State-Level Output Supply and Input Demand Elasticities for Agricultural Commodities

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Abstract. *Own- and cross-price production elasticities, estimated in four major agricultural States (California, Iowa, Texas, and Florida), measure the sensitivity to price changes of as many as 25 individual crop and livestock output supplies and six input demands While most responses were highly inelastic, a wide range of elasticities occurred across States The range was generally greater for crop supplies than for livestock supplies or input demands The wide range of elasticities demonstrates the need for economic analysis to focus on specific groups of producers when assessing distributional consequences of policy changes*

Keywords *Demand, elasticity, multistage, State, supply*

Domestic and international policy simulations require estimates of agricultural output supply and input demand relationships For example, successful GATT negotiations hinge on how producers in the United States and elsewhere respond to changes in market prices and withdrawal of output- and input-distorting government incentives The relative merits of alternative environmental policies depend on producers' input choices Secondary (or indirect) effects on outputs or inputs other than the one(s) directly targeted by a particular policy instrument are sometimes as great as the direct effects How producers are affected can vary with scale of operation, resources, and geographic location Understanding intercommodity and distributional consequences demands reliable estimates of own- and cross-price commodity supplies and input demands for important groups of producers

Yet, because of computational burden and data limitations, empirical research on intercommodity relationships has generally concentrated on estimates at a national or regional level for highly aggregated categories (Ball, 1988, Huffman and Evenson, 1989, Shumway and Alexander, 1988) [1] Policy inferences from such studies have been limited to the aggregate effects of agricultural policies, often ignoring geographic and commodity distributional effects

Because of the large number of agricultural commodities produced and inputs used and because of the heterogeneity of production in most areas of the country, complete output supply and input demand elasticity matrices can be derived only if estimation models can be simplified Simplification in model specification becomes necessary to conserve degrees of freedom in estimation and to reduce collinearity Analytic simplification is justifiable whenever data are consistent with certain theoretical and structural properties For example, when production is nonjoint in inputs, commodity supplies are independent of other output prices When production is separable, quantities can be aggregated and production analysis can be performed in stages with subsets of variables and with the aggregates without distorting the disaggregated results Separability is particularly crucial since, without the ability to perform multistage modeling, estimating all commodity cross-price elasticities from a given data set is often impossible Each of these properties permits specification of individual econometric models that require estimation of fewer parameters Therefore, we require less information from the usually limited and imperfect data available

This article exploits the analytic simplification opportunities permitted when production data exhibit reasonable consistency with homothetic separability and/or nonjointness properties The objective is to estimate complete matrices of output supply and input demand elasticities for four major, geographically separated, agricultural States (California, Iowa, Texas, and Florida), each of which produces a large number of commercial agricultural products Both own- and cross-price elasticities will be computed at the individual commodity level

Model Specification

We assumed that the collection of producers in each State behaved like a price-taking, profit-

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[1]Sources are listed in the references section at the end of this article

maximizing firm with a State-level aggregate production function, and modeled each State as though it was a perfectly competitive firm We assumed regularity conditions on the production function to assure that a twice-continuously-differentiable dual profit function could be derived Application of Hotelling's lemma to the profit function yielded a set of output supply and input demand functions for each State Based on the results of functional form tests conducted by Ornelas, Shumway, and Ozuna (1991), who used U S agricultural data, we modeled the aggregate State-level restricted profit function by using the normalized quadratic functional form

$$\pi = b_0 + \Sigma_{i=1}^{m} b_i p_i + \Sigma_{i=m+1}^{n} b_i z_i + 0.5 (\Sigma_{i=1}^{m} \Sigma_{j=1}^{m} b_{ij} p_i p_j + \Sigma_{i=m+1}^{n} \Sigma_{j=m+1}^{n} b_{ij} z_i z_j) + \Sigma_{i=1}^{m} \Sigma_{j=m+1}^{n} b_{ij} p_i z_j, \quad (1)$$

where π is profit (receipts less variable costs) divided by the price of netput (input or output) 0, $p_1, \ldots, p_m$ are the output and variable input prices divided by the price of netput 0, $z_{m+1}, \ldots, z_n$ are fixed input quantities and other nonprice exogenous variables, and b_0, b_i, and b_{ij} are parameters

To maintain consistency with the competitive theory and a twice-continuously-differentiable technology, linear homogeneity of the profit function in prices was applied through normalization (that is, dividing profit and prices by the price of netput 0), and symmetry (reciprocity) conditions among the first-derivative equations were imposed via linear parameter restrictions Convexity was maintained by using the Cholesky factorization (Lau, 1978) Monotonicity was not maintained but was checked at each observation The estimation system consisted of the first-derivative output supply and input demand equations

$$\partial\pi/\partial p_i = x_i = b_i + \Sigma_{j=1}^{m} b_{ij} p_j + \Sigma_{j=m+1}^{n} b_{ij} z_j, \quad \text{for } i = 1, \ldots, m, \quad (2)$$

where $x_1, \ldots, x_m$ are the netput quantities, positively measured for outputs and negatively measured for inputs

By subtracting these price-weighted supply and demand equations from the normalized restricted profit function, we obtained the numeraire equation (the quantity supplied of netput 0)

$$x_0 = \pi - \Sigma_{i=1}^{m} p_i(\partial\pi/\partial p_i) = b_0 + \Sigma_{i=m+1}^{n} b_i z_i - 0.5(\Sigma_{i=1}^{m} \Sigma_{j=1}^{m} b_{ij} p_i p_j) + 0.5(\Sigma_{i=m+1}^{n} \Sigma_{j=m+1}^{n} b_{ij} z_i z_j), \quad (3)$$

which is a quadratic function in normalized prices and fixed inputs

When the underlying technology is homothetically separable in a partition of variables, data within the partition can be consistently aggregated and consistent multistage choices can be conducted Assuming the same functional form as for the aggregated model, the normalized quadratic suboptimization (second-stage) model for the separable partition, s, was

$$\pi_s + b_{0s} + \Sigma_{i=1}^{m} b_{is} p_{is} + \Sigma_{i=m+1}^{n} b_{is} z_{is} + 0.5(\Sigma_{i=1}^{m} \Sigma_{j=1}^{m} b_{ijs} p_{is} p_{js} + \Sigma_{i=m+1}^{n} \Sigma_{j=m+1}^{n} b_{ijs} z_{is} z_{js}) + \Sigma_{i=1}^{m} \Sigma_{j=m+1}^{n} b_{ijs} p_{is} z_{js} + c_s q_s + \Sigma_{i=1}^{m} c_{is} p_{is} q_s + \Sigma_{i=m+1}^{n} c_{is} z_{is} q_s + 0.5 d_s q_s^2, \quad (4)$$

where π_s is normalized profit for the subset, $p_{1s}, \ldots, p_{ms}$ are the normalized prices within the separable subset, $z_{m+1,s}, \ldots, z_{ns}$ are the exogenous variables not included in the homothetic separability tests, q_s is the aggregate netput quantity index of the separable subset, and b_{0s}, b_{is}, b_{ijs}, c_s, c_{is}, and d_s are parameters

Applying Hotelling's lemma to equation 4, we obtained the system of allocation equations

$$\partial\pi_s/\partial p_{is} = x_{is} = b_{is} + \Sigma_{j=1}^{m} b_{ijs} p_{js} + \Sigma_{j=m+1}^{n} b_{ijs} z_{js} + c_{is} q_s, \quad \text{for } i = 1, \ldots, m, \quad (5)$$

where $x_{1s}, \ldots, x_{ms}$ are the allocation equations for the suboptimization model By subtracting the price-weighted allocation equations from equation 4, we determined the quantity supplied of netput 0 (numeraire equation) of the subset

$$x_{0s} = \pi_s - \Sigma_{i=1}^{m} p_{is} \partial\pi_s/\partial p_{is} = b_{0s} + \Sigma_{i=m+1}^{n} b_{is} z_{is} - 0.5(\Sigma_{i=1}^{m} \Sigma_{j=1}^{m} b_{ijs} p_{is} p_{js}) + 0.5(\Sigma_{i=m+1}^{n} \Sigma_{j=m+1}^{n} b_{ijs} z_{is} z_{js}) + c_s q_s + \Sigma_{i=m+1}^{n} c_{is} z_{is} q_s + 0.5 d_s q_s^2, \quad (6)$$

which is a quadratic function in the normalized prices, aggregate index, and other exogenous variables

Third-stage suboptimization models were formulated whenever the suboptimization model, equation 4, included an aggregate price index among the normalized prices within the separable subset These models were constructed following the pattern described in equation 4, and their allocation equations were obtained from their derivatives as in equations 5 and 6

Data and Variable Specification

Annual State-level data compiled by Evenson and others (1986) for the period 1951-82, and updated to 1986 by McIntosh (1989a), supported this article Output prices and quantities were included for as many as 14 field crops, four vegetables, four fruit crops, and seven livestock commodities, plus residual crop and livestock categories that consisted of other commercial food and fiber production for the given State Variable input prices and quantities were included for fertilizer, pesticides, hired labor, machinery operating inputs, miscellaneous variable inputs, and capital services Quantity data were included for the fixed input categories, land and family labor The aggregate models included such exogenous variables as expected output prices, current variable input prices, and quantities of the fixed inputs (land and family labor), time, temperature, precipitation, and effective diversion payments

Because of the large number of individual outputs (as many as 25 in some States) and input categories (8) and the limited number of data observations available (36), it was at first necessary to aggregate the data Based on common nonrejected nonparametric separability tests using 1956-82 data for each of these States, this aggregation included four output categories and three variable input categories (Lim and Shumway, 1992) The output aggregates were crops, meat animals, milk-poultry, and other livestock The meat animals category included cows and calves, hogs and pigs, and sheep and lambs The milk-poultry category included milk, eggs, broilers, and turkeys The other livestock category included all remaining commercial food animal commodities not included in the meat animal or milk-poultry aggregates The variable input categories were labor-capital, materials, and pesticides The labor-capital category included hired labor, machinery operating inputs, and capital services The materials category included fertilizer and miscellaneous variable inputs We aggregated all price categories using the Tornqvist index

The variable-input category, pesticides, and the two fixed-input categories, family labor and land, were not aggregated further in the aggregate models Pesticide price and quantity data were provided by McGath (1989) at the Economic Research Service A weighted average of effective diversion payments for farm program crops was constructed using profit shares in the respective States as weights

Villezca and Shumway's (1992) findings furnished final aggregate models built to be consistent with nonrejected parametric hypothesis tests of nonjointness and/or homothetic separability They tested these structural properties in all four States using three different functional forms They concluded that shortrun output category supply equations in California can be specified as functions only of their own prices, prices of variable inputs, and quantities of the nonprice exogenous variables The same conclusion applies to crops and other livestock in Texas and Iowa, and to crops and meat animals in Florida No justification was found for a higher level of data aggregation than already maintained in the initial model design

Guided by Lim's (1989) findings, 1-year lagged output prices were used as the expected market prices In using a procedure adapted from Romain (1983), we expected prices of farm program commodities (corn, milk, cotton, sorghum, barley, wheat, oats, soybeans, rice, sugarbeets, peanuts, and tobacco) to be specified as weighted averages of the anticipated market price and effective support price The weights were dependent on the relative magnitudes of the expected market prices and support prices McIntosh's (1990) findings favored the use of this specification in three of the States The specification of effective diversion payments and effective support prices followed Houck and Ryan (1972) The simple average of the maximum and minimum values of these variables compiled by McIntosh (1989b) were used in the specification

Weather variables were cropland-weighted State averages of monthly temperature and totals of monthly precipitation for critical growing months or for the calendar year (Teigen and Singer, 1988) Exploratory analysis was conducted to determine which weather variable specification provided the greatest explanatory power in each State The weather variables chosen were annual average temperature and annual total precipitation in California, April-May average temperature and July-August total precipitation in Iowa, March-April average temperature and June-July total precipitation in Texas, and March-April average temperature and June-August total precipitation in Florida

Second-stage suboptimization, employing corresponding price and quantity disaggregated data, was conducted for crops, meat animals, milk-poultry, materials, and labor-capital categories in each State Third-stage suboptimization models covered crop categories that had to be aggregated in the second stage due to the large number of individual crops for a given State Nonprice exogenous variables included in all suboptimization models were the same as in the aggregate models, except for land and family labor For the multistage model structure, as in the case of the aggregate models, we aggregated the data into output and variable input categories based on the separability test results obtained by Lim and Shumway (1992) Since neither the weak separability tests conducted by them nor the homothetic separability tests conducted by Villezca and Shumway (1992) on the aggregate models included the nonprice exogenous variables of temperature, precipitation, time, or effective diversion payments, these variables were included in all the multistage choice models for each State

Estimation Procedure

For the first-stage (aggregate) models, systems of four output supply equations (crops, meat animals, milk-poultry, and other livestock) and two input demand equations (materials and pesticides) were estimated for each State as specified in equation 2 The capital-labor input price was used to normalize profit and all other output and variable input prices Because of high collinearity in some State models, neither the profit function, equation 1, nor the numeraire, equation 3, was included in the aggregate systems of estimation equations Nevertheless, because of shared parameters and homogeneity restrictions, all price elasticities for the numeraire equations were derived from the estimated systems

Systems of output supplies and input demands estimated for the second-stage suboptimization (allocation) models, as specified in equations 5 and 6, are detailed for each State in table 1 Because of the large number of crops, we estimated third-stage suboptimization models for at least one crop category in each State The numeraire, equation 6, was included in each estimated suboptimization model system estimated Because of high collinearity in several models, parameters on the quadratic terms of the nonprice exogenous variables were not estimated in any of the suboptimization models This exclusion reduced the flexibility of the functional form used for the suboptimization models by imposing cross-equation restrictions on comparative statics among the fixed inputs at the point of approximation

Error terms associated with each model were assumed to be additive and independently and identically distributed with mean zero and a constant contemporaneous covariance matrix The covariance matrix that transformed the observation matrix came from the iterative version of Zellner's seemingly unrelated regression (ITSUR) Using the procedure SYSNLIN ITSUR in the SAS package, the variance-covariance matrix was iterated until it stabilized for each model The Cholesky factorization allowed imposition of the nonlinear inequality restrictions for maintaining convexity With the convexity restrictions imposed, and using the observation matrix transformed by the iterated covariance matrix, we employed a reduced-gradient nonlinear program (Talpaz and others, 1989) by using the algorithm code MINOS 5 1 (Murtagh and Saunders, 1983) to obtain least squares estimates that satisfied curvature properties for each system of output supply and input demand equations Model estimates were subject to homogeneity, symmetry, and convexity in prices and nonrejected nonjointness hypotheses

Results

Table 2 shows summary statistics for the aggregate and each suboptimization model for each State A 0 05 level of significance was used throughout this study in drawing conclusions from hypothesis tests Curvature properties were tested against the nonconvex alternative using the test from Talpaz and others, and were not significantly violated in any State for any aggregate or suboptimization model For the aggregate models, two nonsignificant monotonicity violations occurred in California, six jointly significant violations in Iowa, no violations in Texas, and three nonsignificant violations in Florida Among the 27 suboptimization models, monotonicity was significantly violated in only three (California feed and food grains, Texas oil crops, and Florida meat animals) Consequently, one set of model estimates in each State significantly violated the implications of the competitive theory for individual firms However, all significant violations were limited to the first six observations of the data period No significant violations occurred at the most recent observation (for which elasticities were derived)

Given the model specification, the number of significant parameter estimates varied from 26 percent in the Iowa crops suboptimization model to 72 percent in the Iowa labor-capital suboptimization model Across models, the proportion of significant parameter estimates was 33 percent in California, 36 percent in Iowa, 40 percent in Texas, 33 percent in Florida, and 36 percent in all States combined

Multistage model estimates at the most recent observation (1986) produced disaggregated price elasticities for each State Equations 2, 5, and 6 determined the elasticities for individual commodities

Table 1—Output supply and input demand equations estimated for multistage suboptimization models in the four States

Model	California	Iowa	Texas	Florida
Second-stage allocation		*Crops*		
	Feed and food grains (A)	Feed and food grains (A)	Feed and food grains (A)	Fruit and vegetables (A)
	Fruit and vegetables (A)	Soybeans	Oil crops (A)	Tobacco
	Cotton	Apples	Vegetables (A)	Soybeans
	Sugarbeets	Hay	Oranges	Peanuts
	Hay	Potatoes	Grapefruit	Corn
	Other crops (R) (N)	Other crops (R) (N)	Hay	Sugarcane
			Other crops (R) (N)	Other crops (R) (N)
		Meat animals		
	Cattle	Cattle	Cattle	Cattle
	Hogs	Hogs	Hogs	Hogs (N)
	Sheep (N)	Sheep (N)	Sheep (N)	
		Milk-poultry		
	Milk	Milk	Milk	Milk
	Eggs	Eggs	Eggs	Eggs
	Broilers	Broilers	Broilers	Broilers (N)
	Turkeys (N)	Turkeys (N)	Turkeys (N)	
		Materials		
	Fertilizer	Fertilizer	Fertilizer	Fertilizer
	Miscellaneous variable	Miscellaneous variable	Miscellaneous variable	Miscellaneous variable
	Inputs (R) (N)	Inputs (R) (N)	Inputs (R) (N)	Inputs (R) (N)
		Labor-capital		
	Hired labor	Hired labor	Hired labor	Hired labor
	Capital services	Capital services	Capital services	Capital services
	Machinery operating (N)	Machinery operating (N)	Machinery operating (N)	Machinery operating (N)
Third-stage allocation		*Feed and food grains*		*Fruit and vegetables*
	Wheat	Wheat	Wheat	Oranges
	Rice	Corn	Rice	Grapefruit
	Corn	Sorghum	Corn	Tomatoes
	Barley	Oats (N)	Barley	Lettuce
	Oats (N)		Sorghum	Potatoes (N)
			Oats (N)	
	Fruit and vegetables		*Vegetables*	
	Apples		Onions	
	Grapes		Lettuce	
	Grapefruit		Tomatoes	
	Oranges		Potatoes (N)	
	Onions		*Oil crops*	
	Lettuce		Cotton	
	Tomatoes		Soybeans	
	Potatoes (N)		Peanuts (N)	

A=aggregate category for which a higher level allocation model is estimated R=residual aggregate category for which no further allocation can be estimated N=the numeraire

and inputs by applying the chain rule of calculus (tables 3-10) (Appendix table 1 summarizes all own-price elasticities) Because of the large commercial agricultural output of these States, the supply elasticities reported here are the most detailed and comprehensive ever to appear in economic literature Without the ability to do multistage modeling, it would have been impossible to estimate cross-price elasticities for such a large number of commodities from these data [2] All cross-price

[2]Estimating all cross-price elasticities by a single model would be possible if the time series data were pooled across States A sufficient condition for pooling the data is identical technologies across the pooled States Although not tested here, this hypothesis was rejected by Polson and Shumway for all pairs of States in two contiguous production regions

Table 2—Summary statistics of multistage models in the four States

State	Model	Convexity, F-statistic	Monotonicity		Percent of significant parameters[1]
			Number of violations[2]	χ^2 statistic	
California	Aggregate	0 70	2	1 53	26 9
	Crops	05	0		34 7
	Meat animals	1 28	0		38 9
	Milk-poultry	1 53	0		26 9
	Materials	[3]	0		36 4
	Labor-capital	[3]	0		61 1
	Feed and food grains	19	1	5 86[1]	30 0
	Fruit and vegetables	39	0		32 4
Iowa	Aggregate	1 20	6	49 77[1]	31 7
	Crops	42	0		25 5
	Meat animals	41	0		33 3
	Milk-poultry	85	3	63	34 6
	Materials	[3]	2	1 13	27 3
	Labor-capital	[3]	0		72 2
	Feed and food grains	05	0		47 6
Texas	Aggregate	29	0		39 7
	Crops	57	0		30 5
	Meat animals	38	0		38 9
	Milk-poultry	11	0		26 9
	Materials	[3]	0		45 5
	Labor-capital	[3]	0		66 7
	Feed and food grains	76	1	2 68	37 3
	Vegetables	04	0		53 8
	Oil crops	0002	5	29 49[1]	52 6
Florida	Aggregate	49	3	7 24	30 2
	Crops	20	3	55	31 0
	Meat animals	12	0		54 5
	Milk-poultry	33	1	003	44 4
	Materials	[3]	0		36 4
	Labor-capital	[3]	0		33 3
	Fruit and vegetables	92	2	7 27[1]	28 6

[1] Significant at 0 05 level
[2] Number of violations of monotonicity from a possible total of 36 times the number of equations estimated in the respective model
[3] Unconstrained estimates satisfied convexity restrictions

elasticities were estimated To conserve space, however, some columns of elasticities are not reported in tables 3-10 because all elasticities in the column were zero to the third decimal place Standard errors are not reported for these elasticities, being both complex and merely approximate Nearly all of the elasticity estimates in each table were computed as a nonlinear function of parameters

Output supply and input demand elasticities varied widely across States Weighted averages of the expected market price and effective support price acted as the expected output prices of farm program commodities, so differences in response to government programs and market price information are reflected by the wide range of own- and cross-price elasticities across States

Crop Supply Elasticities

Nearly all own-price output supply elasticities were inelastic in each State Exceptions included wheat and apples in Iowa, barley and oats in Texas, and tobacco and soybeans in Florida With very few exceptions, cross-price output supply elasticities were also inelastic Similarities among own-price responses (differences of 0 2 or less) across all States comprised potatoes, tomatoes (not produced in Iowa), and the other-crops residual category Similarities across pairs of States numbered wheat, rice, corn, grapefruit, oranges, onions, and cotton in California and Texas, oranges and lettuce in California and Florida, and soybeans and hay in Iowa and Texas Some of these responses were virtually the same (differences of 0 05 or less) in some State pairs, such as potatoes in California and Iowa, grapefruit, corn, and tomatoes in California and Texas, potatoes and tomatoes in California and Florida, and the other-crops residual category in Texas and Florida

The signs of the cross-price elasticities indicated a wide variety of shortrun competitive and comple-

Table 3—Crop supply elasticities, California, 1986

Item	Elasticity with respect to the price of[1]																						
	Wheat	Rice	Corn	Barley	Oats	Cotton	Sugar beets	Hay	Onions	Lettuce	Tomatoes	Potatoes	Apples	Grapes	Oranges	Grapefruit	Other crops	Fertilizer	Misc inputs	Pesticides	Hired labor	Capital serv	Mach oper
Wheat	0.070	0.052	0.045	0.021	0.001	-0.051	0.170	-0.034	0.002	0.006	0.008	0.003	0.001	0.012	0.006	0.001	0.037	-0.006	-0.070	0.021	-0.173	-0.068	-0.052
Rice	.037	.072	-.049	.014	.030	-.028	.093	-.019	.001	.003	.004	.001		.007	.003		.020	-.003	-.038	.012	-.094	-.037	-.029
Corn	.015	-.086	.344	-.129	-.114	-.009	.028	-.006		.001	.001			.002	.001		.006	-.001	-.012	.004	-.029	-.011	-.009
Barley	.009	.013	-.254	.181	.075	-.006	.021	-.004		.001	.001			.002	.001		.005	-.001	-.009	.003	-.022	-.009	-.007
Oats	-.019	.821	-2.462	.830	.857	-.007	.025	-.005		.001	.001			.002	.001		.005	-.001	-.010	.003	-.025	-.010	-.008
Cotton	-.006	-.005	-.004	-.002		.674	-.202	-.127	-.006	-.023	-.030	-.010	-.003	-.047	-.024	-.003	.150	-.006	-.067	.020	-.165	-.065	-.050
Sugarbeets	.093	.071	.057	.027	.002	-.671	.396	.062	.005	.018	.023	.008	.003	.037	.019	.002	-.152						
Hay	-.040	-.031	-.024	-.012	-.001	-.916	.143	.758	.089	.345	.447	.152	.051	.698	.363	.038	-1.740	-.005	-.065	.019	-.159	-.063	-.048
Onions						-.027	.005	.037	.013	.015	.011	.003	.008	.031	.023	.019	-.060	-.001	-.012	.004	-.029	-.011	-.009
Lettuce						-.011	.002	.015	.001	.082		.025	-.018	.046	-.047	-.010	-.032		-.005	.001	-.011	-.005	-.003
Tomatoes						-.046	.009	.063	.006	.025	.068	.008	.011	.058	.015	.021	-.137	-.002	-.020	.006	-.050	-.020	-.015
Potatoes						-.009	.002	.013	-.003	.076	-.019	.130	-.008	.027	-.093	-.069	-.027		-.004	.001	-.010	-.004	-.003
Apples						-.013	.003	.018	.015	-.186	.088	-.022	.096	-.126		.195	-.039		-.006	.002	-.011	-.006	-.004
Grapes						-.047	.010	.065	.008	.052	.037	.018	-.001	.083	.037	-.014	-.140	-.002	-.021	.006	-.051	-.020	-.015
Oranges	-.001					-.067	.014	.093	.013	.002	.043	-.005	.006	.100	.149	.002	-.201	-.002	-.030	.009	-.073	-.029	-.022
Grapefruit	-.001	-.001				-.075	.015	.104	.046	-.258	.227	-.140	.157	-.120	.026	.109	-.224	-.003	-.033	.010	-.081	-.032	-.025
Other crops						.006	-.002	-.026	-.002	-.008	-.010	-.003	-.001	-.015	-.008	-.001	.217	-.002	-.030	.009	-.073	-.029	-.022

[1] Blanks = elasticity was zero to third decimal place

Table 4—Livestock supply and input demand elasticities, California, 1986

Item	Elasticity with respect to the price of[1]																													
	Wheat	Rice	Corn	Barley	Cotton	Sugar beets	Hay	Onions	Lettuce	Tomatoes	Potatoes	Apples	Grapes	Oranges	Grape fruit	Other crops	Cattle	Hogs	Sheep	Milk	Eggs	Broilers	Turkeys	Other livestock	Fertilizer	Misc inputs	Pesticides	Hired labor	Capital serv	Mach oper
Cattle																	0.133	-0.002	0.005						-0.027	-0.322	0.052	0.095	0.036	0.029
Hogs																	-.179	.138	.041							-.001				
Sheep																	-.031	.024	.007							-.001				
Milk																				0.012	0.007	0.006	0.004		-.007	-.086	.020	.008	.003	.002
Eggs																					.094	-.133	.038							
Broilers																				.060	-.139	.246	-.083		-.010	-.123	.029	.012	.005	.004
Turkeys																				.082	.071	-.104	.068		-.014	-.170	.040	.016	.006	.005
Other livestock																								0.022	.012	.144	.019	-.116	-.046	-.035
Fertilizer	0.001	0.001	0.001		0.004	0.001		0.001	0.002	0.003	0.001		0.005	0.003		0.030	.053	.002	.003	.037	.006	.005	.004	-.002	-.032	-.224	.012	.031	.012	.009
Misc inputs	.001	.001	.001		.005	.001		.001	.003	.004	.001		.006	.003		.038	.067	.002	.003	.047	.006	.007	.005	-.002	-.024	-.299	.053	.040	.016	.012
Pesticides	-.003	-.003	-.002	-.001	-.011	-.003	-0.001	-.002	-.007	-.010	-.003	-0.001	-.015	-.008	-0.001	-.091	-.067	-.003	-.004	-.088	-.015	-.012	-.009	-.003	-.035	.422	-.091	.010	.004	.003
Hired labor	.006	.004	.003	.002	.019	.005	.002	.003	.013	.016	.006	.002	.025	.013	.001	.153	-.033	-.001	-.002	-.007	-.001	-.001	-.001	.003	.005	.065	.002	-.705	.180	.223
Capital services	.005	.004	.003	.002	.017	.004	.002	.003	.012	.015	.005	.002	.024	.012	.001	.142	-.030	-.001	-.002	-.007	-.001	-.001	-.001	.003	.005	.060	.002	.507	-1.068	.281
Machinery operating	.008	.006	.005	.002	.028	.007	.003	.005	.019	.025	.008	.003	.038	.020	.002	.230	-.049	-.002	-.003	-.011	-.002	-.002	-.001	.005	.008	.098	.003	.732	.341	-1.528

[1] Blanks = elasticity was zero to third decimal place

Table 5—Crop supply elasticities, Iowa, 1986

Item	Elasticity with respect to the price of [1]												
	Wheat	Corn	Oats	Soy-beans	Hay	Pota-toes	Apples	Other crops	Fert-ilizer	Misc inputs	Pest-icides	Capital serv	Mach oper
Wheat	2 079	-1 593	-0 471	0 007	-0 001				-0 003	-0 021	-0 002	0 003	0 002
Corn	- 002	010	001	004					- 002	- 012	- 001	002	001
Oats	- 049	045	013	004					- 002	- 012	- 001	002	001
Soybeans		003		005	-0 003		-0 001	-0 002		- 002			
Hay		- 040	- 001	- 119	095	-0 014	008	074		- 003			
Potatoes		129	002	427	- 396	170	451	- 783		- 001			
Apples	-0 001	- 567	- 009	-1 602	345	699	3 542	-2 405		- 001			
Other crops		- 014		- 054	037	- 013	- 027	072					

[1]Blanks = elasticity was zero to third decimal place

Table 6—Livestock supply and input demand elasticities, Iowa, 1986

Item	Elasticity with respect to the price of [1]																	
	Corn	Oats	Soy-beans	Other crops	Cattle	Hogs	Sheep	Milk	Eggs	Broil-ers	Tur-keys	Other live-stock	Ferti-lizer	Misc inputs	Pesti-cides	Hired labor	Capital serv	Mach oper
Cattle					0 142	0 195	0 007	-0 051	-0 007	-0 001	-0 006		-0 034	-0 267	0 032	-0 001	-0 005	-0 003
Hogs					022	097	- 002	- 017	- 002		- 002		- 012	- 091	011		- 002	- 001
Sheep					282	- 285	048	- 007	- 001		- 001		- 004	- 035	004		- 001	
Milk					- 058	- 116	- 001	119	016	006	005		- 008	- 063	- 042	013	084	044
Eggs					- 155	- 309	- 003	308	165	- 002	- 078		- 022	- 169	- 112	035	224	117
Broilers								257	- 045	261	- 473							
Turkeys					- 048	- 097	- 001	014	- 122	- 076	307		- 007	- 053	- 035	011	070	037
Other livestock												2 433	247	1 931	-1 007	- 337	-2 143	-1 124
Fertilizer	0 035	0 001	0 015	0 001	087	174	001	018	003		002	- 008	- 570	130	006	010	063	033
Misc inputs	019		008		047	094	001	010	001		001	- 005	037	- 274	003	005	034	018
Pesticides	018		007		- 056	- 112	- 001	066	009	001	008	024	004	033	- 040	003	022	012
Hired labor	- 005		- 002		002	004		- 026	- 004		- 003	010	009	068	004	- 921	1 833	- 967
Capital services	- 008		- 003		003	005		- 037	- 005	- 001	- 004	014	012	097	006	301	-1 047	666
Machinery operating	- 005		- 002		002	004		- 025	- 004		- 003	010	008	066	004	- 314	1 330	-1 069

[1]Blanks = elasticity was zero to third decimal place

Table 7—Crop supply elasticities, Texas, 1986

Item	Elasticity with respect to the price of [1]																					
	Wheat	Rice	Corn	Barley	Sorghum	Oats	Soybeans	Peanuts	Cotton	Hay	Onions	Lettuce	Tomatoes	Potatoes	Oranges	Grapefruit	Other crops	Misc inputs	Pesticides	Hired labor	Capital serv	Mach oper
Wheat	0 190	0 052	0 158	0 002	0 220	0 009	–0 016	–0 058	–0 376	0 023	–0 001			–0 001	–0 010	–0 030	–0 161		0 003	–0 001	–0 002	–0 002
Rice	094	187	– 211	002	122	099	– 008	– 027	– 175	011	– 001				– 005	– 014	– 075		001		– 001	– 001
Corn	160	– 049	370	– 021	177	– 094	– 014	– 050	– 323	020	– 001				– 009	– 026	– 139		003	– 001	– 002	– 001
Barley	178	092	–2 065	3 949	–1 939	354	– 015	– 052	– 338	021	– 001			– 001	– 009	– 027	– 145		003	– 001	– 002	– 002
Sorghum		005	– 009	– 016	011	009																
Oats	730	953	–1 893	092	1 106	1 341	– 061	– 214	–1 385	086	– 004			– 002	– 038	– 110	– 595	0 001	011	– 004	– 007	– 006
Soybeans	– 212	– 056	– 179	– 002	– 245	– 009	059	265	521	– 036	– 038	–0 003	–0 004	– 018	026	038	– 103	001	010	– 003	– 007	– 005
Peanuts	– 033	– 009	– 028		– 039	– 001	039	206	– 111	– 006	– 006		– 001	– 003	004	006	– 016		002	– 001	– 001	– 001
Cotton	– 162	– 043	– 137	– 002	– 188	– 007	016	– 042	590	– 028	– 029	– 002	– 003	– 014	020	029	– 079	001	007	– 003	– 005	– 004
Hay	098	026	083	001	113	004	– 012	– 042	– 270	015	014	001	001	007	– 008	– 016	– 014	001	005	– 002	– 004	– 003
Onions	– 003	– 001	– 003		– 004		– 008	– 030	– 191	010	201	– 048	– 004	– 053		001	135					
Lettuce	– 010	– 003	– 008		– 011		– 024	– 083	– 537	027	– 531	340	141	321	– 001	001	378					
Tomatoes											– 113	117	094	– 098								
Potatoes	– 005	– 001	– 004		– 006		– 012	– 043	– 277	014	– 152	061	– 016	246	– 001	001	195					
Oranges	– 901	– 240	– 763	– 009	–1 042	– 039	178	628	4 068	– 166	– 014	– 001	– 001	– 006	260	201	–2 137	003	033	– 011	– 022	– 018
Grapefruit	–2 527	– 674	–2 140	– 024	–2 924	– 109	246	866	5 612	– 324	016	001	001	007	196	415	1 369	002	017	– 006	– 011	– 009
Other crops	– 038	– 010	– 032		– 044	– 002	– 002	– 007	– 043	– 001	011	001	001	005	– 006	004	164		001		– 001	– 001

[1] Blanks = elasticity was zero to third decimal place

Table 8—Livestock supply and input demand elasticities, Texas, 1986

Item	Elasticity with respect to the price of [1]																					
	Wheat	Rice	Corn	Sorghum	Peanuts	Cotton	Hay	Onions	Other crops	Cattle	Hogs	Sheep	Milk	Eggs	Broilers	Turkeys	Fertilizer	Misc inputs	Pesticides	Hired labor	Capital serv	Mach oper
Cattle																		0 001			–0 001	
Hogs										–0 010	0 013	–0 003	–0 001		–0 001		0 001	005	0 001	–0 001	–0 002	–0 002
Sheep										002	– 004	001										
Milk													051	–0 015	– 029	0 001	– 002	– 021	– 006	0 004	0 009	0 007
Eggs										– 002			– 013	031	055		– 018	– 173	– 047	0 037	0 072	0 060
Broilers										– 002			– 023	028	087	– 038	– 014	– 129	– 035	0 027	0 054	0 044
Turkeys										– 010			164	052	– 189	285	– 079	– 749	– 202	0 159	0 313	0 258
Other livestock																		– 001	– 001		0 001	0 001
Fertilizer										– 004			058	022	037	003	– 383	292	– 024	0 018	0 036	0 030
Misc inputs										– 005			079	030	050	003	025	– 149	– 032	0 025	0 049	0 040
Pesticides	–0 004	–0 001	–0 004	–0 005	–0 001	–0 009	–0 001	–0 001	–0 013	– 005			078	030	049	003	– 046	– 437	– 210	0 126	0 248	0 204
Hired labor	001			001		001			002	0 02			– 024	– 009	– 015	– 001	014	133	049	–1 085	0 094	0 837
Capital services						001			001	001			– 018	– 007	– 011	– 001	011	099	037	0 063	–0 954	0 775
Machinery operating	001		001	001		002			002	002			– 032	– 012	– 020	– 001	019	178	066	0 558	0 912	–1 677

[1] Blanks = elasticity was zero to third decimal place

Table 9—Crop supply elasticities, Florida, 1986

Item	Elasticity with respect to the price of [1]																
	Corn	Soybeans	Peanuts	Sugarcane	Tobacco	Lettuce	Tomatoes	Potatoes	Oranges	Grapefruit	Other crops	Fertilizer	Misc inputs	Pesticides	Hired labor	Capital serv	Mach oper
Corn	0 560	–0 062	0 512	–0 157	0 512	–0 006	–0 068	–0 012	–0 152	–0 035	–1 088		–0 001		–0 001	–0 001	
Soybeans	– 088	1 408	364	– 518	– 092	– 015	– 168	– 029	– 375	– 085	– 391	–0 001	– 004		– 003	– 002	–0 001
Peanuts	206	103	651	– 008	– 090	005	052	009	117	027	–1 072						
Sugarcane	– 009	– 021		113	007	001	015	003	034	008	– 088	– 006	– 024	–0 002	– 016	– 010	– 005
Tobacco	514	– 065	– 223	106	1 079	– 018	– 194	– 033	– 434	– 099	– 630		– 001		– 001		
Lettuce	– 008	– 016	021	040	– 026	010	036	– 014	090	– 044	031	– 011	– 046	– 004	– 030	– 019	– 010
Tomatoes	– 007	– 012	016	031	– 020	003	023	– 002	050	– 013	024	– 008	– 036	– 003	– 023	– 015	– 008
Potatoes	– 004	– 007	009	017	– 011	– 008	– 018	117	– 116	057	013	– 004	– 019	– 002	– 013	– 008	– 004
Oranges						002	007	– 010	019	– 018							
Grapefruit	– 006	– 011	014	028	– 018	– 007	– 026	019	– 049	117	022	– 007	– 032	– 003	– 021	– 013	– 007
Other crops	– 013	– 003	– 032	– 012	– 007		005	001	010	002	162	– 010	– 044	– 004	– 029	– 018	– 009

[1] Blanks = elasticity was zero to third decimal place

Table 10—Livestock supply and input demand elasticities, Florida, 1986

Item	Elasticity with respect to the price of [1]																						
	Corn	Soybeans	Peanuts	Sugarcane	Tobacco	Lettuce	Tomatoes	Potatoes	Oranges	Grape fruit	Other crops	Cattle	Hogs	Milk	Eggs	Broilers	Other livestock	Fertilizer	Misc inputs	Pesticides	Hired labor	Capital serv	Mach oper
Cattle												0 060	0 004					–0 005	–0 023	–0 059	0 012	0 007	0 004
Hogs												073	006					– 006	– 028	– 072	014	009	005
Milk														0 063	0 058	–0 120	0 005	002	007	– 003	– 006	– 004	– 002
Eggs														168	153	– 317	012	004	018	– 009	– 015	– 009	– 005
Broilers														– 292	– 267	559							
Other livestock														015	006	007	110	– 005	– 021	– 104	– 005	– 003	– 002
Fertilizer	0 001	0 001	0 001	0 008	0 001		0 005	0 001	0 010	0 002	0 037	003		– 001	– 001	– 001	001	– 233	116	– 016	033	021	011
Misc inputs	002	002	004	028	002	0 001	0 015	003	034	008	125	011	001	– 004	– 002	– 002	004	– 026	– 370	– 056	112	071	037
Pesticides	001	001	001	008	001		005	001	010	002	037	089	006	007	003	003	064	– 041	– 176	– 165	073	046	024
Hired labor	002	001	003	020	001	001	011	002	025	006	090	– 006		004	002	002	001	029	123	025	– 962	312	308
Capital services	001	001	002	012	001	001	007	001	015	003	056	– 004		002	001	001	001	018	076	016	552	– 684	– 078
Machinery operating	001		001	007			004	001	008	002	031	– 002		001	001	001		010	042	009	1 130	– 127	–1 119

[1] Blanks = elasticity was zero to third decimal place

mentary production relationships [3] A few similarities, however, were found across some States In California, Texas, and Florida, relationships were competitive between oranges and potatoes and between potatoes and tomatoes Complementarity occurred between lettuce and tomatoes In California and Texas, where the most similarities were found, results revealed complementary relationships among wheat, rice, barley, and oats, and competitive relationships between rice and corn and between corn and barley All feed and food grains were gross substitutes to cotton Other relationships showed complementarity between oranges and grapefruit, grapefruit, onions, and tomatoes, lettuce and tomatoes, potatoes and lettuce, and competitiveness between potatoes and tomatoes and potatoes and onions All vegetables were gross complements to hay and gross substitutes to cotton and the other-crops residual category Hay and cotton were also gross substitutes Fewer consistent cross-price production relationships played out between California and Florida and between Texas and Florida Cross-price relationships in Iowa were least similar to those in other States

Livestock Supply Elasticities

With only one exception (in Iowa), all own-price livestock elasticities were inelastic, ranging from 0 007 to 0 25 in California, 0 05 to 2 43 in Iowa, 0 001 to 0 29 in Texas, and 0 01 to 0 56 in Florida All cross-price livestock output elasticities were inelastic in each State Although not as varied in magnitude as the crop elasticities, the elasticities for livestock also reflected considerable variation across States Similar own-price elasticities (that is, differences of 0 2 or less) were observed for milk and eggs and spanned all States, for hogs, sheep, and broilers in California, Iowa, and Texas, for cattle in California, Iowa, and Florida, for the other-livestock residual category in California and Florida, and for turkeys in Iowa and Texas Virtually the same elasticities (differences of 0 05 or less) covered California, Texas, and Florida for milk, California and Iowa for cattle, hogs, and broilers, California and Texas for sheep, and Iowa and Florida for eggs

Cross-price elasticities showed consistent signs across some States Milk and turkeys qualified as shortrun gross complements and broilers and turkeys as shortrun gross substitutes in California, Iowa, and Texas Gross substitutability occurred between eggs and broilers in California, Iowa, and Florida Gross complementarity was observed between milk and broilers in California and Iowa, eggs and turkeys in California and Texas, cattle and hogs, and milk and eggs in Iowa and Florida Gross substitutability marked hogs and sheep in Iowa and Texas, and milk and broilers in Texas and Florida Since the estimation of the aggregate models for each State was performed maintaining nonjointness for at least the crops category, no livestock-crop nor crop-livestock cross-price elasticities were derived

Input Demand Elasticities

Own-price input demand elasticities were also generally inelastic in each State A common exception was machinery operating inputs, which ranged from –1 07 in Iowa to –1 68 in Texas Own-price elastic responses also influenced capital services in California and Iowa and hired labor in Texas Across States, similar elasticities spanned miscellaneous variable inputs and pesticides in all States, capital services in California, Iowa, and Texas, hired labor in Iowa, Texas, and Florida, fertilizer in Iowa and Texas and in Texas and Florida, and machinery operating inputs in California and Texas and in Iowa and Florida Nearly identical elasticities turned up in some States miscellaneous variable inputs, pesticides, and capital services in California and Iowa, pesticides in Texas and Florida, and hired labor and machinery operating inputs in Iowa and Florida

Except for two elasticities in Iowa and one in Florida, all cross-price input demand relationships were inelastic They ranged from 0 002 to 0 97 in absolute value The signs of these elasticities revealed that all variable inputs were shortrun gross substitutes, except for fertilizer-miscellaneous variable inputs in California, hired labor-machinery operating inputs in Iowa, fertilizer-pesticides and miscellaneous variable inputs-pesticides in Texas, and fertilizer-pesticides, miscellaneous variable inputs-pesticides, and capital services-machinery operating inputs in Florida

Output-input relationships showed that increases in the prices of inputs generally caused quantities of crops to decrease in all States, except for pesticides in California and Texas, capital services

[3]When all inputs and outputs are variable, economic incentive for a joint technology (in which one firm produces multiple out puts) exists only if outputs are longrun gross complements Inputs must also be gross complements if multiple inputs are used economically by the same firm in the long run There are two reasons why gross complementarity of either outputs or inputs is not a theoretical implication in the current context First, our analysis is short run Family labor and land are treated as fixed inputs The impact of allocatable fixed inputs (such as labor and land) on shortrun cross-price output relationships is opposite to that of technical interdependence (which gives rise to joint production in the long run) Second, our analyses are for State aggregates rather than for individual firms Externalities can give rise to either competitive or complementary relationships at the community (or larger geographic) level when they do not exist in the firm

and machinery operating inputs in Iowa, and miscellaneous variable inputs in Texas Because of symmetry restrictions on price parameters within a model, input demands generally increased as crop prices increased Output-input responses for livestock showed a wide variation across States regarding the direction of the relationships between the quantities of livestock categories and the prices of several inputs and vice versa

Conclusions

Disaggregated parameter estimates for multiple-output production relationships in California, Iowa, Texas, and Florida came from dual models that were consistent over most of the data period with competitive theory, nonrejected analytic simplifying assumptions (nonjointness), and multistage choice (homothetic separability) Linear homogeneity, symmetry, and convexity restrictions were maintained in the estimation Monotonicity was checked at every observation and was significantly violated by only four of the 31 models estimated and only at early observations in the data period Convexity was not rejected by any model

The multistage parameter estimates were used to derive full matrices of disaggregated elasticities Multistage modeling allowed these elasticities to be computed at the most detailed and comprehensive level ever to appear in economic literature

A wide diversity among output supply and input demand elasticities was observed across States Nearly all output supply elasticities for crops were inelastic and showed a wider variation across States than did livestock supplies or input demands With only one exception, all livestock supply elasticities were also inelastic A common pattern regarding the magnitude of the own-price supply elasticities (differences of 0 2 or less) across all States occurred only for potatoes, tomatoes, the other-crops residual category, milk, and eggs Other important similarities were observed across pairs of States

Input demand elasticities were generally inelastic A common exception was machinery operating inputs, which showed an elastic response in all States Own-price elasticities for miscellaneous variable inputs and pesticides appeared similar in all States Important similarities in other elasticities were found in two or three States Output-input relationships across States showed that, in general, crop supplies decreased as input prices increased, and input demands increased as crop prices increased

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Appendix table 1—Output supply and input demand own-price elasticities, 1986

Output or input	California	Iowa	Texas	Florida
Wheat	0 070	2 079	0 190	NA
Rice	072	NA	187	NA
Corn	344	010	370	0 560
Barley	181	NA	3 949	NA
Sorghum	NA	NA	011	NA
Oats	857	013	1 341	NA
Soybeans	NA	005	059	1 408
Peanuts	NA	NA	206	651
Cotton	674	NA	590	NA
Sugarbeets	396	NA	NA	NA
Sugarcane	NA	NA	NA	113
Hay	758	095	015	NA
Tobacco	NA	NA	NA	1 079
Onions	013	NA	201	NA
Lettuce	082	NA	340	010
Tomatoes	068	NA	094	023
Potatoes	130	170	246	117
Apples	096	3 542	NA	NA
Grapes	083	NA	NA	NA
Oranges	149	NA	260	019
Grapefruit	409	NA	415	117
Other crops	217	072	164	162
Cattle	133	142	000	060
Hogs	138	097	013	006
Sheep	007	048	001	NA
Milk	042	119	051	063
Eggs	094	165	031	153
Broilers	246	261	087	559
Turkeys	068	307	287	NA
Other livestock	022	2 433	000	110
Fertilizer	– 032	– 570	– 383	– 233
Miscellaneous	– 299	– 274	– 149	– 370
Pesticides	– 091	– 040	– 210	– 165
Hired labor	– 705	– 921	–1 085	– 962
Capital services	–1 068	–1 047	– 954	– 684
Machinery operating	–1 528	–1 069	–1 677	–1 119

NA = not applicable