A REGIONAL ANALYSIS OF VEGETABLE VERSUS ROW CROP PRODUCTION USING QUADRATIC PROGRAMMING

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ABSTRACT

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The paper presents initial findings of interdisciplinary research to ascertain the potential of vegetable relative to row crop production in the Southeast via a partial equilibrium model couched in a quadratic programming framework. Findings support the notion: vegetable production may be "one" answer to more diversified agriculture in the Southeast.

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Economic conditions in the agricultural sector have deteriorated rapidly in many areas of the U.S. The southeastern U.S. has shared in this recent trend, especially in regions where large acreages of row crops traditionally have been produced. In the tri-state area of North Carolina, South Carolina, and Georgia the nominal value of farmland and buildings fell almost 17 percent from 1981 to 1985, and from 1981 to 1984 the nominal value of farm mortgage loans rose over 21 percent (U.S. Department of Agriculture (f)).

Because of the dramatic decline in the profitability of traditional row crops, an interdisciplinary research team was formed comprised of researchers from North Carolina, South Carolina, and Georgia to ascertain the potential for producing vegetables as competing or complementary enterprises in the tri-state area. The project was deemed plausible because of an abundance of natural resources, human capital stock, and an array of climates in the area. Underground water, irrigation systems in place, and vast areas of quality land without the threat of urban encroachment are abundant in the tri-state area (Davis and Meyer; Geraghty et al.; Kiker and Lynne; Kundell; La Moreaux; Meister et al.; Todd; Babb et al.).

As the fresh vegetable industry has been growing slowly, though steadily, in the area since the early 1970s, numerous packing operations, which deal through major brokerage firms or direct with major food chains, are already in place. Moreover, tobacco production, which requires the same intensive management sophistication as commercial vegetable production, is common in the tri-state region. Further, the growing season in the tri-state area is as long as 290 days on the coast and as few as 200 days in the mountainous region. It is possible that three or four plantings of some vegetable crops could be produced in certain regions of the tri-state area with cool season crops being grown in the summer in the mountains. There is also the potential of multiple cropping systems composed of horticultural and row crops.

In order to ascertain the competitive and complementary potential of fresh vegetable production relative to traditional row crop production in the tri-state area a regional partial equilibrium model is employed which is couched in a quadratic programming framework. The model, which encompasses 11 selected fresh vegetable and five row crop activities, 12 monthly time periods, and four regions, has three major components: demand, production cost including risk, and a constraint set. The analysis employs a comparative static procedure such that model solutions involving an array of possible fresh vegetable market shares are compared to a base solution. The base solution, which tracks average production and prices of row crops and fresh vegetable crops actually produced in the tri-state area in the 1980-1984 period, is obtained by adjusting production costs in a trial and error fashion using dual values of production activities as a guide. Changes in the value of the welfare function are also observed from the analysis.

The Programming Model

The basic quadratic programming model used in this study is the interregional activity formulation of Takayama and Judge. The study model differs from the formulation of Takayama and Judge in that it does not contain a transportation component. The focus of this study is to determine the relative competitiveness of alternative cropping activities in specified regions as opposed to spatial allocation of commodities among regions of demand. In matrix-vector notation the model formulation for this study may be expressed as follows:

(1) MAX NSP (YX)

$$= [A\ -C]\ [Y'X'] - (1/2)\ [Y\ X] \begin{bmatrix} D & 0 \\ 0 & 0 \end{bmatrix} [Y'X']$$

$$\text{S.T.} \begin{bmatrix} I & -P \\ 0 & G \end{bmatrix} [Y'X'] \leq [0'L']$$

and

$$[Y'X'] \geq [0']$$

where NSP = Net Social Payoff, Y = a row vector of monthly aggregate demand of each commodity in 100 cwt, X = a row vector of regional activity levels in 100 cwt, A = a row vector of intercepts (dollars per 100 cwt) of price dependent demand equations, C = a row vector of costs per 100 cwt, including variable and risk costs of production, D = a nonnegative diagonal submatrix of demand coefficients without cross-price flexibilities. (The quadratic form should be positive semidefinite to insure that the algorithm reaches a global maximum (Takayama and Judge). This condition is satisfied in that the diagonal elements of D are positive and the off-diagonal elements are zero.), I = an identity submatrix, P = a submatrix including elements of 1 and 0, G = a submatrix of land constraint coefficients in acres per 100 cwt, and L = a row vector of the availability of cropland by region and growing season in acres.

The constraints used in the model are explained as follows: The aggregate monthly quantity demanded, say Y, is less than or equal to the monthly quantity harvested from all producing regions. Thus,

(2) $IY - PX \leq 0.$

Cropland is constrained by the availability of cropland in each region and growing period. Thus,

(3) $G' X \leq L$.

Demand and supply quantities are constrained to be nonnegative such that

(4) $[Y'X'] \geq [0']$.

Model Components

Demand Component

Price-quantity demand functions for the fresh vegetable commodities were computed from price elasticity estimates from previous studies, while price-quantity demand functions for the row crops were estimated with ordinary least squares. Price elasticity estimates for row crops from published sources were not used as preliminary model solutions involving such estimates yielded unrealistically high prices.

Price flexibilities used to compute slope coefficients for the U.S. demand functions for selected fresh vegetable commodities are the reciprocals of the price elasticity estimates shown in Table 1. Computation of U.S. demand functions were based on average monthly price and quantity for each vegetable commodity for 1980-1984 (U.S. Department of Agriculture (a-f)). In order to obtain monthly demand functions with respect to the study area for seven of the vegetable crops produced in the study area, U.S. monthly demand functions were adjusted by the monthly shares of the U.S. market attributable to the study area in accordance with the procedure followed by Mathia and Brooker. In the analysis to follow an array of possible market shares for all 11 vegetable commodities are considered for the study area. Thus, the slopes of the demand functions are adjusted to reflect given market shares; that is, the slopes of the U.S. demand functions for the vegetable commodities are divided by an array of possible

Table 1. U.S. Price Elasticity Estimates and Sources by Fresh Vegetable Commodity

Commodity	Price Elasticity	Source
Snapbeans	-0.5000	Mathia and Brooker
Cucumber	-0.1980	Mittelhammer
Broccoli[a]	-0.1980	Mittelhammer
Cauliflower[a]	-0.1980	Mittelhammer
Bell pepper	-0.1110	Mittelhammer
Cantaloupe	-1.4370	Price and Mittelhammer
Carrots	-0.0388	Huang
Greens[b]	-0.0385	Huang
Leaf lettuce[c]	-0.1371	Huang
Potatoes	-0.3688	Huang
Tomatoes	-0.5584	Huang

[a]Price elasticity estimates for broccoli and cauliflower were not found. However, since broccoli and cauliflower may be considered salad vegetables in a similar vein to that of cucumber, price elasticity estimates for broccoli and cauliflower were assumed to be the same as that for cucumber.

[b]Price elasticity estimates for greens such as collard greens, turnip greens, or mustard greens were not found. However, since greens are staples for those who consume them, much like cabbage, the price elasticity for greens was assumed to be the same as that for cabbage.

[c]A price elasticity estimate for leaf lettuce was not found; thus, the estimate for iceberg or head lettuce was assumed for leaf lettuce.

market share ratios to obtain demand functions with respect to the study area that reflect the assumed market shares.

The general form of the demand functions estimated for row crops is

(5) P = f(Q, QS, QC, ST, I, D)

where P is the price per 100 cwt for a particular commodity in the study area, Q is own quantity (100 cwt) in the study area, QS represents quantities (100 cwt) of possible substitutes in the study area, QC represents quantities (100 cwt) of possible complements in the study area, ST is own U.S. stocks (100 cwt) at the end of the year, I is per capita income in the U.S., and D is an own quantity slope dummy variable reflecting possible structural change in the decade of the 1970s due to dramatic increases in the price of OPEC oil. Seasonal data used to estimate demand functions for corn, soybeans, cotton, and wheat with respect to the study area were obtained from U.S. Department of Agriculture (f) and U.S. Department of Commerce for the period from 1955 to 1984. Seasonal data used to estimate the demand function for "additional" peanuts, peanuts grown for the export market without government supply restrictions, were from U.S. Department of Agriculture (f) and unpublished price data from the Commodity Analysis Division, ASCS, U.S. Department of Agriculture. In order to compute the price-quantity relationships for row crops used in the quadratic programming model average values for the variables in the estimated equations for the period 1980-1984 were used.

Production Cost Component

Production costs used in this study include variable cost, reflecting the short-run nature of the analysis, and risk cost. Sources of variable cost estimates were selected on the basis of relevance to a particular region in the study area by agricultural economists and biological scientists from the tri-state area. Variable cost and yield estimates were obtained from extension budgets from various states. The procedure employed by Adams et al. was used to compute risk cost. Risk cost is the product of variable cost and the coefficient of variation (risk coefficient).

Price variability was used to estimate risk coefficients for the fresh vegetable crops, while yield variability was used for the row crops. Price variability by month for the vegetable crops was estimated using monthly F.O.B. prices for the period 1975-1984 (U.S. Department of Agriculture (b,c)). Yield variability by region of the study area for the row crops was estimated from yield data for the period 1975-1984 (Crop Reporting Services for Alabama, Florida, Georgia, North Carolina, South Carolina, and Tennessee).

Land Constraint Component

Land constraints by region of the study area were set at total average acres of land in use in the peak season for row crops in 1983-1984 excluding crops regulated by the government such as tobacco and quota peanuts. The land constraint coefficients are the reciprocals of respective yields in 100 cwt. per acre.

There are many cases where growing seasons for vegetables and row crops overlap in a given region causing competition for land. For this reason biological constraints were employed in the quadratic programming model to insure that crops with overlapping growing seasons in a given region could not occupy the same area of land.

Results

A summary of the results of the comparative static analysis is conveyed in Tables 2-4. Table 2 shows the effects of alternative market shares of

Table 2. Effects of Alternative Market Shares for Fresh Vegetables on Acreage of Selected Vegetable and Row Crops in the Study Area

				Market Share							
				1%		5%		10%		20%	
Commodity	Actual Acreage	Base Model Acreage	Diff. (%)[a]	Acreage	Diff. (%)[b]	Acreage	Diff. (%)[b]	Acreage	Diff. (%)[b]	Acreage	Diff. (%)[b]
Vegetable crops											
Snap beans	12,460	15,242	22.33	15,366	0.81	15,866	4.09	16,491	8.19	18,521	21.51
Cucumber	12,447	12,942	3.98	13,035	0.72	13,571	4.86	15,271	18.00	19,014	46.92
Broccoli	NA	NA	NA	378	NA	1,894	NA	3,789	NA	7,579	NA
Cauliflower	NA	NA	NA	347	NA	1,732	NA	3,467	NA	6,932	NA
Bell pepper	2,637	2,783	5.54	3,125	12.29	4,697	68.77	6,747	142.44	11,770	22.92
Cantaloupe	2,051	3,030	47.73	3,829	26.37	11,117	266.90	22,233	633.76	44,466	1,367.52
Carrots	NA	NA	NA	868	NA	4,347	NA	8,687	NA	17,373	NA
Greens	1,393	1,417	1.72	1,417	0	1,417	0	1,417	0	1,417	0
Leaf lettuce	NA	NA	NA	30	NA	149	NA	297	NA	593	NA
Potatoes	1,581	1,806	14.23	4,826	167.22	19,856	1,999.45	39,711	2,098.84	79,420	4,297.56
Tomatoes	5,504	6,406	16.39	6,576	2.65	7,996	24.82	10,022	56.45	14,581	127.61
Subtotal	38,073	43,626	14.59	49,797	14.15	82,642	89.43	128,132	193.71	221,666	408.11
Row crops											
Corn	3,399,553	3,324,162	-2.22	3,324,222	0	3,324,171	0	3,324,166	0	3,294,169	-0.90
Soybeans	4,059,760	4,063,427	0.09	4,063,404	0	4,063,299	0	4,063,171	0	4,054,889	-0.19
Wheat	1,925,527	1,925,457	0	1,925,457	0	1,925,457	0	1,925,457	0	1,925,457	0
Cotton	253,887	253,850	-0.01	253,850	0	253,850	0	253,850	0	253,169	-0.27
"Additional" peanuts	219,676	227,686	3.65	227,686	0	227,686	0	227,686	0	227,410	-0.12
Subtotal	9,858,403	9,794,582	-0.65	9,794,619	0	9,794,463	0	9,794,330	0	9,756,094	-0.39
Total	9,896,476	9,838,208	-0.59	9,844,416	0.06	9,877,105	0.40	9,922,462	0.86	9,977,760	1.42

Note: Actual market shares for snap beans, cucumber, greens, and tomatoes exceed the market share categories depicted in this table.

[a]Difference = (Base Acreage-Actual Acreage)/Actual Acreage.

[b]Difference = (Adjusted Acreage-Base Acreage)/Base Acreage.

Table 3. Production of Selected Fresh Vegetable Crops by Harvest Month for the Study Area Assuming Ten and Twenty Percent Market Shares

Commodity	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
	Harvest Period											
	100 cwt											
Ten Percent Market Share												
Snap beans	NA	NA	NA	654	924	2,722	1,124	573	561	1,315	704	NA
Cucumber	NA	NA	NA	1,301	1,827	8,980	4,842	784	693	2,591	1,324	NA
Broccoli	NA	NA	NA	459	463	392	342	325	377	403	444	536
Cauliflower	416	295	NA	290	322	286	254	236	289	417	373	379
Bell pepper	NA	NA	NA	833	949	1,554	706	473	633	658	794	NA
Cantaloupe	NA	NA	NA	1,833	3,825	6,686	6,688	4,430	2,497	1,406	426	NA
Carrots	2,651	1,386	1,709	1,634	1,538	1,415	1,039	861	975	1,063	1,139	1,297
Greens	634	677	949	866	696	222	226	202	290	326	330	751
Leaf lettuce	NA	NA	93	67	52	26	33	34	30	27	68	164
Potatoes	NA	NA	NA	15,623	16,400	12,440	9,804	9,405	9,415	10,218	NA	NA
Tomatoes	NA	NA	NA	NA	4,634	25,829	6,249	2,362	2,620	3,241	3,087	NA
Twenty Percent Market Share												
Snap beans	NA	NA	NA	1,309	1,233	2,722	1,124	573	561	1,315	1,005	NA
Cucumber	NA	NA	NA	2,602	3,654	8,980	4,842	1,569	1,259	2,591	2,649	NA
Broccoli	NA	NA	NA	918	926	785	684	650	754	807	888	1,072
Cauliflower	832	590	NA	579	645	572	508	472	577	833	746	758
Bell pepper	NA	NA	NA	1,666	1,898	1,829	1,412	945	1,265	1,317	1,588	NA
Cantaloupe	NA	NA	NA	3,665	7,651	13,371	13,375	8,860	4,995	2,812	853	NA
Carrots	5,303	2,771	3,419	3,269	3,076	2,829	2,078	1,722	1,949	2,127	2,277	2,595
Greens	634	677	949	866	696	222	226	202	290	326	330	751
Leaf lettuce	NA	NA	186	135	104	52	66	67	60	53	136	327
Potatoes	NA	NA	NA	31,245	32,799	24,880	19,608	18,810	18,830	20,435	NA	NA
Tomatoes	NA	NA	NA	NA	9,267	25,829	6,943	4,724	5,240	6,482	6,173	NA

Note: Actual market shares for snap beans, cucumber, greens, and tomatoes exceed the market share categories depicted in this table. Production may occur in any of the four regions of the study area given profitability and climate restrictions where NA indicates infeasibility of production given such restrictions.

Table 4. Comparison of Values of the Welfare Function (Net Social Payoff), Base Solution and Solutions With Alternative Market Shares for Fresh Vegetable Crops

Model Station	Value of Welfare Function (NSP)	Difference Value[a]	Difference Percentage[b]
	(1,000 dollars)	(1,000 dollars)	(%)
Base	462,808	-	-
Market Share			
1%	516,052	53,244	11.50
5%	759,024	296,215	64.00
10%	1,122,093	659,285	142.45
20%	1,788,937	1,326,128	286.54

[a]Value Difference = Market Share Solution Value - Base Value.

[b]Percentage Difference = Value Difference/Base Value.

fresh vegetable commodities on acreage of selected vegetable and row crops in the study area. Effects by region of the study area are not shown because of space limitations. Fresh vegetable production by harvest month, assuming two different market shares, is presented in Table 3, while Table 4 illustrates the partial equilibrium welfare gains from increased fresh vegetable production in the study area.

Base solution acreages represent the foundation against which acreages associated with each fresh vegetable market share assumption are compared. In order to provide an anchor for base solution acreages, actual acreages of vegetable crops (imputed) and row crops are presented, Table 2.

As shown in Table 2, fresh vegetable crops utilize relatively few acres compared to row crops even assuming a 20 percent market share for fresh vegetables. Nevertheless, given that acreage utilization may be somewhat important, all but snap beans, greens, and leaf lettuce seem to deserve consideration.

As shown in Table 3, with the vast diversity of climates in the study area, production of vegetables is possible 8 to 12 months of the year. Planting and harvesting dates provided by biological scientists serve as the foundation for the results depicted in Table 3. The fringe possibilities embedded in Table 3 are being tested empirically.

Relative to the base solution the value of the objective function, which represents net social payoff, increases dramatically as market share for fresh vegetables increases, Table 4. This type of comparison which was employed by Adams et al. must be considered in light of the assumptions behind the analysis which in this case is a normative partial equilibrium analysis. Nevertheless, the magnitudes of the increases in the welfare function seem compelling.

Conclusions

This paper represents an earnest start in the evaluation of alternatives to traditional row crops in the study area. As reflected in this paper, it seems clear that vegetable crops are not destined in the near future to replace row crops in terms of land utilization. Nevertheless, vegetable crops appear to compete with and complement row crops well as evidenced by substantial increases in production as market share was assumed to increase.

Empirical evaluation that is now underway may show that the production potential of vegetables in the study area is not as great as depicted in certain fringe months. As data becomes available, variability in yield or gross returns may be better measures of variation for the risk coefficient.

Though vegetables do not utilize large acreages of cropland, the dramatically increasing value of the welfare function with an increasing market share clearly signals the importance of fresh vegetables as possibly profitable enterprises in the study area. Certainly, vegetables are not "the" answer to the diversification of agricultural production in the study area, but this paper does reveal that vegetables should be strongly considered as part of the answer.

The realization of greater market shares for vegetables in the study area goes beyond the scope of this paper. Greater market shares are likely to depend on spatial comparative advantage and the entrepreneurial spirit of agricultural producers in the study area. Indeed, market shares for fresh vegetables in the study area have been increasing slowly since the early 1970s.

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