PLANT LOCATION MODELS FOR A HONEY PACKER: SENSITIVITY OF FINDINGS TO SOME ALTERNATIVE SPECIFICATIONS WITH REFERENCE TO THE SOUTH

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This paper discusses plant location models applied to a honey processing-marketing cooperative firm with emphasis on sensitivity of findings to some alternative objectives and specifications. Though the study was nationwide in scope, the southern regions of the United States played a significant role in the analyses.

OBJECTIVES AND METHODOLOGY

The first objective was to determine the number, size, and location of honey processing plants which would minimize total assembly, processing, and product shipment cost. In pursuit of the first objective, two of several questions receiving consideration were: 1. In comparing an optimizing least-cost result to an actual operating cost result, what is a valid specification of "actual" cost?[1] 2. Is there a simple way of checking on the validity of a minimum cost solution?

The second objective was to compare the minimum cost solution to alternative net revenue maximization analyses.

The major analytical methodology was a computerized adaptation of the transshipment spatial equilibrium model with economies-of-scale in plant processing as presented by King and Logan [6]. Technical details concerning the transshipment model are thoroughly documented elsewhere [3, 6, 9].

In this study, the United States was divided into 54 regions. The firm had markets in all of these regions and raw honey supply in 30 of these same regions. Fifteen southern market regions had nearly 30 percent of the aggregate market tonnage. Eight southern supply regions accounted for 15 percent of the aggregate supply tonnage.

FINDINGS AND THEIR SENSITIVITY

Regarding the first objective, major findings were: 1. A current network operating with 5 processing plants in Georgia, Texas, Iowa, Idaho, and California could be reduced to a 2 plant network in Iowa and California. One 3 plant network in Florida, Iowa, and California could be nearly as efficient as a 2 plant network. 2. One plant could increase its share of total volume from 40 percent to about 67 percent. 3. Annual costs of combined processing and transportation could be reduced 8 percent. 4. The cost reduction would be equivalent to about $7.00 per thousand pounds of marketed honey or an average of 250 dollars per each of the 1,200 member beekeepers who supply raw honey to the packer. Three hundred and seventy of the member beekeepers are located in the South.

COMPARING MODEL COSTS AND ACTUAL COSTS

Conceptually, a comparison of actual operating costs to model optimal costs could provide some useful quantifiable indication of whether or not an actual network tends to operate at minimum cost.

In practice, comparisons usually must be made with less than perfect information conditions. For example, a comparison of "model" processing costs based on "synthetic" economic-engineering equations and "actual" costs based on accounting statements could occur. However, accounting statements' costs data have several limitations with respect to conventions, judgment and insufficient detail regarding the effects of scale, excess capacity, work methods, delays and idle work time [11]. With such

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[1] In a review of this study, F. E. Bender emphasized the importance of this question.

insufficiency of detail, it would be an impossible task to determine whether differences between model and accounting costs were due to differences in costing methods or reality. Thus, any claim of substantial potential saving or efficiency based on this approach, while not conclusively disproved, would be questionable. The main difficulty with this approach is that two different costing methods prevent true comparability.

Alternatively, the costs of "actual" processing plants could be estimated by substituting current plant volumes into their respective processing synthetic unit cost equations to get estimated unit costs for each plant. Unit costs multiplied by the respective plant volumes would yield estimated "actual" total processing costs. In this manner, the same costing method would be used for both the optimizing model costs and the current operation and a better comparability base would be established.

A better comparability base reduces the risk of producing illusions regarding potential cost savings. Table 1 shows an example from the honey firm study for an optimal 2 plant network.

A substantial synthetic savings will remain after disregarding a large illusion of 155 thousand dollars. This overstatement is more than half of the synthetic cost savings. The synthetic cost savings are 8.23 percent and the accounting cost savings are 12.59 percent of the synthetic "actual" costs. The accounting cost savings are 12.08 percent of the accounting "actual" costs.

A substantial cost savings illusion may seem to suggest poor synthetic modeling. This may or may not be so. Normally, synthetically derived costs will differ from accounting costs. Synthetic unit costs may be good approximations of accounting unit costs but large physical volume can magnify slight unit cost differences into total cost differences of some size. In this study, the savings illusion was about 4 percent of the accounting "actual" costs. That is, the synthetic "actual" costs were about 96 percent of the accounting "actual" costs.

Table 1. COST SAVINGS ILLUSION

"Actual" Operation Costs: Accounting:	Synthetic :	Model Least-Cost :	Accounting Savings :	Synthetic Savings :	Illusion
		Dollars			
3,847,534	3,692,215	3,382,588	464,946	309,627	155,319

CONSISTENCY OF MINIMUM COST WITH MARGINAL RATE OF SUBSTITUTION

A useful way to use the expected inverse relationship between plant processing costs and transportation costs (as the number of plants vary) is to apply the optimizing theory of marginal revenue equaling marginal cost. The cost savings from decreasing plant processing costs may be thought of as a marginal revenue or gain, G; the transportation cost increases may be thought of as a marginal cost, C.

There are three relationships possible between G and C,

(1) $G > C$

(2) $G = C$

(3) $G < C$

Expressions (1), and (2), and (3) can be arranged so that (1) becomes

(4) $\frac{G}{C} > 1$ $\left(\text{or } \frac{C}{G} < 1\right)$

and

(2) becomes

(5) $\frac{G}{C} = \frac{C}{G} = 1$

and

(3) becomes

(6) $\frac{G}{C} < 1$ $\left(\text{or } \frac{C}{G} > 1\right)$.

Table 2 compares the extra savings, G, in processing costs to the extra costs of transportation, C, for each of several successive pairs of plant number reduction alternatives in the honey packer study.[2]

The ratios of $\frac{G}{C}$ in Table 2 may be considered as

[2] For each number of plants, the least-cost alternative of several alternatives was chosen.

Table 2. **PROCESSING AND TRANSPORTATION COST CHANGES FOR SUCCESSIVE PAIRS OF PLANT NUMBER ALTERNATIVES**

Alternatives	Processing Savings, G	Extra Transportation Costs, C	Relationship Between G and C	Ratio of G to C
	Dollars			
5 to 4 plants	36,801	15,416	$G > C$	2.39
4 to 3 plants	161,583	67,854	$G > C$	2.38
3 to 2 plants	109,823	104,188	$G \doteq C$	1.05
2 to 1 plant	143,832	206,689	$G < C$	.70

crude or rough measures of marginal rates of substitution of transportation dollars for processing dollars [5]. For example, going from 5 to 4 or from 4 to 3 plants, each additional dollar of transportation cost produces more than two dollars in processing savings and $\frac{G}{C} > 1$. However, changing from a 3 to a 2 plant alternative, each additional dollar of transportation cost produces only about one dollar in processing savings and $\frac{G}{C}$ is practically equal to unity which supports the optimality of a 2 plant alternative. If a change were made from a 2 to a one plant alternative, an additional dollar of transportation cost would yield only 70 cents in processing savings and $\frac{G}{C} < 1$.

NET REVENUE MAXIMIZATION ALLOCATIONS COMPARED TO LEAST-COST ALLOCATIONS

The transshipment spatial equilibrium cost minimizing model may be converted into a net revenue-maximization model by introducing: (1) appropriate market gross price data in the objective function and/or (2) appropriate changes in the constraint rows.

The three net revenue maximization models used in the honey firm study were distinguished from each other by certain specifications.

Model I used weighted market prices (horizontal demand curve in each market) which were added to the objective function of the otherwise unchanged cost matrix. The cost minimizing objective function was expanded into a net revenue maximizing objective function:

$$(7) \quad \text{Max } W = \sum_i \sum_j M_j X_{ij} - \sum_i \sum_j T_{ij} X_{ij} - \sum C_i P_i - \sum_i \sum_j t_{ij} R_{ij}$$

where: Max W = maximum total net revenue,

M_j = gross weighted market price in region j,

T_{ij} = unit cost of transporting processed honey from a plant in region i to a market destination in region j,

X_{ij} = amount of processed honey transported from a plant in region i to a market destination in region j,

C_i = a processing unit cost for a processing plant in region i,

P_i = amount of raw honey processed into packaged honey at a processing plant in region i,

t_{ij} = unit cost of transporting raw honey from a source in region i to a processing plant in region j, and

R_{ij} = amount of raw honey transported from a raw honey source in region i to a processing plant in region j.

Model II was identical to Model I except that (1) each of the market demand quantities were increased 4 percent and (2) the "sense" for each market demand quantity was changed from an "equal to" to a "less than or equal to" constraint. In effect, each market region's demand was converted from a given required amount to a restricted unknown which could vary from zero to a given moderate growth target amount.

Model III was identical to Model II except that each market region's demand quantity was increased to the total estimated amount of market demand available to all competitors in each market region. In effect, this model allowed each market to vary from zero to a 100 percent market share. Aggregate demand remained constant in all cost and net revenue models.

Findings were based on allocations at three processing plants located in Florida, Iowa, and California. Thus, the number and location of plants were given. However, the size of each plant was not given and, therefore, was to be determined by the analyses.

Lack of sufficient detail regarding demand functions and industry demand in each of the various market regions precluded any attempts to make

Table 3. COMPARISON OF PLANT SIZES AND SHARES OF TOTAL VOLUME: LEAST-COST MODEL AND THREE NET REVENUE MAXIMIZATION MODELS

Type Model		Plant Location			
		Iowa	California	Florida	Total
Least-Cost Model					
Plant Size:	100 Pounds	279,970	101,917	38,264	420,151
Plant Share:	Percent	66.63	24.26	9.11	100.00
Model I					
Plant Size:	100 Pounds	277,574	90,700	51,877	420,151
Plant Share:	Percent	66.06	21.59	12.35	100.00
Model II					
Plant Size:	100 Pounds	266,994	101,321	51,836	420,151
Plant Share:	Percent	63.54	24.12	12.34	100.00
Model III					
Plant Size:	100 Pounds	325,465	40,922	53,764	420,151
Plant Share:	Percent	77.46	9.74	12.80	100.00

reasonably accurate statements concerning comparisons of net revenues or market shares. Therefore, comparisons focus on changes in plant sizes and costs. Data in Table 3 compares the results with respect to plant sizes and plant shares of total volume. All three net revenue maximizing models caused changes in the minimum cost model sizes and shares of plant processing volume. In all three revenue models, the Florida plant volume increased approximately 1.5 million pounds and the California plant decreased by as much as 6 million pounds in Model III as compared to the least-cost solution. The Iowa plant size varied substantially in Models II and III as compared to the least-cost solution.

Data in Table 4 compares the total cost differences between the least-cost model and the three net revenue models. Two of the three net revenue applications caused only slight changes in total combined processing and transportation costs. However, within the totals, substantial cost changes occurred. For example, Model I total cost increased only $9,150 but the California and Florida plants each showed a cost change of more than $100,000. A similar situation occurred in Model II.

Model III showed nearly $69,000 less cost than the least-cost model. This was due to Model III excluding more distant and less profitable markets. Model III did this since it could allow each market allocation to vary from zero to 100 percent share while satisfying the same fixed aggregate demand quantity required in the least-cost model. The California plant cost in Model III decreased $525 thousand but the Iowa and Florida plants showed a combined increase of $456 thousand.

Table 4. COST DIFFERENCES BETWEEN THE LEAST-COST MODEL AND THREE NET REVENUE MAXIMIZATION MODELS

Plant location	Model I	Model II	Model III
	Dollars		
Iowa	- 11,427	-101,290	+305,568
California	-102,657	- 19,590	-525,362
Florida	+123,234	+124,148	+150,895
Total	+ 9,150	+ 3,268	- 68,899

CONCLUSIONS

Computerized mathematical optimization analyses revealed that a nationwide honey processing-marketing cooperative could reduce its 5 plant operation to 2 plants for annual cost saving of about $300,000. This cost reduction averages (1) over $7.00 per thousand pounds marketed and (2) about $250 for each of the 1,200 member beekeepers of the cooperative. More than one-fourth of the member beekeepers are located in the South.

To reduce the risk of seriously misleading decision-makers with illusory cost savings possibilities, comparison of least-cost model results to actual operation results should be in terms of the same costing method. Substantial potential cost savings from fewer and larger honey processing plants as recommended by a synthetic cost minimizing model were 155 thousand dollars lower when compared to synthesized costs of the actual operation (cost savings of 310 thousand dollars) rather than accounting costs of the actual operation (cost savings of 465 thousand dollars).

A method of supporting a mathematical programming optimal cost solution which recommends fewer plants is to require that the plant processing cost savings produced by N-1 rather than N plants (a marginal revenue or benefit) be equal to the increased costs of transportation (a marginal cost). Alternatively, the ratio of marginal processing savings to marginal transportation costs should equal unity. In the honey packer study, a decrease from 3 to 2 processing plants produced a ratio of 1.05.

Two of three net revenue maximization applications caused only slight changes in total costs compared to a least-cost solution. Within the totals, significant changes occurred. Individual plant sizes changed as much as 6 million pounds and costs varied as much as 500 thousand dollars.

FUTURE RESEARCH

The findings of a study are partly predestined by characteristics inherent in the choice criteria and methods used. Since scarce resources prevent any one researcher from experimenting with all known economic choice criteria and methods, any particular finding must be stated cautiously. Other specifications which might have been applied to this study include: Alternative disaggregations of geographical regions, present value criteria, seasonality, Baumol's sales maximization with a profit constraint model, ecological and environmental constraints, separable and quadratic programming, stochastic models, and other specifications. The list could be endless. Much interesting research remains regarding sensitivity of plant location findings to alternative specifications.

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