Supply Response and Impact of Government-Supported Crops on the Texas Vegetable Industry

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Supply functions, elasticity estimates, and nonjointness test results consistently indicated that few commodities compete economically in the production of six major Texas vegetables (cabbage, cantaloupes, carrots, onions, potatoes, and watermelons). Significant bias effects caused by government-supported commodities, fixed inputs, and technological change were observed and measured. Nonnested test results for the hypothesis of sequential decision making by vegetable producers were inconclusive, but they gave greater likelihood support to sequential than to contemporaneous decision making.

Many crops are produced under provision of government programs intended both to prevent severe drops in prices received by farmers and to limit supplies. Diversion payments, price supports, and acreage restrictions are examples of governmental policies designed to stabilize and control field crop production in the U.S. Vegetable production and marketing, on the other hand, are often subject only to minimum standards implemented by growers' associations and shippers to ensure quality of the fresh produce. Their prices are allowed to vary according to market conditions prevailing at the time of harvest. Meanwhile, health-conscious consumers are enhancing their diets by expanding consumption of vegetables. For example, per capita consumption of fresh vegetables in the U.S. has increased more than a third in less than 15 years, rising from 75 to 102 pounds between 1975 and 1989 (USDA).

Texas is a major vegetable producing state. In 1989 it ranked sixth among the 50 states in value of vegetables produced and fourth in value of fresh vegetables produced (USDA). Considerable resources are devoted to them, and income generated from vegetable production and associated agribusiness activities contribute substantially to the economic viability of the state and many local communities. Nevertheless, its high ranking among vegetable producing states masks the facts that (a) in 1989 Texas produced only 3 percent of fresh vegetables and 2.7 percent of all vegetables produced in the U.S., and (b) its share of the value of U.S. vegetable production has fallen by more than half since 1975. The two states of California and Florida jointly supply ⅔ of the rapidly growing domestic vegetable market. Thus, all other states, including Texas, are relatively minor vegetable suppliers, and many are becoming even less significant in the industry. To understand reasons for these dramatic changes requires an understanding of both production and consumption relationships. This paper will focus on the former.

Considerable production research has focused on supply responsiveness of major field crops. Some have emphasized responsiveness for state-level aggregates of producers, including Texas (Shumway; Villezca and Shumway 1992b). Some of this research has also been oriented to technology specification, but little attention has been given to supply response of vegetables and none to the impact of government-supported crop decisions on vegetable supplies or the bias effect of government-supported crops, environmental factors, or policy variables on the vegetable industry.

These issues will be addressed in this paper for Texas vegetable production. The objectives are to: (a) determine whether Texas farmers collectively make vegetable planting decisions contemporaneously or sequentially with government-supported field crop planting decisions, (b) estimate supply

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Texas Agricultural Experiment Station Technical Article No. 30812.

functions and derive supply elasticities for six major Texas vegetables—cabbage, cantaloupes, carrots, potatoes, onions, and watermelons, and (c) evaluate bias effects on the vegetable industry introduced by technological change, government policy, and the production environment.

Conceptual Model

The state was modeled as though it were a price-taking, profit-maximizing firm with a state-level production (transformation) function. To quantify the impact of government-supported crops on crops with no direct government intervention, consider the possibility that farmers make government-supported crop planting decisions first. A subsequent decision might then be made on how to allocate resources to other field crops, livestock, and/or vegetables. Therefore, production decisions could be incorporated in the conceptual model affecting two subsets of outputs: (a) government-supported commodities, y^c, and (b) commodities without government intervention, y^f. Following Moschini's approach, the global restricted profit function for this sequential model could be expressed as:

$$(1) \qquad \pi(p,r,y,\theta) = p^c y^c + \pi'(p^f,y^c,r,\theta),$$

where $\pi'(p^f,y^c,r,\theta) = \max_{y^f} \{p^f y^f - C(y,r,\theta)\}$ is the restricted profit function which satisfies the following regularity conditions: nondecreasing in the vectors of prices of commodities without government support (p^f) and in the vector of fixed input quantities (θ), nonincreasing in the vector of variable input prices (r) and in the vector of government-supported commodity quantities (y^c), convex and linear homogeneous in the vector (p^f,r), and continuous and twice differentiable in all variables; p^c is the vector of government-supported commodity prices. The variables on the right side of the latter equation are regarded as exogenous to the second-stage decision in which the quantities of non-supported commodities and total quantities of variable inputs are determined.

Upon application of Hotelling's lemma to (1) we obtain:

$$(2) \qquad \partial\pi/\partial p_i^f = \partial\pi'/\partial p_i^f = y_i^f(p^f,y^c,r,\theta)$$

and

$$(3) \qquad -\partial\pi/\partial r_i = -\partial\pi'/\partial r_i = x_i(p^f,y^c,r,\theta).$$

Functions (2) and (3) are the Marshallian output supplies and input demands for non-supported commodities. They depend upon the levels of outputs for which major production decisions were previously made by farmers. Thus, in order to achieve profit maximization, the output supplies in the subset, y^f, and the Marshallian demands for variable inputs, x, have to be assessed in relation to the subset of outputs in y^c. If all output production decisions are made contemporaneously, y^c is an empty subset and y^f includes both government-supported and non-supported crops.

Considering nested hypothesis test results, predictive accuracy, and theoretical/statistical performance, Ornelas found that the normalized quadratic was preferred over alternative flexible functional forms for a dual specification of Texas agricultural production. Therefore, this study utilizes the normalized quadratic restricted profit function:

$$(4) \qquad \pi = b_0 + b'W + c'Z + .5W'BW + .5Z'CZ + W'DZ,$$

where π is profit divided by the price of an arbitrarily selected netput 0; $W = (w_1, \ldots, w_n)$ is the vector of non-supported output and input prices divided by the price of netput zero; $Z = (z_1, \ldots, z_q)$ is the vector of government-supported crops (quantities in the sequential model, prices in the contemporaneous model), quantities of fixed inputs, and other exogenous variables; and b_0, b, c, B, C, and D are conformable parameters to be estimated. Applying Hotelling's lemma to (4) yields the system of non-supported commodity output supply equations and input demand equations

$$(5) \qquad X = b + BW + DZ,$$

where $X = (x_1, \ldots, x_n)$ is the vector of netput quantities, positively measured for non-supported outputs and negatively measured for inputs.

Vegetable production is greatly influenced by seasonality. Some vegetables like carrots, cabbage, and lettuce are generally grown during the winter in Texas. Others like cantaloupes, honeydews, onions, potatoes, and watermelons are grown in early spring and late summer. Each vegetable requires some unique production technologies. Therefore, substitutability or complementarity relationships among vegetables are expected to be limited. To determine whether supply of each vegetable can be modelled without regard to other non-supported output prices, nonjointness among output supplies is tested.

Short-run nonjointness implies the following constraint on the parameters of equation (5):

$$(6) \qquad B_{ij} = 0, \forall i \in y^s; j = 1, \ldots, \ell; \; i \neq j.$$

where y^s represents a subset of outputs within y^f, and $j = 1, \ldots, \ell$ is an index of all output prices in p^f. Failure to reject (6) indicates that short-run decisions to grow a certain vegetable are independent of decisions to grow other outputs whose planting decisions are made contemporaneously.

The measurement of "bias" in agricultural production has typically been restricted to the effect of technological change (using time as a proxy) on marginal rates of substitution or optimal input/output choices. An occasional study has also investigated the bias effects of research, extension, and educational investments (Huffman and Evenson) and production environmental factors (Fawson et al.). Alternative methods to capture these bias effects have been proposed in the literature. Using the concept of indirect Hicks neutrality (Moschini), the ratios of vegetable output supplies must be independent of changes in government-supported crops, policy, and other exogenous variables if these exogenous variables do not bias the production decision. Indirect Hicks neutrality implies that

$$\partial(x_i/x_j)/\partial z_k = (x_i/x_j z_k)(e_{ik} - e_{jk}) = 0, \tag{7}$$

where i,j denotes output variables, and e is the elasticity of output i or j with respect to the exogenous factor. Defining $B^j_{ik} = (e_{ik} - e_{jk})$, $B^j_{ik} = 0$ implies bias neutrality. If the coefficient is positive it indicates bias in favor of output i relative to output j. A negative sign means that the exogenous variable is biased in favor of output j relative to output i.

Because equation (7) renders a large number of pairwise bias measures, revenue share-weighted summary measures of indirect Hicksian bias with respect to the above exogenous variables were also computed for each output as:

$$B_{ik} = \Sigma_j S_j B^j_{ik}. \tag{8}$$

This procedure is qualitatively identical to Antle and Capalbo's dual summary measures of Hicksian bias. If $B_{ik} > 0$, an increase in the exogenous variable z_k biases production in favor of output i; if it is negative, the bias is against output i; if it is zero, x_i is indirectly Hicks neutral with respect to z_k.

Empirical Specification

Data and Variable Specification

Annual state-level data for the period 1951 to 1986 were used in this study. Livestock, field and fruit crop, and input quantity and price data came from the series compiled by Robert Evenson at Yale University, Chris McIntosh at the University of Georgia, and their associates. Their output data covered 14 field crops, four fruit crops, and seven livestock commodities grown in Texas as well as residual crop and livestock categories that included other commercial food and fiber products. Their input data covered seven inputs.

Prices and quantities for the six vegetables employed in this analysis were collected from *Texas Vegetable Statistics* (Texas Department of Agriculture). These data were collected for two reasons: (a) not all major vegetables were included in the Evenson-McIntosh series, and (b) the same source for all vegetable quantities and prices was desired.

Exogenous variables in both initial model specifications included prices of expected vegetables, non-supported crops, and variable inputs; fixed input quantities; government programs; weather; and time. The models differed only in the specification of the exogenous government-supported crop variable; its quantity was used in the sequential model, and its expected price was used in the contemporaneous model. The weather data used in both models was March-April average temperature and annual precipitation data weighted by cropland harvested (Teigen and Singer). These weather variable specifications were selected based on exploratory work by Villezca and Shumway (1992a). Government policy data for each farm program commodity were assembled by McIntosh (1989). Effective support price and effective diversion payment variables were specified following Houck and Ryan using a simple average of McIntosh's maximum and minimum values.

Based on Lim's comparison of four alternatives, expected prices for non-government-supported commodities were specified as one-year lagged prices. For government-supported crops (barley, corn, oats, cotton, peanuts, rice, sorghum, soybeans, and wheat), we used a modification of Romain's specification which was a weighted average of anticipated market price and effective support price.[1] The weight was based on the relative magnitudes of the anticipated market price and effective support price. This specification was found by McIntosh (1990) to result in better out-of-sample predictive performance in this state than either of two alternatives.

To construct a data set relevant for the objectives outlined in this study and to retain adequate degrees of freedom for econometric estimation,

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[1] Dairy production also operates under government support programs. It was not included with the subset of government-supported crops since it is a livestock commodity and does not compete greatly for the same localized resources as does vegetable production.

government-supported crops were grouped into one category. The remaining non-vegetable crops and livestock and poultry products were aggregated into an "other crops-livestock" aggregate. Inputs were aggregated into two variable input categories—materials (consisting of fertilizer, feed, seed, and miscellaneous inputs) and hired labor-capital (including capital services and machinery operating inputs)—and one fixed input category (consisting of family labor and land). These aggregate input categories were created based on (a) the results of nonparametric separability tests conducted by Lim and Shumway, and (b) the fact that the agricultural inputs which exhibit least aggre-

Table 1. Parameter Estimates for the Eight-Equation Model

Parameter	Estimate	Standard Error	Parameter	Estimate	Standard Error
b_1	−0.2446296	(0.1623906)	d_{39}	−0.0000075	(0.0000016)
b_2	0.9593351	(0.2283427)	d_{49}	0.0000012	(0.0000002)
b_3	−0.1553630	(0.0877269)	d_{59}	0.0000000	(0.0000000)
b_4	0.0471171	(0.0101452)	d_{69}	0.0000003	(0.0000004)
b_5	−0.0013609	(0.0015437)	d_{79}	−0.0000043	(0.0000056)
b_6	0.0126014	(0.0201223)	d_{89}	−0.0000070	(0.0000052)
b_7	−1.3165884	(0.3115378)	d_{110}	0.0001010	(0.0000470)
b_8	−0.9471908	(0.2943017)	d_{210}	−0.0002783	(0.0000666)
b_{11}	0.1190595	(0.1036992)	d_{310}	0.0000549	(0.0000254)
b_{12}	0.0143565	(0.0922328)	d_{410}	−0.0000139	(0.0000029)
b_{22}	0.5672394	(0.1512086)	d_{510}	0.0000011	(0.0000004)
b_{13}	−0.0074523	(0.0584603)	d_{610}	−0.0000039	(0.0000059)
b_{23}	0.0315710	(0.0634286)	d_{710}	0.0005116	(0.0000921)
b_{33}	0.0113663	(0.0594145)	d_{810}	0.0000223	(0.0000863)
b_{14}	0.0012719	(0.0061527)	d_{111}	−0.0001589	(0.0006044)
b_{24}	0.0020972	(0.0067433)	d_{211}	0.0010918	(0.0008579)
b_{34}	0.0010068	(0.0047290)	d_{311}	−0.0008715	(0.0003226)
b_{44}	0.0005556	(0.0007556)	d_{411}	0.0000953	(0.0000390)
b_{15}	0.0003587	(0.0010068)	d_{511}	−0.0000004	(0.0000058)
b_{25}	−0.0005061	(0.0010194)	d_{611}	−0.0000054	(0.0000755)
b_{35}	−0.0000379	(0.0007714)	d_{711}	−0.0007657	(0.0011955)
b_{45}	0.0000022	(0.0000864)	d_{811}	−0.0003456	(0.0011207)
b_{55}	0.0000879	(0.0000234)	d_{112}	0.0000878	(0.0010788)
b_{16}	−0.0006209	(0.0074469)	d_{212}	−0.0009090	(0.0015437)
b_{26}	0.0058875	(0.0096370)	d_{312}	0.0006177	(0.0005734)
b_{36}	−0.0008700	(0.0049458)	d_{412}	−0.0001074	(0.0000671)
b_{46}	−0.0001107	(0.0005647)	d_{512}	−0.0000162	(0.0000102)
b_{56}	−0.0000514	(0.0000818)	d_{612}	0.0001070	(0.0001364)
b_{66}	0.0041538	(0.0011618)	d_{712}	0.0012776	(0.0021781)
b_{17}	−0.0126499	(0.0221288)	d_{812}	0.0018565	(0.0020251)
b_{27}	−0.0099498	(0.0317937)	d_{113}	0.0421578	(0.0891958)
b_{37}	−0.0175373	(0.0124495)	d_{213}	0.1183786	(0.1286657)
b_{47}	−0.0019997	(0.0014494)	d_{313}	0.1146987	(0.0466315)
b_{57}	−0.0002474	(0.0002170)	d_{413}	0.0088971	(0.0054768)
b_{67}	−0.0005280	(0.0028692)	d_{513}	0.0026143	(0.0008319)
b_{77}	0.0659727	(0.0380435)	d_{613}	0.0015817	(0.0112754)
b_{18}	−0.0023470	(0.0398462)	d_{713}	−0.4256280	(0.1818460)
b_{28}	−0.0216378	(0.0578923)	d_{813}	0.6825258	(0.1672584)
b_{38}	0.0360031	(0.0228659)	d_{114}	0.0055292	(0.0016165)
b_{48}	0.0038297	(0.0026527)	d_{214}	−0.0115119	(0.0023114)
b_{58}	0.0006477	(0.0003946)	d_{314}	0.0037476	(0.0008772)
b_{68}	−0.0028047	(0.0052382)	d_{414}	−0.0005269	(0.0000998)
b_{78}	−0.0195002	(0.0380863)	d_{514}	0.0000095	(0.0000155)
b_{88}	0.2888529	(0.0783841)	d_{614}	0.0001695	(0.0002027)
d_{19}	−0.0000036	(0.0000029)	d_{714}	0.0358430	(0.0031440)
d_{29}	0.0000096	(0.0000041)	d_{814}	−0.0017591	(0.0030040)

To promote convergence, estimation for the eight-equation model was implemented by scaling all dependent variables by 1/3493.1. Parameter codes: b_i ($i = 1, \ldots, 8$) *represent the intercept parameters for the eight-equation system;* b_{ij} ($i,j = 1, \ldots, 8$) are the parameters for the output and input prices (cabbage, carrots, cantaloupes, potatoes, watermelons, onions, other crops-livestock, and hired labor-capital, respectively); the normalizer price is the aggregate of materials; d_{i9}, d_{i10}, d_{i11}, d_{i12}, d_{i13}, and d_{i14} are the parameters for the exogenous non-price variables (government-supporteed crops, fixed input, rainfall, temperature, aggregate diversion payment, and time).

Table 2. Output Supply and Input Demand Elasticity Estimates, Data Means

	Elasticity with Respect to the Normalized Price of:								
Output or Input	Cabbage	Carrots	Canta-loupes	Potatoes	Water-melons	Onions	Other Non-Supported Commodities	Labor-Capital	Materials
Cabbage	0.092	0.013	-0.011	0.012	0.015	-0.006	-0.181	-0.024	0.090
	(0.082)	(0.085)	(0.084)	(0.059)	(0.041)	(0.069)	(0.318)	(0.415)	(1.063)
Carrots	0.010	0.462	0.040	0.018	-0.018	0.048	-0.125	-0.199	-0.236
	(0.063)	(0.158)	(0.081)	(0.057)	(0.037)	(0.079)	(0.402)	(0.533)	(1.332)
Cantaloupes	-0.011	0.057	0.032	0.019	-0.003	-0.015	-0.488	0.731	-0.320
	(0.088)	(0.115)	(0.167)	(0.089)	(0.061)	(0.089)	(0.358)	(0.484)	(1.241)
Potatoes	0.013	0.025	0.019	0.069	0.001	-0.013	-0.367	0.513	-0.258
	(0.061)	(0.080)	(0.088)	(0.094)	(0.045)	(0.067)	(0.270)	(0.360)	(0.362)
Watermelons	0.017	-0.030	-0.003	0.001	0.222	-0.030	-0.221	0.422	-0.379
	(0.049)	(0.058)	(0.069)	(0.052)	(0.063)	(0.047)	(0.195)	(0.260)	(0.340)
Onions	-0.003	0.034	-0.008	-0.007	-0.013	0.237	-0.047	-0.180	-0.014
	(0.035)	(0.055)	(0.044)	(0.033)	(0.020)	(0.072)	(0.253)	(0.337)	(0.324)
Other Non-Supported Commodities	-0.001	-0.001	-0.003	-0.002	-0.001	-0.001	0.116	-0.025	-0.081
	(0.002)	(0.004)	(0.002)	(0.002)	(0.001)	(0.003)	(0.067)	(0.049)	(0.160)
Labor-Capital	0.0003	0.003	-0.008	-0.005	-0.004	0.004	0.041	-0.438	0.407
	(0.004)	(0.008)	(0.005)	(0.004)	(0.002)	(0.007)	(0.079)	(0.121)	(0.219)
Materials	-0.001	0.003	0.003	0.002	0.003	0.0003	0.112	0.346	-0.468
	(0.010)	(0.017)	(0.011)	(0.003)	(0.003)	(0.006)	(0.211)	(0.186)	(0.290)

Approximate standard errors are in parentheses.

gate year-to-year fluctuations from a secular trend are land and family labor. All output and variable input price aggregates and fixed input quantity aggregates were computed using the Tornqvist index. Aggregate effective diversion payments were computed as an arithmetic index using value shares as weights.

Estimation

To estimate the system of equations specified in (5), the following stochastic version of the model was utilized

$$(8) \qquad X_t = f(W_t, Z_t, \theta) + \xi_t, \quad t = 1, \ldots, T,$$

where X_t is nx1 vector of output supplies and input demands, W_t is a vector of exogenous prices, Z_t is a vector of the quantity or price of government-supported crops, diversion payment, and other exogenous variables, θ is a vector of parameters to be estimated, and T represents the number of observations. The stochastic error term, ξ, was assumed to be normal, independent and identically distributed with mean zero and a constant variance-covariance matrix, Ω. The iterative version of Zellner's seemingly unrelated regression was employed to estimate the equation system specified in (8).

Six vegetable supply equations (cabbage, cantaloupes, carrots, onions, potatoes, and watermelons), one aggregate supply equation (other commodities), and one aggregate demand equation (hired labor-capital) were estimated maintaining linear homogeneity, symmetry, and convexity conditions.[2] Linear homogeneity in prices was imposed on the profit function by using the price of materials as a normalizer. Symmetry was maintained with equality restrictions on cross-price parameters. Convexity was maintained by the Cholesky factorization. The covariance matrix for the seemingly unrelated system was obtained by iterative SUR. After the covariance matrix stabilized, least squares estimates of the parameters were obtained subject to homogeneity, symmetry, and convexity conditions using the nonlinear programming algorithm of Talpaz et al. This procedure ensured that own-price elasticities for outputs and inputs had the expected signs.

To determine whether farmers made vegetable planting decisions sequentially or contemporaneously with field crop planting decisions, two models were constructed. The sequential model included an aggregate quantity of government-

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[2] Monotonicity of the profit function in prices is the final implication of price-taking, profit-maximizing behavior. This property was not maintained because it can only be maintained as a local property and prior empirical research on agricultural production has seldom found it violated (e.g., Moschini; Weaver; Villezca and Shumway 1992b).

supported crops in the set of independent variables. The contemporaneous model contained a price aggregate for government-supported crops in the set of independent variables. The other independent variables in both models included expected normalized prices for the response variables, the fixed input aggregate, aggregate diversion payments, rain, temperature, and time. The last variable was included as a proxy for disembodied technical change.

To test for the aggregate appearance of sequential decision making, we utilized the nonnested testing techniques outlined by Pesaran and Deaton. The null hypothesis that the model specification contained an aggregate quantity of government-supported crops as an exogenous variable was tested against the alternate hypothesis that aggregate price for those crops entered the specification as an exogenous variable. To test for contemporaneous decision making, the test was repeated with the hypothesis reversed, i.e., the null hypothesis became the alternate hypothesis.

Empirical Results

Parameter estimates for the eight-equation system (5) with the aggregate quantity of government-supported crops included as an independent variable are reported in table 1. Because of high collinearity, the profit function (4) was not included in the system of equations. Of all parameters estimated, 30 percent were significant at the .05 level, which is within the range of other multiple-output supply model estimates. Only four own-price parameters were statistically significant. No output cross-price parameters were significant, suggesting that short-run production interrelationships were minimal among cabbage, carrots, cantaloupes, potatoes, watermelons, onions, and the aggregate of other non-supported commodities. Exogenous nonprice variables that were most frequently significant were the aggregate quantity of fixed inputs and time, followed by government-supported crops and the aggregate diversion payment.

Table 3. Parameter Estimates for the Seven-Equation Model Maintaining Short-Run Nonjointness

Parameter	Estimate	Standard Error	Parameter	Estimate	Standard Error
b_1	−1254.39	597.96	d_{410}	−0.05870	0.01359
b_{11}	276.24534	178.57820	d_{412}	−0.39901	0.30211
b_{1L}	9.19320	4.26299	d_{413}	49.02602	25.38894
d_{19}	−.0086536	0.01070	d_{414}	−1.90197	0.46404
d_{110}	0.41012	0.17211	b_5	−9.10766	7.00070
d_{112}	2.58540	3.93931	b_{55}	0.34598	0.04564
d_{113}	76.47516	371.93	b_{5HD}	0.21122	0.08400
d_{114}	18.45053	5.93384	d_{59}	.00022601	.00015034
b_2	3099.82	852.68	d_{510}	.00439057	.00205892
b_{22}	1508.18985	237.83976	d_{512}	−0.02202	0.04496
b_{2C}	−0.02171	.00812422	d_{513}	12.72998	3.97938
d_{29}	−0.002449	0.01870	d_{514}	.00181762	0.07405
d_{210}	−0.86840	0.25304	b_6	−4.32220	70.95077
d_{212}	−1.80308	5.58743	b_{66}	12.35797	2.03949
d_{213}	494.43	474.74	b_{6SO}	−.0030994	.00120548
d_{214}	−28.62677	9.13735	d_{69}	−.00099280	.00140916
b_3	−1064.20	340.07	d_{610}	.00212274	0.02111
b_{33}	192.71270	80.81242	d_{612}	0.55378	0.47320
b_{3HD}	25.68571	4.22888	d_{613}	−1.58376	38.75272
d_{39}	−.0018141	.00717617	d_{614}	1.42994	0.74292
d_{310}	0.24966	0.10087	b_7	−4742.43	1279.72
d_{312}	4.43049	2.21565	b_{77}	296.81777	57.49100
d_{313}	674.92	190.47	d_{79}	−.0065106	0.02274
d_{314}	5.97150	3.59214	d_{710}	1.66623	0.38635
b_4	206.40	46.27008	d_{712}	7.58763	8.50854
b_{44}	0.06928	1.28659	d_{713}	−1674.91	715.76
d_{49}	.00442449	.00084648	d_{714}	122.75256	12.88661

Parameter codes: b_i ($i = 1, \ldots, 7$) are the intercept parameters for the seven-equation system; b_{ii} ($i = 1, \ldots, 7$) are own-price parameters for output supplies (cabbage, carrots, cantaloupes, potatoes, watermelons, onions, and aggregate of livestock and other crops); b_{1L} is a parameter for the expected price of lettuce; b_{2C} is a parameter for winter carrot production in Arizona and California; b_{3HD} and b_{5HD} are parameters for expected honeydew prices; and b_{6SO} is a parameter for lagged stock of onions. The normalizer price is an aggregate of all variable inputs; d_{i9}, d_{i10}, d_{i12}, d_{i13}, and d_{i14} are the parameters for the exogenous non-price variables (government-supported crops, fixed input, temperature, aggregate effective diversion payment, and time).

At a .05 significance level, the results of the nonnested specification test indicated that both variable specifications were rejected against the alternative hypothesis. This finding means that neither the quantity nor the price variable was a sufficient explanatory variable without the other. In other words, both variables added information in the specification. The quantity specification of government-supported crops received the higher likelihood support without the alternative variable, but only weak support. The quantity of government-supported crops was kept as an independent variable in the subsequent model specifications.

Elasticity estimates for all output and input categories, including the numeraire, were computed at the means. They are reported along with their approximate standard errors in table 2 for the model with quantity of government-supported crops as an independent variable. Standard errors were computed based on first-order Taylor-series expansions of the elasticity equations (Miller et al.). Only carrots, watermelons, onions, and labor-capital had statistically significant own-price elasticities. Own-price supply elasticities ranged from 0.03 for cantaloupes to 0.46 for carrots. Cross-price elasticities were not significant for any output which indicates that no complementary or substitute relations existed among the vegetables considered. This result agrees with previous findings on vegetables produced elsewhere (Hammig and Mittelhammer; Shonkwiler and Emerson). At a .05 level of significance, a test for short-run nonjointness was not rejected. The χ^2 statistic was 28.38 with a critical value of $\chi^2_{.05,21} = 32.67$.[3] This finding supported the hypothesis that all endogenous outputs were nonjoint in the short run. The endogenous outputs included each of the six vegetables as well as the aggregate of non-supported crops and livestock.

Utilizing these findings, the model was respecified to focus on nonjoint vegetable supplies by dropping all cross-price parameters among these outputs, dropping rainfall, and aggregating all variable inputs. Based on other work focusing on individual vegetables, some new variables were introduced into this nonjoint model specification to account for supply shifters that could be expected to impact on a particular commodity's unique production characteristics. For instance, U.S. stocks of onions compete with fresh onions from Texas in the spring (Fuller et al.). Winter carrot production in Arizona and California are major competitors with Texas carrot production. Honeydew melons share many of the same production techniques as cantaloupes and watermelons, and compete in the melon market in the same season as Texas cantaloupes and watermelons. Lettuce shares some of the same production techniques as cabbage.

Thus, to explore production relationships, the expected (lagged) price of lettuce was introduced into the cabbage supply function. Expected (lagged) honeydew price was introduced into the cantaloupe and watermelon supply equations. No input demands were estimated; instead an aggregate price for all variable inputs was used as the normalizer. Parameter estimates are reported in table 3.

This model captured vegetable production relationships better than the eight-equation model. Thirty of the 50 parameters were significant. Maintaining convexity and short-run nonjointness among the seven modelled outputs, all own-price parameters were positive and all but cabbage and potatoes were statistically significant. The parameter on expected lettuce price in the cabbage supply equation suggested that lettuce was a significant short-run gross substitute for cabbage. Significant parameters on expected honeydew price in the supply equations for cantaloupes and watermelons indicated that producers treated honeydews as a short-run gross substitute for these two vegetables. Quantities of winter carrots produced in California and Arizona significantly and adversely affected Texas carrot supply. Lagged U.S. stock of stored onions similarly affected Texas onion supply.

Own-price elasticities for this model were also

Table 4. Own-Price Output Supply Elasticity Estimates Maintaining Short-Run Nonjointness Among These Commodities, Data Means

Output	Elasticity
Cabbage	0.064 (0.043)
Carrots	0.374 (0.099)
Cantaloupes	0.166 (0.076)
Potatoes	0.003 (0.060)
Watermelons	0.597 (0.096)
Onions	0.216 (0.044)
Other Non-Supported Commodities	0.160 (0.032)

Approximate standard errors are in parentheses.

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[3] Convexity was not maintained in the test for nonjointness. The asymptotic properties of the test are the same whether or not convexity is maintained (Jorgenson and Lau).

computed at the means. These results are presented in table 4. All the elasticities, except for cabbage and potatoes, were statistically significant. All were inelastic, and the significant ones ranged from 0.16 for other non-supported crops to 0.60 for watermelons. The small magnitudes of vegetable supply elasticities were also supported by the estimates presented in table 2 (for the eight-equation model) and by previous work (e.g., Villezca and Shumway 1992b).

To measure the effect of technology, policy, and the production environment on vegetable production decisions, indirect Hicksian bias coefficients were computed. Both pairwise and revenue-share-weighted measures were computed.

The pairwise measures using equation (7) are reported in table 5. Share-weighted summary measures developed from equation (8) are reported in table 6. Standard errors were computed based on a first-order Taylor-series expansion for the pairwise

Table 5. Pairwise Bias Effects (B^j_{ik}) of Exogenous Variables on Vegetables, Data Means

Outputs		Exogenous Variable (k)				
i	j	Government-Supported Crops	Fixed Inputs	Temperature	Effective Diversion Payment	Time
Cabbage	Carrots	−0.107	9.705	0.816	−0.031	2.662
		(0.277)	(1.877)	(1.007)	(0.037)	(0.500)
Cabbage	Cantaloupes	−0.084	−0.634	−1.184	−0.108	0.414
		(0.288)	(2.140)	(1.132)	(0.042)	(0.553)
Cabbage	Potatoes	−1.084	9.614	1.509	−0.048	2.614
		(0.266)	(2.143)	(1.143)	(0.042)	(0.542)
Cabbage	Watermelons	−0.376	1.117	0.775	−0.062	1.116
		(0.237)	(1.780)	(0.951)	(0.035)	(0.461)
Cabbage	Onions	−0.042	3.274	−0.163	0.008	0.586
		(0.208)	(1.604)	(0.870)	(0.031)	(0.413)
Cabbage	Other NS[a]	0.130	−1.696	−0.323	−0.025	−0.206
		(0.168)	(1.340)	(0.729)	(0.026)	(0.341)
Carrots	Cantaloupes	0.023	−10.340	−2.001	−0.077	−2.248
		(0.351)	(2.349)	(1.226)	(0.047)	(0.629)
Carrots	Potatoes	−0.978	−0.091	0.693	−0.017	−0.048
		(0.318)	(2.262)	(1.188)	(0.045)	(0.592)
Carrots	Watermelons	−0.269	−8.589	−0.042	−0.031	−1.546
		(0.298)	(2.012)	(1.049)	(0.040)	(0.536)
Carrots	Onions	0.066	−6.431	−0.979	0.039	−2.076
		(0.291)	(1.971)	(1.036)	(0.039)	(0.526)
Carrots	Other NS	0.023	8.010	0.493	−0.056	2.456
		(0.288)	(1.992)	(1.042)	(0.039)	(0.526)
Cantaloupes	Potatoes	−1.000	10.248	2.694	0.059	2.200
		(0.261)	(1.862)	(0.976)	(0.037)	(0.486)
Cantaloupes	Watermelons	−0.292	1.751	1.959	0.045	0.702
		(0.192)	(1.375)	(0.718)	(0.027)	(0.359)
Cantaloupes	Onions	0.043	3.909	1.022	0.116	0.172
		(0.253)	(1.779)	(0.932)	(0.035)	(0.468)
Cantaloupes	Other NS	0.045	−2.330	−1.508	−0.133	0.208
		(0.248)	(1.787)	(0.931)	(0.036)	(0.465)
Potatoes	Watermelons	0.708	−8.497	−0.735	−0.014	−1.497
		(0.192)	(1.360)	(0.713)	(0.028)	(0.356)
Potatoes	Onions	1.043	−6.339	−1.672	0.056	−2.028
		(0.229)	(1.777)	(0.939)	(0.035)	(0.453)
Potatoes	Other NS	−0.955	7.919	1.186	−0.073	2.408
		(0.202)	(1.632)	(0.858)	(0.032)	(0.410)
Watermelons	Onions	0.335	2.157	−0.937	0.070	−0.530
		(0.210)	(1.489)	(0.781)	(0.029)	(0.392)
Watermelons	Other NS	−0.247	−0.579	0.451	−0.087	0.911
		(0.164)	(1.147)	(0.595)	(0.023)	(0.302)
Onions	Other NS	0.088	1.579	−0.486	−0.017	0.380
		(0.147)	(1.108)	(0.588)	(0.022)	(0.287)

Approximate standard errors are in parentheses.

[a] Other NS is other non-supported commodities.

Table 6. Revenue-Share-Weighted Bias Effects (B_{ik}) of Exogenous Variables, Data Means

	Exogenous Variable (k)				
Vegetable (i)	Government Supported Crops	Fixed Inputs	Temperature	Effective Diversion Payment	Time
Cabbage	−0.135	1.818	0.321	0.022	0.255
Carrots	−0.027	−7.888	−0.496	0.053	−2.407
Cantaloupes	−0.050	2.452	1.505	0.130	−0.159
Potatoes	0.950	−7.797	−1.189	0.070	−2.359
Watermelons	0.242	0.701	−0.454	0.084	−0.861
Onions	−0.093	−1.457	0.483	0.014	−0.331
Other Non-Supported Commodities	−0.005	0.122	−0.003	−0.003	0.049

measures. Because of the complexity of the expansion and the approximate nature of these standard errors, they were not computed for the summary measures.

Government-supported crops had a significant bias effect on all vegetables when paired with potatoes. The signs of the coefficients indicated that, while changes in levels of government-supported crops directly (positively) biased potatoes, they inversely (negatively) impacted the other five vegetables. The share-weighted summary measures indicate that watermelon production was also directly affected by changes in the level of government-supported crops, but to a much lesser degree than potato production was affected.

Aggregate effective diversion payment registered three cases of significant bias impact on output pairs. These effects occurred on output pairs involving cantaloupes and onions. The summary bias measures indicate that production of each vegetable was directly affected by changes in effective diversion payment. Production of non-supported crops was inversely affected. Since increases in the diversion payment increase incentive to take land out of production of program crops, these results suggest they stimulate transfer of resources to vegetables and away from both program and nonprogram field crops. Nevertheless, both the pairwise and summary measures document that the magnitude of each of these biases is small.

Time and aggregate fixed input quantity had the greatest biasing impacts on vegetable supplies. More than half of the 21 output pairs were significantly impacted by each of these exogenous variables. The summary bias measures with respect to both of these exogenous variables were very large for several of the vegetables. Carrots and potatoes were inversely and substantially affected by both variables. Onions were also inversely affected while cabbage and other non-supported crops were directly affected by both. Cantaloupes and watermelons were directly affected by changes in fixed inputs and inversely affected by time. These empirical findings suggested that vegetable production patterns could be significantly and substantially impacted by the availability of suitable land and/or family labor. The frequency of significant pairwise bias associated with the time variable implied that technical change was not Hicks neutral.

While often large in estimated magnitude, the smallest number of significant pairwise bias effects was found for the temperature variable.

Conclusions

This study has focused on supply relationships for six important Texas vegetables (cabbage, carrots, cantaloupes, potatoes, watermelons, and onions). Somewhat higher likelihood support was found from nonnested tests for sequential than for contemporaneous decision making of government-supported crops and vegetables, but the support was weak and the test inconclusive.

Output response was inelastic for all vegetables and exhibited few significant cross-price responses. Thus, production relationships among these vegetables were largely independent. However, bias effects of technology and government policy were frequently significant and substantial. Judging from the magnitudes of both pairwise and share-weighted summary measures and the statistical significance of the pairwise measures, fixed inputs and time registered the most important biasing effects on the production of all outputs. The quantity of government-supported crops also had a significant pairwise biasing impact on all outputs, and aggregate effective diversion payments significantly affected several vegetables. Thus, there was ample evidence of production bias among

Texas vegetables created by technology, asset fixity, and government programs.

References

Antle, J.M., and S.M. Capalbo. "An Introduction to Recent Developments in Production Theory and Productivity Measurement." Chapter 2 in *Agricultural Productivity: Measurement and Explanation* (eds., S.M. Capalbo and J.M. Antle). Washington: Resources for the Future, 1988.

Fawson, C., C.R. Shumway, and R.L. Basmann. "Agricultural Production Technologies with Systematic and Stochastic Technical Change." *American Journal of Agricultural Economics* 72(1990):182–99.

Fuller S.W., O. Capps, H. Bello, and C. Hall. "U.S. Tariffs and the Import of Fresh Vegetables from Mexico: Effect of Alternative Tariff Levels on Texas Spring Dry Onion Producers." TAMRC International Market Research Report No. IM-1-92, Texas A&M University, January 1992.

Hammig, D.M., and R.C. Mittelhammer. "An Imperfectly Competitive Market Model of the U.S. Lettuce Industry." *Western Journal of Agricultural Economics* 5(1980):1–12.

Huffman, E.W., and R. Evenson. "Research Bias Effects for Input and Output Decisions: An Application to U.S. Cash-Grain Farms." *American Journal of Agricultural Economics* 71(1989):761–73.

Houck, J.P., and M.E. Ryan. "Supply Elasticities of Corn in the United States: The Impact of Changing Government Programs." *American Journal of Agricultural Economics* 54(1972):878–92.

Jorgenson, D.W., and L.J. Lau. "The Structure of Consumer Preferences." *Annals of Economic and Statistical Measurement* 4(1975):49–101.

Lim, H. "Profit Maximization, Returns to Scale, Separability, and Measurement Error in State-Level Agricultural Technology." Ph.D. dissertation, Texas A&M University, 1989.

Lim, H., and C.R. Shumway. "Separability in State-Level Agricultural Technology." *American Journal of Agricultural Economics* 74(1992):120–31.

McIntosh, C.S. "Specification of Government Policy Variables for Feed Grains, Wheat, Soybeans, Rice, Cotton, Peanuts, Tobacco, Sugar Beets, and Milk 1950–1986." Division of Agricultural Economics FS89-61, University of Georgia, 1989.

______. "Evaluating Alternative Methods of Including Government Policy Information for Multiproduct Supply Analysis." Working paper, University of Georgia, 1990.

Miller, S.E., O. Capps, and G.J. Wells. "Confidence Intervals for Elasticities and Flexibilities from Linear Equations." *American Journal of Agricultural Economics* 66(1984): 392–96.

Moschini, G. "A Model with Supply Management for the Canadian Agricultural Sector." *American Journal of Agricultural Economics* 70(1988):318–29.

Ornelas, Fermin. "Functional Form Selection and Impact of Government-Supported Crops on Vegetable Supplies in Texas." Ph.D. Thesis, Texas A&M University, 1991.

Pesaran, M.H., and A.S. Deaton. "Testing Non-Nested Nonlinear Regression Models." *Econometrica* 46(1978):677–94.

Romain, R.F.J. "A Commodity-Specific Policy Simulation Model for U.S. Agriculture." Ph.D. dissertation, Texas A&M University, 1983.

Shonkwiler, J.S., and R.D. Emerson. "Imports and the Supply of Winter Tomatoes: An Application of Rational Expectations." *American Journal of Agricultural Economics* 64(1982):634–41.

Shumway, C.R. "Supply, Demand, and Technology in a Multiproduct Industry: Texas Field Crops." *American Journal of Agricultural Economics* 4(1983):748–60.

Talpaz, H., W.P. Alexander, and C.R. Shumway. "Estimation of Systems of Equations Subject to Curvature Constraints." *Journal of Statistical Computation and Simulation* 32(1989):201–16.

Teigen, L.D., and F. Singer. "Weather in U.S. Agriculture: Monthly Temperature and Precipitation by State and Farm Production Region, 1950–1986." United States Department of Agriculture Economic Research Service Statistical Bulletin No. 765, Washington, D.C., 1988.

Texas Department of Agriculture. *Texas Vegetable Statistics, 1958–87*. Austin, Texas.

United States Department of Agriculture. *Agricultural Statistics*, Washington, DC, 1978, 1990.

Villezca, P., and C.R. Shumway. "Multiple-Output Production Modeled with Three Functional Forms." *Journal of Agricultural and Resource Economics* 17(1992a):13–28.

______. "State-Level Output Supply and Input Demand Elasticities for Agricultural Commodities." *Journal of Agricultural Economics Research* 44(1992b):22–34.

Weaver, R.D. "Multiple Input, Multiple Output Production Choices and Technology in the U.S. Wheat Region." *American Journal of Agricultural Economics* 65(1983): 45–56.