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Equilibrium Quantity and Timing of Exports of Mexican Vegetables

Richard L. Simmons and Carlos Pomareda

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Key Words: linear programming, Mexican export vegetables, risk aversion, monopoly, partial equilibrium

EQUILIBRIUM QUANTITY AND TIMING OF MEXICAN VEGETABLE EXPORTS

Richard L. Simmons and Carlos Pomareda

Florida's principal competitor for the U. S. winter market for fresh tomatoes, cucumbers and bell peppers is Northwest Mexico. From 1968 to 1973 Mexico's share of this market increased from 32% to 58% largely at Florida's expense (USDA, Fresh Fruit and Vegetable Shipments). An appraisal of the effects of changing economic factors on Mexico's future production potential is necessary to help formulate U.S. trade policy.

This study develops a model of aggregate producer behavior in Mexico's export winter vegetable regions and uses it to evaluate the impact of changes in economic factors on equilibrium timing and quantity of tomato, pepper and cucumber exports. The model takes monthly net import demand functions in the U. S. and Canada as given, and uses linear programming to generate static industry equilibria under a range of alternative specifications concerning risk, competitive supply structure, and wage rates. Since vegetable prices are endogenous to the model, equilibrium U. S. prices and Mexican production are simultaneously generated.

The Problem

Two regions in the Mexican state of Sinaloa, Culiacan and Fuerte Sur, are analyzed. Together these two regions comprised 90, 88 and 80 percent of Mexico's tomato, pepper and cucumber exports in 1971-72 (Union Nacional de Productores de Hortalizas). Although the regions are approximately one hundred miles apart and have somewhat different climates,

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each can produce a wide variety of intensive irrigated crops on a year-round basis. It was necessary to include a full range of production alternatives in the analysis, omitting only livestock and perennial crops.

The timing of vegetable plantings and the resulting shipment pattern is important in determining total annual net revenue. Intra- seasonal changes in demand interact with changes in production conditions, yields and costs to determine a conceptual optimum program of plantings over the season. The structure is further complicated by the opportunity to divert export tomatoes into the domestic market. Although input requirements generally reflect a machine oriented, high technology production method, the harvesting of cotton and vegetables and part of the weeding is done by hand. Tomatoes are grown both as staked and unstaked (ground tomatoes). Ground tomatoes use less fertilizer, are picked less frequently, yield about one-third as much as staked tomatoes, and involve lower investment costs and less risk of large negative net returns. Less frequent picking saves labor and allows substitution of other inputs for labor in the face of rising wage rates.

Returns from the production of export vegetables are notoriously variable and it was considered necessary to include risk as a factor affecting decisions in the model, to avoid overstatement of vegetable supplies relative to the less risky traditional crops.

By virtue of national and state producer organizations, export vegetable producers in Mexico were able to exert direct control over plantings for the first time in the 1973-74 season, after several years of reliance on quality controls, shipping holidays and informal coercion. The actual degree of monopoly power both before and after institution of planting

controls is a matter for question. This study compares equilibrium shipments under a competitive structure which implies P=MC for each activity, with those under a monopoly structure implying MR=MC for each activity. A comparison of the solutions under the two alternative specifications with actual 1972-73 plantings is used as an informal test of the hypothesis that Mexican producers acted competitively prior to the enactment of the 1973-74 controls.

One of Mexico's production advantages has been low farm wages. Recent government concern about farm income caused a doubling of minimum farm wage rates from 1968 to 1974, and further rapid increases are likely. With current technologies for vegetables labor comprises about 40% of total production costs. Hence, wage rates are important in determining future production trends. The wage rate is entered at levels ranging from 36 to 70 pesos per day, to determine the effect on optimal solutions.

The Model

The model draws heavily on the work of Duloy and Norton, Hazell, and Hazell and Scandizzo.

The objective function is

$$\text{Max } \Pi = X'W(A - 0.5\ BWX) - C'X - \phi(X'\Omega X)^{1/2}$$

where X is a vector of aggregate activity levels, in hectares

W is a diagonal matrix of average yields

C is a vector of cost coefficients

A, B are the coefficient matrices of the linear demand structure P=A - BXW, where market quantities (Q) equal WX. All individual demand functions are assumed independent.

ϕ is a risk aversion coefficient, and

Ω is a variance-covariance matrix of gross activity returns.

Hazell and Scandizzo show that this formulation yields solutions corresponding to industry equilibrium under perfect competition, in the sense that P=MC for each activity. They show that MC contains a marginal risk element in addition to the marginal factor cost and represents the additional expected return demanded by farmers as compensation for taking risk. The supply curves which include risk thus lie above the supply curves in the deterministic case and reduce equilibrium supplies accordingly. The risk aversion coefficient relates to the amount of risk compensation farmers demand. The limiting case of $\phi=0$ implies no risk aversion, which gives the deterministic solutions.

Conceptually, ϕ is an aggregation of the risk aversion coefficients of individual micro units. No attempt was made in this study to estimate ϕ values for either the micro units or the corresponding aggregate coefficient. Instead, alternative levels of ϕ were used to determine the sensitivity of the optimal solution as ϕ varies, and to determine the value of ϕ which yielded solutions most closely corresponding to real world situations.

For the monopoly case the objective function was modified as follows:

$$\text{Max } \Pi = X'W(A - BWX) - C'X - \phi(X'\Omega X)^{1/2}$$

Duloy and Norton show for the deterministic case the correspondence of this formulation with the monopoly condition of MR=MC for each activity. The addition of the risk element is straight forward following the interpretation of MC given above for the competitive case.

The objective function is quadratic but was linearized by a separable linear programming procedure as set forth by Duloy and Norton.

The measure of variability in activity gross returns used in this study was the mean absolute deviation (m.a.d.), a method first proposed by Hazell and later adapted in Hazell and Scandizzo. An estimate of the variance of the set of activities based on the mean absolute deviation is

$$\text{Est}(X'\Omega X) = \Delta\{\frac{1}{T} \sum_t |\sum_j (r_{jt} - \bar{r}_j) X_j|\}^2, \qquad (1)$$

where $\Delta = \frac{T\Pi}{2(T-1)}$ is a correction factor to convert the square of the mean absolute deviation to an estimate of the population variance (assuming the population is normally distributed). The measure used in this study was not the estimate of the variance, but rather the estimate of the standard deviation, i.e.

$$\sqrt{\frac{\Delta}{T}} \{\sum_t |\sum_j (r_{jt} - \bar{r}_j) X_j|\}. \qquad (2)$$

This formulation was entered in the objective function according to the procedure of Hazell and Scandizzo by defining new variables,

$Z_t \geq 0$, all t, and forming the

problem

$$\text{Min} \sum_t Z_t$$

such that

$$\sum_j (r_{jt} - \bar{r}_j) X_j + Z_t \geq 0, \text{ all } t.$$

The Z_t variables then measure the negative deviations in total revenue from the mean for the activity revenue outcomes, and $\sum_t Z_t$ is the sum

of the negative deviations over all t. Obviously $2 \sum_t Z_t$ is the sum of absolute deviations, which is the expression in braces in (2) above. The LP tableau given by Hazell and Scandizzo appropriately describes this model, except that they used the m.a.d. estimate of the variance instead of the standard deviation, which required evaluation and linearization of Z^2.

Product Demands

Monthly demand equations were estimated for tomatoes, peppers and cucumbers for the winter season. The winter season was defined as December through May for tomatoes and December through April for peppers and cucumbers. The procedure followed was similar to the one used by Castro and Simmons.

The statistical model was a single equation least squares pooled-data type using dummy variables to allow for changes in intercepts and coefficients of explanatory variables. Price was the dependent variable and quantities shipped and income were assumed predetermined. The form of the demand functions was assumed linear to facilitate subtraction of marketing costs. Hypothesis tests indicated that monthly slopes and intercepts were significantly different for all three products.

Demand equations for peppers and cucumbers used Florida shipping point prices, and the demand equations for tomatoes used Nogales prices for "breakers and riper, 5x6's and larger." The use of retail or wholesale prices would have involved the estimation and subtraction of a complex system of commission, brokerage and shipping charges in order to derive the on-farm demand.

Supplies from Florida and other production areas (average of last three years) were subtracted from the estimated demand functions to obtain estimated import demand functions. Then marketing charges including the sales commission of 12%, the U. S. tariff, and transport costs from Culiacan to Nogales were subtracted from the import demand functions to obtain at-plant demand functions at the Culiacan level. Finally, demand functions at the Culiacan level were converted to terms of pesos per kilogram. The resulting demand functions for export vegetables are given in Table 1.

The Mexican demand functions for tomatoes and other crops were estimated by using the direct price elasticities given by Duloy and Norton (p. 317) and passing the demand equation through the 1972 price-quantity equilibrium points. Time-series quantity data were not available to statistically estimate equations. The demand for tomatoes in Mexico was assumed equal in all of the months included. Mexican demand functions for peppers and cucumbers were omitted from the model because these products are not produced in these regions in significant quantities for Mexican consumption. Demand functions for traditional crops and for tomatoes in Mexico are in Table 2.

The model allows the Mexican market to absorb non-exportable qualities of tomatoes as well as transfers of exportable qualities according to the principles of optimal market allocation.

Production Data

Each region is treated as a single, aggregate decision unit, implying homogenity in resource quality within the region and a relative absence of restrictions in resource combination in the individual micro units.

Table 1. Estimated Demand Functions for Export Vegetables f.o.b. Culiacan, Mexico[a]

Product	Month	Demand Equation[b]
Tomatoes (U.S. and Canada)	Dec.	P = 3.351 - .000043755 Q
	Jan.	P = 3.184 - .000036722 Q
	Feb.	P = 2.856 - .000020254 Q
	Mar.	P = 4.309 - .000044305 Q
	Apr.	P = 3.229 - .000019006 Q
	May	P = 3.533 - .000039815 Q
Peppers	Dec.	P = 1.905 - .00046591 Q
	Jan.	P = 4.270 - .00040690 Q
	Feb.	P = 5.092 - .00026592 Q
	Mar.	P = 5.968 - .00035203 Q
	Apr.	P = 5.896 - .00042629 Q
Cucumbers	Dec.	P = 1.752 - .00016589 Q
	Jan.	P = 2.419 - .00011539 Q
	Feb.	P = 2.636 - .00009907 Q
	Mar.	P = 3.121 - .00015937 Q
	Apr.	P = 1.591 - .00008637 Q

[a]Price data was taken from USDA, Fresh Fruit and Vegetable Prices, various issues, Quantities were based on USDA, Fresh Fruit and Vegetable Shipments, various issues.

[b]Price is measured in pesos per kilo and Q in metric tons.

Table 2. Demand Functions for Tomatoes and Traditional Crops in Mexico[a]

Crops	Demand Equation[b]	Direct Price Elasticity
Tomatoes	P = 2.993 - .00008372 Q	-0.5
Sesame	P = 3.068 - .00011210 Q	-1.2
Cotton	P = 3.276 - .00000537 Q	-0.5
Rice	P = 2.960 - .00001536 Q	-0.3
Safflower	P = 2.069 - .00000531 Q	-1.2
Beans	P = 5.573 - .00008800 Q	-0.3
Chickpeas	P = 3.448 - .00007409 Q	-0.3
Corn	P = 1.126 - .00001938 Q	-0.2
Sorgo	P = 1.185 - .00000208 Q	-0.3
Soybeans	P = 2.334 - .00000423 Q	-1.2
Wheat	P = 0.936 - .00000107 Q	-0.5

[a]Price elasticities were taken from Duloy and Norton. Mean prices and quantities were taken from Secretaria de Recursos Hidraulicos, Estadistica Agricola del Ciclo 1971-72, Mexico, D. F., July, 1972.

[b]Price is measured in pesos per kilo, Q in metric tons.

The principal resource restrictions for each region are monthly land and water supplies and an annual water restriction. Other input supplies are assumed to be perfectly elastic at existing market prices. The only link between the two areas is through the demand constraints.

Most of the input-output data for cropping activities was taken from unpublished budgets prepared by the Confederacion de Asociaciones Agricolas del Estado de Sinaloa (CAADES) and was verified in part by several informal field visits. The yield distributions of staked tomatoes by months over the harvest season were estimated from unpublished experimental data obtained from the Centro de Investigaciones Agricolas de Sinaloa.

Variation in gross revenue per hectare for all crops over six cropping years was taken from published CAADES bulletins. Table 3 indicates the large variation in gross revenues per hectare of export vegetables compared with traditional crops.

Estimates of water requirements and availabilities in the two regions were obtained from the Division of Water Resources. Good measures of water requirements by months for specific crops are scarce and the water constraints are considered the weakest part of the data base. However, equilibrium acreages of vegetables are not greatly affected by inaccuracies in the water constraints.

Solutions

The first set of solutions used the 1972-73 wage rate of 36 pesos per day, the objective function corresponding to the competitive case, and risk aversion levels of 0, 0.5, 0.75, 1.0 and 1.5. Equilibrium acreages for each solution were compared with actual acreages planted in 1972-73

Table 3. Variation in Gross Revenues, Total Costs and Input Requirements per Hectare for Cropping Activities.

Crops	$\sum_{t=1}^{6} \lvert r_{jt} - \bar{r}_j \rvert$		Total Costs per Hectare a/		Annual water requirements	Labor requirements
	Culiacan (pesos)	Fuerte Sur (pesos)	Culiacan (pesos)	Fuerte Sur (pesos)	Both regions (10,000 m^3)	Both regions (man-days)
Tomatoes	99,204	68,405	41,175	36,236	.960	133.0 b/
Peppers	134,178	92,878	22,500	21,020	.960	132.0 b/
Ground Tomatoes	-	26,396	-	13,893	.710	28.2 b/
Cucumbers	58,731	33,792	16,418	10,065	.470	19.7 b/
Sesame (spring)	997	889	2,112	2,064	.820	15.8
Sesame (summer)	997	889	2,112	2,112	.650	15.8
Rice	2,916	2,834	2,227	3,235	1.950	9.7
Safflower	3,662	3,293	1,678	1,704	.700	3.9
Beans	2,389	2,114	2,160	2,170	.890	14.1
Chickpeas	3,796	3,274	2,586	2,614	.990	10.7
Corn (summer)	997	724	2,052	2,212	.910	18.4
Corn (winter)	997	724	2,052	2,212	.840	18.4
Sorgo	3,220	1,456	2,574	2,629	.790	9.5
Soybeans	3,174	3,537	2,110	2,159	.960	5.4
Wheat	2,009	1,922	2,510	2,540	.880	9.6
Cotton	-	3,830	-	6,022	-	72.2

a/ wage rate of 36 pesos per day

b/ pre-harvest labor only

to determine the level of ϕ which resulted in the solution most closely corresponding to actual plantings. The results are presented in Table 4. No single level of ϕ is best for all crops. For export vegetables, chickpeas, beans and wheat the level of ϕ=0.5 seems best. For other crops higher levels of ϕ give solutions more closely corresponding to actual acreages. Since the empbasis of this study is on the three export vegetables the level of ϕ=0.5 was selected for use in subsequent solutions.

Using the objective function corresponding to the monopoly case for export vegetables, solutions were also generated for the same levels of ϕ and the same wage rate as for the competitive case just described. These solutions are presented in Table 5. For all levels of ϕ, optimal acreages of the three vegetables were unrealistically low when compared with actual plantings. It was thus concluded that vegetable producers were operating in the context of a competitive environment in 1972-73. The monopoly solution indicates the possible future trend in planted acreages if, in fact, recent controls enacted by the vegetable producers have created significant monopolistic characteristics.

The competitive case with a risk aversion level of 0.5 is used in most of the remainder of the analysis.

Effect of Increased Wages on Vegetable Exports

The first comparison is the effect of increased minimum wages for farm labor on equilibrium plantings of export vegetables and other crops. These comparisons are given in Table 6. An increase in the wage rate causes sharp decreases in equilibrium plantings of the three export vegetables and other relatively labor intensive crops such as corn and

Table 4. Comparison of Actual 1972-73 Plantings with Equilibrium Solutions, Competitive Case, Wage of 36 pesos per day

Crops	Equilibrium Planted Area (hectares)					1972-73 Actual (hectares)
	ϕ=0	ϕ=.5	ϕ=.75	ϕ=1.0	ϕ=1.5	
Tomatoes	19,239	15,709	14,317	13,356	9,217	16,382
Peppers	3,633	3,332	3,309	3,128	2,440	4,869
Cucumbers	3,177	2,803	3,177	3,447	3,552	5,614
Sesame	0	3,194	3,790	4,386	4,983	4,883
Rice	33,047	34,733	34,733	33,890	33,047	33,047
Safflower	96,986	65,196	48,825	43,219	29,885	51,837
Beans	33,555	33,555	32,165	32,166	30,350	47,192
Chickpeas	13,352	14,989	14,147	13,730	12,897	25,580
Corn	14.875	18,769	18,769	18,769	18,769	21,503
Sorghum	55,717	54,749	55,550	46,552	47,495	68,608
Soybeans	104,037	104,170	89,355	79,478	79,478	75,048
Wheat	26,552	39,588	25,034	25,034	10,479	45,620
Cotton	57,024	46,210	42,605	39,001	31,792	37,056

Table 5. Comparison of Actual 1972-73 Plantings with Optimal Solutions, Monopoly Case, Wage of 36 pesos per day

Crops	Optimal Planted Area (hectares)				Actual
	ϕ=0	ϕ=.5	ϕ=.75	ϕ=1.0	1972-73
Tomatoes	9,644	7,653	6,912	6,720	16,382
Peppers	1,921	2,047	1,879	1,936	4,869
Cucumbers	1,572	1,628	1,680	1,679	5,614
Sesame	810	0	3,790	4,386	4,883
Rice	33,890	33,047	34,733	33,890	33,047
Safflower	99,575	64,982	48,952	31,962	51,837
Beans	34,018	32,165	32,165	32,200	47,192
Chickpeas	13,352	13,730	13,730	13,314	25,580
Corn	14,875	18,769	18,769	18,769	21,503
Sorghum	55,717	55,717	50,855	50,855	68,608
Soybeans	111,460	104,243	87,969	75,614	75,048
Wheat	26,447	39,588	25,034	25,034	45,620
Cotton	57,024	24,583	42,605	35,397	37,056

Table 6. The Effect of Increased Wage Rates on the Equilibrium Area Planted to Mexican Vegetables and Other Crops, Competitive Case, ϕ=.5

Crops	Area Planted (hectares) Wage Rate (pesos per) 36	50	70
Tomatoes	15,709	13,174	8,695
Peppers	3,332	2,790	2,103
Cucumbers	2,803	2,439	1,870
Sesame	3,194	0	0
Rice	34,733	34,733	33,890
Safflower	65,196	63,298	63,298
Beans	33,555	32,165	30,333
Chickpeas	14,980	14,147	13,314
Corn	18,769	10,982	0
Sorghum	54,749	50,855	45,993
Soybeans	104,170	95,533	86,533
Wheat	39,588	25,034	9,449
Cotton	46,210	24,503	0

cotton. The average are elasticities of the vegetable acreages in response to wage rate increases are -0.9 for tomatoes, -0.7 for peppers, and -0.6 for cucumbers. Clearly the government policy of rapid increases in rural wages will have a substantial impact on vegetable exports. A shift from the production of staked tomatoes to ground tomatoes was noted at the higher wage rates indicating substitution of other inputs for labor. Further innovations in labor saving techniques could modify the elasticity estimates somewhat. The quantitative effects of such innovations are difficult to predict accurately and inclusion of additional such activities in the model was not attempted.

Seasonal Distribution of Vegetable Exports

The equilibrium distribution of exports over the season is affected by monthly changes in demand and production costs and the normal pattern of competitive shipments from Florida and Caribbean countries. These three factors are taken into account in the model. Table 7 compares the equilibrium monthly distribution of tomatoes, peppers, and cucumbers exports over the winter season with the 1970-73 average actual pattern of shipments. An increase can be expected in December tomato shipments and a reduction in February and March if the differential in monthly production costs and demands are adequately represented and if the industry moves toward the equilibrium position according to the assumptions of competitive behavior. By using the monthly demand functions to estimate the expected prices for the equilibrium and actual quantities shipped each month, it was estimated that industry net revenue from tomatoes could be increased by 10% by adopting the equilibrium shipment patterns.

By comparing the normal shipment pattern for peppers with the equilibrium pattern it can be concluded that shipments of peppers could be

Table 7. Equilibrium Monthly Distribution of Exports of Tomatoes, Peppers and Cucumbers Compared to Actual Shipments

Months	Total Seasonal Shipments (metric tons)					
	Tomatoes		Peppers		Cucumbers	
	Equilibrium	Actual	Equilibrium	Actual	Equilibrium	Actual
December	27,676	8,080	0	1,816	1,519	12,441
January	30,458	27,211	2,015	7,419	7,964	13,357
February	32,389	53,697	8,243	9,398	11,466	11,165
March	44,247	59,381	8,715	7,550	10,171	11,557
April	49,082	57,513	6,793	3,409	1,053	5,762
May	35,991	34,251	0	0	0	0
Total	219,843	240,133	25,946	29,592	32,173	54,282

reduced in December and January and increased in March and April. Industry net revenue could be increased by 6% by so doing. Cucumber shipments appear excessive in December and January, months of heavy Florida shipments.

Allocation of Production Between Export and National Market

Although tomatoes are grown primarily for the export market, about 30% of total field production is sold in Mexico. The Mexican market is normally used for non-exportable qualities and occasionally for diversion of exportable supplies when the U. S. market becomes temporarily oversupplied. Optimal allocation of the crop between the two markets has not yet been pursued by producers. It is of interest to evaluate possibilities for increased income from allocation according to established maximization criteria.

In the absence of supply restrictions or quality differentials the prices in two competitive markets tend to be equalized (net of handling costs) by the process of individual producer decisions to ship to the market yielding the highest price. The monopoly case is similar except that marginal revenues are equalized in the two markets instead of prices. The present model simulates this process by including a transfer activity to divert exportable supplies from the export market to the domestic market.

In the first set of solutions this non-exportable portion of total field production was entered at 30% in accordance with recent practice. Under these conditions no transfers from the export market to the Mexican market were economical. The normal quantity of non-exportable qualities

was sufficient in each month to keep the Mexican prices below U. S. prices, and thus prevent price equalization. Given that non-exportable supplies are joint products with no current alternative use, any price above disposal costs is profitable.

To investigate the effects of a possible relaxation of export quality restrictions or a possible technological breakthrough which would increase the proportion of exportable fruit, the basic input data were changed to reflect a proportion of non-exportable quality of 20% of total field production. In this case exportable supplies were transferred to the domestic market in December, January, February and May and prices were equalized in the two markets according to principles of market allocation (Table 8). However, in March and April non-exportable supplies were still sufficient to keep the Mexican price below the export price and no transfers were made. Of course, additional work in estimating Mexican demand for tomatoes would make this type of allocation decision more precise.

Conclusions

By using demand functions and risk factors for cropping activities in the mathematical programming model for Culiacan and Fuerte Sur, acceptable representations of actual aggregate behavior for the base year 1972-73 were obtained.

Equilibrium solutions were obtained for both the competitive and monopolistic case and producer behavior in the base year 1972-73 corresponded more closely to the competitive case. Risk aversion coefficients (ϕ) of 0, 0.5, 0.75, and 1.0 were tested and the level of risk

Table 8. Equilibrium Allocation of Tomatoes Between the Export and Mexican Market

Month	Quantities Sold (metric tons)		Net Farm Price (pesos per kilo)	
	Export	Mexican	Export	Mexican
December	26,305	9,400	2.20	2.20
January	30,921	10,665	2.12	2.10
February	32,389	9,465	2.20	2.20
March	49,859	12,459	2.10	1.95
April	52,216	13,054	2.25	1.90
May	41,015	13,054	1.90	1.90

Note: Assumes exportable quality for 80% of total field production.

aversion corresponding to $\phi=0.5$ appeared to function best in obtaining solutions most closely corresponding to actual plantings in 1972-73.

Using the competitive objective function and $\phi=0.5$ the model was then used to evaluate possible effects on tomato pepper and cucumber exports of changes in wage rates and changes in the percentage of total production which is of exportable quality.

It was found that, given present technologies, an increase of 10% in the minimum daily wage would decrease exports by 9% for tomatoes, 7% for peppers and 6% for cucumbers. Given present Mexican government policies of rapidly increasing the minimum farm wage, substantial decreases in vegetable exports can be expected (other factors such as Florida production assumed constant).

In general, it is concluded that the recent rapid expansion of Mexican exports of tomatoes, peppers and cucumbers is over. Given the demands for competing crops in the export production areas, the rapidly rising labor costs in Mexico, and the institution of more effective supply controls starting in the 1973-74 season it appears that some contraction in planted acreages of these three export vegetables can be expected.

Additional investigation of the monopolistic aspects of the model is warranted, including allowance for Florida adjustments.

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FOOTNOTES

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