)
Mach.	-0.093	0.294	-0.349	-0.473	0.001	0.507	0.011	0.000	0.132	-0.057	0.026
Oper.	(0.037)	(0.192)	(0.467)	(0.188)	(0.008)	(0.182)	(0.064)	(0.001)	(0.195)	(0.109)	(0.147)
Misc.	-0.060	0.340	-0.190	-0.597	0.010	0.163	0.081	0.001	0.124	-0.058	0.186
Inputs	(0.019)	(0.049)	(0.073)	(0.078)	(0.003)	(0.057)	(0.025)	(0.000)	(0.065)	(0.039)	(0.058)
Corn	-0.000	0.000	-0.000	-0.001	1.772	-0.000	-0.066	-0.428	0.000	-0.000	-1.277
	(0.020)	(0.062)	(0.006)	(0.100)	(0.738)	(0.029)	(0.386)	(0.418)	(0.020)	(0.010)	(0.547)
Cotton	-0.067	0.211	-0.423	-0.339	-0.006	0.809	-0.048	-0.001	-0.068	0.043	-0.111
	(0.025)	(0.133)	(0.155)	(0.125)	(0.008)	(0.243)	(0.063)	(0.001)	(0.206)	(0.133)	(0.143)
Rice	-0.025	0.079	-0.007	-0.128	-0.003	-0.037	0.382	-0.056	0.026	-0.013	-0.218
	(0.010)	(0.040)	(0.041)	(0.052)	(0.041)	(0.048)	(0.117)	(0.031)	(0.060)	(0.035)	(0.092)
Sorghum	-0.001	0.003	-0.000	-0.005	-3.818	-0.001	-4.763	1.740	0.001	-0.000	6.844
	(0.112)	(0.353)	(0.032)	(0.569)	(6.666)	(0.163)	(7.481)	(4.448)	(0.115)	(0.059)	(10.458)
Soybeans	-0.053	0.168	-0.116	-0.270	0.005	-0.072	0.036	0.000	0.425	-0.206	0.082
	(0.031)	(0.150)	(0.173)	(0.158)	(0.011)	(0.216)	(0.084)	(0.001)	(0.434)	(0.217)	(0.191)
Other	0.016	-0.051	0.032	0.081	-0.001	0.029	-0.012	-0.000	-0.131	0.064	-0.027
Crops	(0.011)	(0.056)	(0.061)	(0.054)	(0.004)	(0.089)	(0.031)	(0.000)	(0.135)	(0.094)	(0.070)
Livestock	-0.035	0.110	-0.010	-0.178	-0.055	-0.051	-0.086	0.037	0.036	-0.018	0.250
	(0.011)	(0.049)	(0.056)	(0.058)	(0.022)	(0.066)	(0.062)	(0.014)	(0.083)	(0.048)	(0.095)

[a] Approximate standard errors are in parentheses.

ticities is further evidence of the diverse production relationships between states.

At the other extreme was livestock supply. Its own-price elasticities in all states also were significant. Yet those elasticities varied only from .11 to .34. Decisions about the amount of livestock to produce as own price changed were much less variable across states than were decisions about certain cropping patterns such as that for cotton. Although fewer of their own-price elasticities generally were signifi-

Table A.3. Disaggregated Output Supply and Input Demand Elasticities, Mississippi

	Elasticity with Respect to the Price of										
Quantity	Fertilizer	Hired Labor	Mach. Oper.	Misc. Inputs	Corn	Cotton	Rice	Sorghum	Soy-beans	Wheat	Other Crops	Live-stock
Fertilizer	-0.293	0.195	-0.112	-0.192	-0.173	0.100	-0.104	0.002	0.215	-0.154	0.042	0.475
	(0.093)[a]	(0.081)	(0.166)	(0.150)	(0.087)	(0.117)	(0.059)	(0.000)	(0.109)	(0.101)	(0.101)	(0.113)
Hired Labor	0.138	-0.643	0.260	0.384	0.126	0.250	0.197	-0.002	-0.431	0.428	-0.192	-0.514
	(0.058)	(0.119)	(0.178)	(0.140)	(0.088)	(0.142)	(0.063)	(0.000)	(0.131)	(0.112)	(0.089)	(0.135)
Mach. Oper.	-0.065	0.216	-0.473	-0.118	-0.188	0.654	-0.052	-0.000	0.219	-0.261	0.172	-0.102
	(0.098)	(0.149)	(0.594)	(0.275)	(0.161)	(0.243)	(0.106)	(0.001)	(0.212)	(0.200)	(0.148)	(0.207)
Misc. Inputs	-0.037	0.106	-0.039	-0.277	0.023	0.075	0.031	0.001	0.161	-0.216	-0.056	0.229
	(0.029)	(0.037)	(0.091)	(0.100)	(0.046)	(0.058)	(0.029)	(0.000)	(0.055)	(0.057)	(0.045)	(0.060)
Corn	0.359	-0.370	0.667	-0.248	0.637	-0.678	0.136	0.000	0.163	-0.180	-0.567	0.079
	(0.198)	(0.270)	(0.586)	(0.491)	(0.508)	(0.493)	(0.229)	(0.002)	(0.456)	(0.445)	(0.361)	(0.425)
Cotton	-0.022	-0.079	-0.248	-0.085	-0.073	0.651	0.072	-0.001	0.061	-0.126	-0.000	-0.151
	(0.026)	(0.045)	(0.091)	(0.067)	(0.051)	(0.146)	(0.038)	(0.000)	(0.092)	(0.059)	(0.047)	(0.076)
Rice	0.303	-0.807	0.256	-0.461	0.190	0.946	0.944	-0.001	-0.925	0.303	-0.351	-0.396
	(0.193)	(0.349)	(0.529)	(0.459)	(0.322)	(0.566)	(0.422)	(0.002)	(0.534)	(0.368)	(0.314)	(0.472)
Sorghum	-0.054	0.083	0.020	-0.134	0.004	-0.077	-0.016	0.159	0.094	-0.095	-0.026	0.041
	(0.115)	(0.177)	(0.058)	(0.287)	(0.025)	(0.168)	(0.038)	(0.447)	(0.205)	(0.205)	(0.058)	(0.661)
Soybeans	-0.097	0.275	-0.169	-0.376	0.036	0.124	-0.144	0.001	0.544	-0.499	-0.072	0.376
	(0.051)	(0.090)	(0.164)	(0.140)	(0.099)	(0.188)	(0.074)	(0.001)	(0.237)	(0.127)	(0.093)	(0.178)
Wheat	0.989	-3.886	2.862	7.155	-0.557	-3.627	0.670	-0.020	-7.102	7.727	1.187	-5.399
	(1.014)	(3.205)	(3.122)	(5.942)	(1.441)	(3.307)	(0.949)	(0.016)	(5.783)	(6.421)	(1.494)	(4.513)
Other Crops	-0.028	0.184	-0.198	0.194	-0.185	-0.001	-0.082	-0.001	-0.107	0.125	0.252	-0.152
	(0.068)	(0.084)	(0.170)	(0.156)	(0.110)	(0.142)	(0.069)	(0.000)	(0.138)	(0.123)	(0.146)	(0.128)
Livestock	-0.070	0.107	0.026	-0.173	0.006	-0.100	-0.020	0.000	0.122	-0.123	-0.033	0.259
	(0.016)	(0.026)	(0.052)	(0.045)	(0.030)	(0.049)	(0.023)	(0.002)	(0.055)	(0.035)	(0.028)	(0.062)

[a]Approximate standard errors are in parentheses.

Table A.4. Disaggregated Output Supply and Input Demand Elasticities, Oklahoma

	Elasticity with Respect to the Price of									
Quantity	Fertilizer	Hired Labor	Mach. Oper.	Misc. Inputs	Corn	Cotton	Sorghum	Soy-beans	Wheat	Other Crops	Live-stock
Fertilizer	-0.678	0.118	-0.873	0.250	0.010	0.057	0.025	0.009	-0.043	0.553	0.572
	(0.256)[a]	(0.260)	(0.365)	(0.317)	(0.002)	(0.014)	(0.006)	(0.002)	(0.238)	(0.273)	(0.141)
Hired Labor	0.101	-0.353	0.191	0.262	-0.001	-0.004	-0.002	-0.001	0.305	-0.457	-0.040
	(0.221)	(0.426)	(0.484)	(0.369)	(0.003)	(0.017)	(0.007)	(0.003)	(0.309)	(0.344)	(0.174)
Mach. Oper.	-0.302	0.078	-0.479	-0.098	0.008	0.048	0.021	0.008	0.036	0.201	0.481
	(0.126)	(0.197)	(0.432)	(0.215)	(0.002)	(0.011)	(0.005)	(0.002)	(0.180)	(0.189)	(0.114)
Misc. Inputs	0.032	0.040	-0.036	-0.377	0.006	0.033	0.014	0.005	-0.076	0.027	0.332
	(0.041)	(0.056)	(0.080)	(0.120)	(0.001)	(0.007)	(0.003)	(0.001)	(0.086)	(0.074)	(0.071)
Corn	-0.271	0.023	-0.659	-1.228	0.091	0.111	0.063	0.127	-0.097	0.164	1.677
	(0.137)	(0.097)	(0.330)	(0.605)	(0.765)	(0.485)	(0.510)	(0.354)	(0.285)	(0.157)	(0.933)
Cotton	-0.076	0.006	-0.185	-0.344	-0.003	0.893	-0.369	0.127	-0.027	0.046	-0.068
	(0.034)	(0.027)	(0.083)	(0.151)	(0.083)	(0.264)	(0.107)	(0.058)	(0.080)	(0.043)	(0.262)
Sorghum	-0.000	0.000	-0.001	-0.002	-0.005	-0.806	0.392	-0.174	-0.000	0.000	0.596
	(0.019)	(0.002)	(0.045)	(0.084)	(0.180)	(0.200)	(0.229)	(0.127)	(0.007)	(0.011)	(0.243)
Soybeans	-0.022	0.002	-0.053	-0.099	0.090	0.631	-0.432	0.600	-0.008	0.013	-0.723
	(0.030)	(0.008)	(0.073)	(0.136)	(0.313)	(0.311)	(0.329)	(0.342)	(0.025)	(0.021)	(0.547)
Wheat	0.008	-0.069	-0.020	0.114	-0.001	-0.004	-0.002	-0.001	0.186	-0.172	-0.040
	(0.046)	(0.071)	(0.101)	(0.131)	(0.002)	(0.011)	(0.005)	(0.002)	(0.219)	(0.093)	(0.115)
Other Crops	-0.250	0.243	-0.262	-0.095	0.003	0.015	0.007	0.003	-0.403	0.583	0.156
	(0.124)	(0.182)	(0.247)	(0.259)	(0.002)	(0.013)	(0.006)	(0.002)	(0.209)	(0.284)	(0.133)
Livestock	-0.037	0.003	-0.091	-0.169	0.003	-0.027	0.036	-0.011	-0.013	0.023	0.284
	(0.010)	(0.013)	(0.023)	(0.039)	(0.007)	(0.018)	(0.008)	(0.005)	(0.039)	(0.019)	(0.057)

[a]Approximate standard errors are in parentheses.

cant, other inputs and outputs reflected similar extremes in diversity across states. Hired labor demand elasticity was highly sensitive to state, while the miscellaneous input demand elasticity was not. When knowledge is sought about the geographic distributional impacts of changes in the economic environment and/or governmental policies on such decisions as cotton production or hired labor demand, the importance of modeling individual states and sub-state areas becomes increasingly obvious.

Table A.5. Disaggregated Output Supply and Input Demand Elasticities, Texas

	Elasticity with Respect to the Price of											
Quantity	Fertilizer	Hired Labor	Mach. Oper.	Misc. Inputs	Corn	Cotton	Rice	Sorghum	Soy-beans	Wheat	Other Crops	Live-stock
Fertilizer	-0.762	0.185	-0.318	-0.451	0.171	0.671	0.080	0.026	0.011	-0.164	0.317	0.234
	(0.260)[a]	(0.283)	(0.439)	(0.332)	(0.261)	(0.200)	(0.047)	(0.284)	(0.007)	(0.225)	(0.186)	(0.164)
Hired Labor	0.077	-0.958	0.928	-0.090	0.049	0.547	-0.105	-0.264	-0.015	0.001	-0.416	0.246
	(0.117)	(0.256)	(0.359)	(0.238)	(0.197)	(0.154)	(0.034)	(0.216)	(0.005)	(0.154)	(0.134)	(0.131)
Mach. Oper.	-0.110	0.769	-1.020	-0.098	-0.137	-0.308	0.071	0.103	0.010	0.374	0.281	0.065
	(0.152)	(0.317)	(0.877)	(0.383)	(0.317)	(0.288)	(0.052)	(0.350)	(0.007)	(0.258)	(0.207)	(0.235)
Misc. Inputs	-0.051	-0.025	-0.032	-0.211	-0.121	0.394	0.001	-0.027	0.000	-0.021	0.004	0.089
	(0.037)	(0.065)	(0.126)	(0.136)	(0.074)	(0.070)	(0.013)	(0.095)	(0.002)	(0.062)	(0.053)	(0.064)
Corn	-0.253	-0.176	0.590	1.577	1.429	-2.874	0.007	0.133	0.001	0.029	0.027	-0.488
	(0.405)	(0.708)	(1.388)	(1.221)	(1.388)	(1.547)	(0.151)	(1.096)	(0.021)	(0.650)	(0.597)	(0.701)
Cotton	-0.145	-0.285	0.193	-0.749	-0.419	1.643	-0.018	-0.094	-0.003	-0.235	-0.072	0.184
	(0.045)	(0.085)	(0.180)	(0.158)	(0.119)	(0.255)	(0.017)	(0.119)	(0.002)	(0.084)	(0.066)	(0.110)
Rice	-0.033	0.105	-0.086	-0.004	0.002	-0.035	0.311	0.035	-0.025	-0.045	-0.203	-0.021
	(0.032)	(0.086)	(0.089)	(0.049)	(0.042)	(0.042)	(0.171)	(0.058)	(0.085)	(0.045)	(0.303)	(0.036)
Sorghum	-0.011	0.268	-0.126	0.102	0.038	-0.184	0.035	0.130	0.005	-0.181	0.139	-0.215
	(0.120)	(0.221)	(0.430)	(0.354)	(0.312)	(0.233)	(0.052)	(0.447)	(0.007)	(0.216)	(0.207)	(0.226)
Soybeans	-0.349	1.101	-0.897	-0.043	0.020	-0.368	0.006	0.362	0.280	-0.471	0.584	-0.224
	(0.249)	(0.571)	(0.745)	(0.515)	(0.443)	(0.367)	(0.544)	(0.557)	(0.620)	(0.361)	(0.732)	(0.353)
Wheat	0.157	-0.003	-1.039	0.176	0.018	-1.039	-0.104	-0.410	-0.015	1.948	-0.410	0.722
	(0.219)	(0.355)	(0.753)	(0.523)	(0.420)	(0.451)	(0.073)	(0.500)	(0.010)	(0.690)	(0.287)	(0.382)
Other Crops	-0.088	0.278	-0.227	-0.011	0.005	-0.093	-0.024	0.091	0.002	-0.119	0.242	-0.057
	(0.052)	(0.091)	(0.165)	(0.130)	(0.112)	(0.085)	(0.049)	(0.136)	(0.024)	(0.078)	(0.108)	(0.086)
Livestock	-0.020	-0.050	-0.016	-0.067	-0.028	0.072	-0.004	-0.043	-0.001	0.064	-0.017	0.110
	(0.014)	(0.027)	(0.058)	(0.048)	(0.038)	(0.043)	(0.007)	(0.045)	(0.001)	(0.029)	(0.026)	(0.051)

[a] Approximate standard errors are in parentheses.

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