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# AN ANALYSIS OF THE COMPETITIVENESS OF SOUTHEASTERN FRESH VEGETABLE CROPS USING QUADRATIC PROGRAMMING

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## Abstract

This study determined the competitive potential of the temperate southeastern U.S. region to produce selected fresh vegetables for the national market. Results indicated that the region may be competitive in the production and marketing of snap beans, cucumbers, bell peppers, and spring tomatoes. The region would also be competitive in the production and marketing of broccoli, summer and fall tomatoes, and spinach, given cost reductions of 10 to 15 percent. Major cost reductions were required for the region to be competitive in the production and interregional marketing of sweet onions in the absence of effective product differentiation.

**Key words:** interregional competition, alternative crops, production, marketing, transportation

Cyclical patterns in economic activity impact the agricultural sector both nationally and regionally. During the 1970s, the agricultural sector prospered in concert with a seemingly ever-expanding export market. From 1972 to 1981 the value of U.S. agricultural exports increased from just over 8 billion dollars to 43.8 billion dollars, an increase of 444 percent in nine years. However, by 1986, U.S. agricultural exports had declined to about 26.3 billion dollars or by nearly 40 percent (U.S. Department of Agriculture [a and c]). The period from 1986 to 1987, though, seems to have marked another upward turning point for U.S. agricultural exports (U.S. Department of Agriculture [b and c]).

Following 1981, during the economic downturn in the U.S. agricultural sector, regions that had traditionally produced large acreages of row crops were especially hard hit. In 1981, 21 percent of the corn, 40 percent of the soybeans, 47 percent of the wheat, and 35 percent of the cotton produced in the U.S. were exported. By 1985, however, only 14 percent of the corn, 35 percent of the soybeans, 38 percent of the wheat, and 14 percent of the cotton produced

in the U.S. were exported (U.S. Department of Agriculture [a]). Prices fell as export demand declined.

Because of the potential for major fluctuations in the profitability of traditional row-crop production, southeastern U.S. producers of these crops seek alternatives that may provide a higher profit margin and/or more financial stability. The purpose of this study was to determine the economic potential for the production of fresh vegetables as alternative crops in the temperate Southeast for the national market.

An abundance of natural resources, substantial human capital stock, and varying climate zones exist in the region. Numerous irrigation systems, an abundance of underground water, and large acreages of suitable land without danger of urban encroachment can be found in the study area (Davis and Meyer; Geraghty *et al.*; Kiker and Lynne; Kundell; La-Moreaux; Meister *et al.*; Todd; Babb *et al.*).

Of major importance are the varied growing seasons in the area, ranging from as long as 290 days on the coast to as few as 200 days in the mountains. Three or four plantings of some vegetables are possible in some areas of the region, with cool season crops produced in the mountains during the summer (Decoteau, *et al.*).

The fresh vegetable industry in the temperate southeastern region has been growing continuously in volume since the early 1970s. As a result, a number of packing operations which deal through brokerage firms or directly with large food chains are located in the area. In addition, tobacco production, which requires sophisticated management not unlike that essential for commercial vegetables, is found in parts of the region.

## METHODOLOGY

Fresh vegetables selected for analysis were identified as the result of evaluation by an interdisciplinary research team. Nine vegetables were identified on the bases of biological and expected economic

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**Table 1. Regional Designation of Producing and Consuming Areas**

Representative Origin/Destination Point <sup>a</sup>	Producing/Consuming Region Delineation
Atlanta, GA	Alabama, Georgia, Florida, Mississippi, North Carolina, South Carolina, Tennessee
Dallas, TX	Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas, Arkansas, Louisiana, Oklahoma, Texas
Chicago, IL	Illinois, Indiana, Ohio, Kentucky, Michigan, Wisconsin
New York, NY	Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia
Los Angeles, CA	Montana, Idaho, Wyoming, Colorado, Oregon, California, New Mexico, Arizona, Utah, Nevada, Washington

<sup>a</sup>Reference points for respective regions.

potential for the region. Climate, potential yield, existence of national market channels for vegetables from the region, and per capita consumption estimates were considered in the selection of the nine vegetables for analysis. The fresh vegetables identified for study were sweet onions, snap beans, tomatoes, potatoes, bell peppers, spinach, cucumbers, broccoli, and cantaloupes.

Five origin/destination regions were designated based on spatial propinquity as shown in Table 1. The five regions were identified as Atlanta, Dallas, Chicago, New York, and Los Angeles. Each of these regional designations represented an existing or potential producing area or point of origin, and each represented a destination point, market, or consuming area.

Competing production areas by season for each of the nine vegetables were ascertained from Agricultural Marketing Service shipment and arrival data, U.S. Department of Agriculture (h, j). Since shipment and arrival data did not indicate commercial production of broccoli and spinach in the Atlanta region, harvesting seasons for these vegetables in the Atlanta region were verified by biological scientists.

In order to determine the competitive potential for the Atlanta region in producing fresh vegetables for the national market, an interregional partial equilibrium model was employed, couched in a quadratic

programming framework. The model, which encompassed nine selected fresh vegetables, four seasonal time periods, and five market regions, had four major components: demand, transportation cost, production cost, and a constraint component. The analysis involved a comparative static procedure. Model solutions, encompassing an array of simulated production and marketing cost reductions ranging from 5 to 25 percent for the Atlanta region, were compared to a base solution. The base solution tracked average regional production and dominant interregional movements for the 1983-1987 period.

## MODEL

The quadratic programming model used in this study is an interregional activity formulation (Takayama and Judge 1971). The value of the objective function for the model represents net social payoff (NSP) or the sum of the areas under the demand functions across markets and seasons less all costs associated with the optimal volume of shipments within and among regions for each commodity.

Thus, optimal shipment quantities, quantities demanded, and wholesale prices are determined endogenously. The assumptions for the model are that regional markets are competitive, production technology within region is uniform with constant input/output proportions and commodities produced are homogeneous and transportable between regions (Takayama and Judge 1964).

In matrix-vector notation, the model formulation for this study may be expressed as follows:

$$(1) \quad \text{OBJ} = \text{MAX NSP}(Y, X) \\ = [A' - T'] \begin{bmatrix} Y \\ X \end{bmatrix} - \frac{1}{2} [Y' \ X'] \begin{bmatrix} D & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} Y \\ X \end{bmatrix}$$

$$(2) \quad \text{s.t.} \quad [I - G] \begin{bmatrix} Y \\ X \end{bmatrix} \leq [0], \text{ and}$$

$$(3) \quad [Y, X]' \geq [0]',$$

where NSP is Net Social Payoff, Y is a vector of seasonal aggregate demand for each commodity in 100 cwt, X is a vector of interregional production activity levels in 100 cwt, A is a vector or intercepts (dollars per 100 cwt) of price-dependent demand equations, T is a vector of costs per 100 cwt, including production, marketing, and transportation costs, D is a nonnegative diagonal submatrix of coefficients in the demand equations, I is an identity submatrix, and G is a submatrix including elements of "1."

The constraints incorporated in the model are explained as follows: (1) The aggregated seasonal quantity consumed is less than or equal to the seasonal quantity shipped from all supply regions including the region of destination; thus,  $IY - GX \leq 0$ . (2) Demand and supply quantities are constrained to be nonnegative such that  $[YX]' \geq [0]'$ .

## MODEL COMPONENTS AND DATA

The model has four major components: demand, transportation cost, production and marketing cost, and a constraint set. Each component is discussed in turn.

Demand functions for fresh vegetable commodities were computed from own price elasticity estimates from previous studies: -0.5 for snap beans (Mathia and Brooker), -0.198 for cucumbers and -0.111 for bell peppers (Mittelhammer), -1.437 for cantaloupes (Price and Mittelhammer), and -0.3688 for potatoes, and -0.5584 for tomatoes (Huang). Estimates were not found for broccoli, sweet onions, or spinach. The estimate of -0.198 for cucumbers was assumed for broccoli. Estimates of -0.1964 for onions and -0.1371 for lettuce were assumed for sweet onions and spinach, respectively (Huang).

Average seasonal wholesale price and quantity demanded in each region for each commodity for 1983 to 1987 were required. Monthly wholesale prices for each region were obtained from the U.S. Department of Agriculture (d-g). Simple averaging was used to convert monthly wholesale prices to seasonal prices. Seasonal quantities demanded in each region were derived by multiplying the imputed seasonal U.S. per capita consumption for each vegetable commodity by the total population for each region (U.S. Department of Agriculture [a,h,k]; U.S. Department of Commerce). The imputed seasonal U.S. per capita consumption for each vegetable commodity was obtained by dividing seasonal average total quantity (adjusted shipment volume) by the total U.S. population. Because seasonal shipments within the U.S. reported by the Agricultural Marketing Service do not account for total quantity, the seasonal shipment data were adjusted by shipment/production ratios computed from the U.S. Department of Agriculture (a, h). Production data were not used directly to obtain seasonal quantities needed to compute demand functions because most production data are published on an annual basis.

Transportation costs for shipments of fresh vegetables from region to region were obtained from simple averaging of truck rates for fresh vegetables for the period 1983-1987 (U.S. Department of

Agriculture [i]). Production and marketing costs for each region were obtained from Extension Service budgets for selected states. The constraint component considered in this study encompasses a market constraint. The total quantity demanded must be less than or equal to total quantity supplied. Because the constraint set does not include input restrictions, the analysis may be considered long-run in nature (Takayama and Judge 1964).

## SOLUTION PROCEDURE

A comparative static approach was employed in this analysis. Model solutions encompassing an array of possible cost reductions for selected fresh vegetables originating or possibly originating from the Atlanta region were compared to a base solution. The base solution was derived through an iterative (trial and error) cost-adjustment process, using shipment and wholesale price differences with respect to actual and solution values as guides. This process was continued until the solution reflected actual shipment volume, wholesale prices, and dominant source of supply by regional market and season. Differences in actual and base solution shipping patterns and actual and base solution wholesale prices were small. The iterative process to achieve a realistic base solution was required because initial estimates of production, marketing, and transportation costs by region were sufficient only as a means of obtaining an initial solution.

## RESULTS

Fresh vegetable acreage in the Atlanta region by commodity and season were imputed for the base solution and each of the simulated cost reduction alternatives. These acreage estimates were based on the volume of shipments originating from the Atlanta region. Yields used in deriving acreages were from Cooperative Extension Service budgets.

Selected fresh vegetable acreages for the Atlanta region are shown in Table 2. Positive acreages for the base model solution reflect competitiveness. Thus, snap beans, cucumbers, bell peppers, spring potatoes, tomatoes, and sweet onions produced in the Atlanta region were shown to be competitive in ranging degrees. Of these, supplies of snap beans, cucumbers, bell peppers, and tomatoes originating from the Atlanta region were dominant in more than one regional market. Supplies of spring potatoes and sweet onions from the Atlanta region did not penetrate other regional markets in the base model solution. (The base solution of dominant trade flows and wholesale prices and relative differences from actual values by selected fresh vegetable, season,

Table 2. The Impact of an Array of Simulated Percentage Decreases in the Cost of Producing and Marketing Selected Fresh Vegetables on Acreage in the Atlanta Area by Season

Commodity and Season	Base Model Acreage	Percentage Decrease				
		5%	10%	15%	20%	25%
-----*----- (1000 acres) -----						
Snap beans						
Spring	26.2	26.8	34.0	34.8	35.6	36.4
Summer	3.1	3.2	4.8	6.1	6.2	6.4
Fall	15.5	23.5	29.8	30.5	31.3	32.0
Winter	NA	NA	NA	NA	NA	NA
Cucumbers						
Spring	16.4	16.5	16.7	21.8	22.0	27.5
Summer	4.6	4.6	4.7	10.6	10.7	13.4
Fall	19.3	19.5	19.7	19.8	20.0	25.0
Winter	NA	NA	NA	NA	NA	NA
Broccoli						
Spring	—	—	—	21.0	21.2	21.5
Summer	—	—	—	16.5	16.7	16.9
Fall	—	—	4.0	21.0	21.3	21.5
Winter	—	—	4.1	21.8	22.1	22.3
Bell peppers						
Spring	16.2	16.3	26.4	26.6	26.7	26.9
Summer	9.2	9.3	13.9	13.9	17.4	17.5
Fall	19.4	19.5	19.6	24.5	24.7	24.8
Winter	NA	NA	NA	NA	NA	NA
Cantaloupes						
Spring	—	—	—	64.7	69.7	74.8
Summer	—	—	—	—	61.7	80.7
Fall	—	—	2.0	10.5	13.8	14.9
Winter	NA	NA	NA	NA	NA	NA
Potatoes						
Spring	35.6	36.3	95.3	97.2	225.4	230.1
Summer	—	—	49.3	120.5	189.9	193.8
Fall	—	—	57.8	136.8	182.9	228.0
Winter	NA	NA	NA	NA	NA	NA
Tomatoes						
Spring	32.6	33.5	34.4	43.4	44.6	45.7
Summer	4.0	4.1	15.5	25.3	26.1	26.8
Fall	10.3	10.6	18.7	30.6	31.5	32.3
Winter	NA	NA	NA	NA	NA	NA
Sweet onions						
Spring	6.1	6.1	6.2	23.3	37.9	38.4
Summer	2.1	2.2	2.2	2.2	10.8	13.4
Fall	NA	NA	NA	NA	NA	NA
Winter	NA	NA	NA	NA	NA	NA
Spinach						
Spring	—	—	0.4	0.8	1.0	1.0
Summer	—	—	0.2	1.1	1.1	1.1
Fall	—	—	1.1	1.9	2.4	2.5
Winter	—	—	3.7	3.8	4.7	4.7
Total						
Spring	133.0	135.6	213.4	333.5	484.3	502.3
Summer	23.0	23.3	90.5	196.2	340.6	369.9
Fall	64.5	73.1	152.6	275.7	327.8	380.9
Winter	—	—	7.8	25.6	26.8	27.0

Note: The estimated acreages for each vegetable commodity were computed by dividing total shipments that originate from the Atlanta area as obtained from model solutions by expected yields per acre in 100 cwt. The expected yields per acre for each vegetable commodity are from Cooperative Extension Service budget sources: sweet onions—300, 50-lb. bags; snap beans—125, 30-lb. bushel baskets; tomatoes—1,000, 30-lb. cartons; potatoes—150 cwt; bell peppers—350, 30-lb. cartons; spinach—600, 25-lb. crates; cucumbers—225, 55-lb. crates; broccoli—400, 23-lb. cartons; and cantaloupes—125 cwt.

and market area is available upon request from the authors.)

Increases in acreage of snap beans, a very competitive crop in the Atlanta region, began with only a 5 percent reduction in the cost of supplies from the region. A 10 percent reduction in cost induced increased acreage of bell peppers, potatoes, tomatoes, and spinach, while a 15 percent reduction in cost resulted in acreage increases for the relatively less competitive fresh vegetables: cucumbers, broccoli, cantaloupes, and sweet onions.

Acreage by commodity and season, given a (25) percent cut in the cost of supplies from the Atlanta region as reported in Table 2, roughly reflected the quantities needed to satisfy seasonal U.S. demands for the selected fresh vegetables. Thus, at any point in time, only about one-half of a million acres were needed to satisfy demand, an insignificant amount considering the millions of acres devoted to traditional row crop production. Moreover, about half of the vegetable acreage was attributable to potato production. Given a 25 percent reduction in cost, and excluding potatoes, total fresh vegetable area in the Atlanta region was 272,200 acres in the spring, 176,100 acres in the summer, and 152,940 acres in the fall.

## CONCLUSIONS AND IMPLICATIONS

The spatial equilibrium model, encompassing activity analysis, utilized in this study was formulated based on assumptions of pure competition. Thus, the model is a simplified abstract reflection of reality. Other limitations are embodied in judgments required for selecting parameters and data. Given

these limitations, the model facilitated determination of the relative magnitudes of plausible effects under varying scenarios.

The results of the study indicate that the temperate southeastern region may be competitive in the production and marketing of snap beans, cucumbers, bell peppers, and spring tomatoes. The southeastern region generally would also be competitive in the production and marketing of broccoli, summer and fall tomatoes, and spinach with simulated exclusive cost reductions of 10 to 15 percent. The analysis also indicated that major cost reductions would be required for the southeastern region to be competitive in interregional markets for sweet onions. However, because sweet onions lend themselves to product differentiation, effective promotion and advertising may be sufficient to overcome possible cost disadvantages. Major cost reductions would also be required for cantaloupes to be generally competitive.

With regard to the potential of fresh vegetables as an instrument of agricultural diversification in the temperate southeastern region, the results of the study are positive for selected producers provided technological innovations resulting in lower costs continue. However, extensive acreage utilization through fresh vegetable production is not a relevant goal.

More accurate estimates of spatial and temporal demand for individual fresh vegetables are needed. Accurate yield, acreage, and cost data for individual vegetables are also needed by season and location. Such information is essential to more definitive regional competition research.

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