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A VARIANCE COMPONENT APPROACH TO INDUSTRY COST ANALYSIS

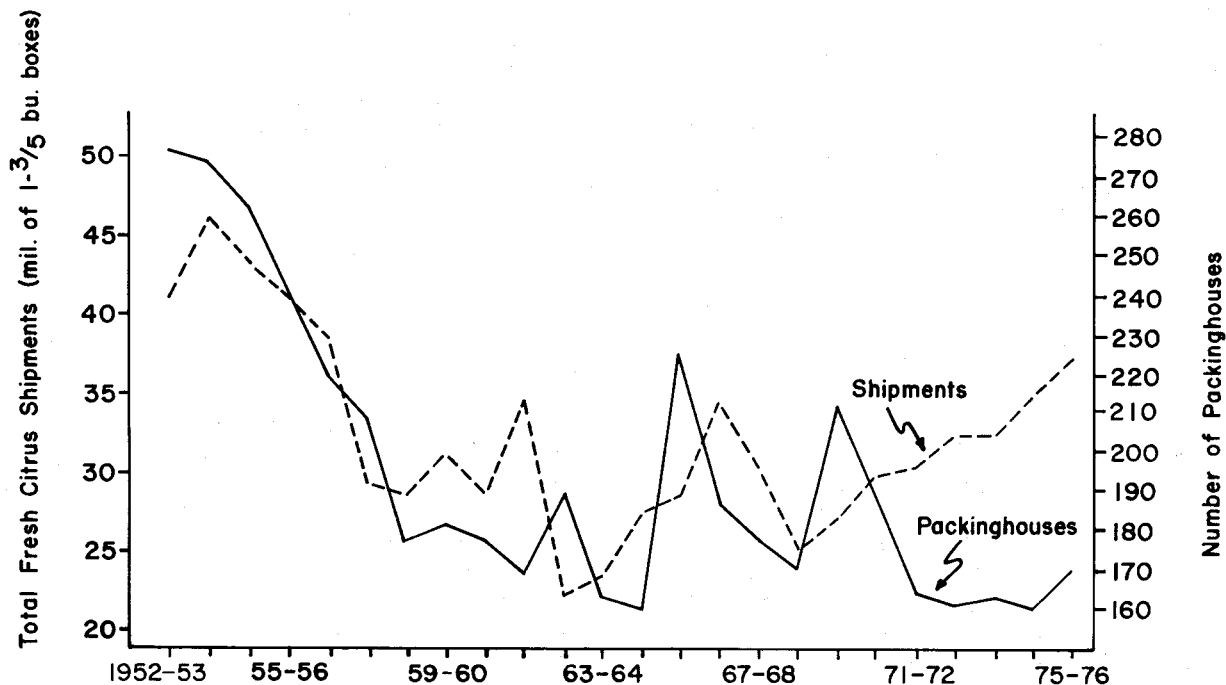
Richard L. Kilmer and Daniel S. Tilley

Cost and volume data used in long-run cost studies often are observations from a single cross-section on firms or the average of multiple observations for each firm [1, 3, 5]. Averaging costs and volume over a time series is designed to eliminate the effect of short-run disturbances on the estimated long-run cost function. This practice results in a loss of information on the cost effects of short-run disturbances and significantly reduces the potential degrees of freedom that could result from pooling cross-sectional time-series data. In order to pool data, binary variables for each firm previously have been used to account for short-run fixed firm effects [4]. However, firm

binary variables do not allow individual estimation of the short-run fixed effects. The objective of this research is to set forth a long-run cost function in which the short-run fixed firm effects of citrus packinghouses are directly estimated through continuous and binary variables that measure managerial ability, operating characteristics, and physical plant characteristics. Random firm effects are accounted for by using a variance component regression model.

From 1952 through 1971, the number of Florida fresh citrus packinghouses decreased 40 percent (Figure 1). Since 1971 the number has been relatively stable although the average

FIGURE 1. TOTAL FRESH CITRUS SHIPPED AND NUMBER OF PACKINGHOUSES SHIPPING FRESH CITRUS, 1952-53 THROUGH 1975-76.



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volume packed per plant increased 22 percent in response to an increase in total industry output. Currently, capacity utilization is 50 percent¹ and packout is 63 percent. The degree of competition is high in this industry which has low product differentiation, low concentration, and low barriers to entry [12]. Machado [6] found that the optimum number of packinghouses in the Indian River region of Florida is 15 compared with the actual number in 1975-76 of 68. Thus, firm managers need information that will facilitate present and future firm responses to impending structural adjustments. In the following sections the economic model is described, the results of the firm and industry analyses are presented, and conclusions are stated.

ECONOMIC MODEL

Johnson [4] proposed a cost model that combined cross-sectional with time-series data. He sought to estimate a cost-output relation that was corrected for fixed differences in time and space that were nonmeasurable. Assuming R stores and T years,

$$(1) \quad AC_{rt} = f(A_r, A_t, X_{rt})$$

where AC_{rt} is the output cost for store r in time period t , A_r (binary variable) is the fixed firm effect for store r , A_t (binary variable) is the fixed time effect for time t , and X_{rt} is the output by store r in time period t . The binary variables contain information which could be used by firms to make short-run adjustments that affect cost. The model in this study identifies the sources of fixed effects contained in the fixed firm effect binary variables of the Johnson model. The model is:

$$(2) \quad APC_{it} = \beta_0 + \beta_1 C_i + \beta_2 C_i^2 + \beta_3 \ln CU_{it} + \beta_4 \ln PO_{it} + \beta_5 S_{it} + \beta_6 PK_{it} + \beta_7 \ln O_{it} + \beta_8 LI_i + \beta_9 Y1_{.1} + \beta_{10} Y2_{.2} + \beta_{11} M2_i + \beta_{12} M3_i + \omega_{it}$$

where APC_{it} is the total annual dollar cost of running a packinghouse divided by the total 1 3/5 bushel boxes of citrus shipped from packinghouse i in year t , C_i is the seasonal capacity for packinghouse i and equals 11 times its maximum monthly output during 1973-74 through the 1975-76 seasons (11 months is the maximum season length regis-

tered by sample firms),² C_i^2 is the capacity of packinghouse i squared, CU_{it} is the capacity utilization (ratio) of packinghouse i in year t , PO_{it} is the percentage of citrus accepted by packinghouse i in year t that is sold as fresh citrus,³ S_{it} is the supply variability of packinghouse i in year t as measured by the coefficient of variation of weekly citrus supply, PK_{it} is the percentage of citrus from packinghouse i in year t that is not packed in standard 4/5 bushel boxes (this variable represents the heterogeneity of product produced), O_{it} is the ratio of oranges to grapefruit packed by packinghouse i in year t , LI_i equals 1 if packinghouse i is in the Indian River region and zero if it is in the Interior region, $Y1_{.1}$ equals 1 for the 1973-74 packing season and zero otherwise, $Y2_{.2}$ is 1 for the 1974-75 packing season and zero otherwise, $Y3_{.3}$ represents the 1975-76 packing season and is always zero (deleted for estimation of dummies), $M1_i$ is modernization category 1 for packinghouse i defined as a packinghouse accepting pallet boxes (deleted for estimation of dummies), $M2_i$ equals 1 if packinghouse i accepts pallet boxes and has modern degreening rooms as well as centralized rather than roll-board sizing, $M3_i$ equals 1 if packinghouse i has the modernization characteristics described plus mechanical packing for most citrus, lift trucks throughout, and perhaps mechanized palletization.

The natural logarithm was taken of capacity utilization, packout percentage, and the ratio of oranges to grapefruit packed out because the relationship between the three variables and average packing cost is assumed to be nonlinear. As capacity utilization increases which increases the total volume of fresh fruit packed, average cost per unit packed is expected to decrease at a decreasing rate.

The same relationship is assumed between average packing cost and packout percentage. The cost of unloading, grading, reloading, and shipping eliminations (see footnote 3) to processing plants is included in the cost of packing citrus that is sold to consumers as fresh fruit. As the packout percentage increases, the number of boxes required to pack an equivalent box of fresh citrus is reduced for a given volume of fresh fruit packed. This reduction decreases the total annual cost that is charged against packed fruit for the handling of eliminations.

Finally, the natural logarithm was taken of the ratio of oranges packed to grapefruit

¹Fresh citrus harvesting starts in September, increases slowly to a peak in December and January, and declines through July. Capacity utilization of 60 percent for an 11-month season would be an optimum industry average. An individual packinghouse could reach a much higher factor. One firm sampled had a capacity utilization factor of 90 percent.

²An economic engineering study would be required to establish better the capacity of the firms sampled. A monthly maximum sustainable capacity is assumed to have been reached during a month in the 1973-74 to 1975-76 seasons during which time total fresh citrus packed was increasing and total packinghouses in operation were relatively constant (Figure 1).

³Fruit not packed because of exterior appearance or size is called eliminations and is sent to citrus processors for manufacture into processed product.

packed. Grapefruit are more costly to pack because heavier cartons are used.

The error in model 2 is assumed to be:

$$(3) \quad \omega_{it} = \mu_i + v_{it}$$

where μ_i is the component of ω_{it} due to random difference in firms and v_{it} is the conventional random disturbance in regression models. Season variables (intercept shifters) were included in the model to account for systematic changes over time. Generally, it is easier to account for time-series than cross-sectional differences. The inclusion of the season variables implies that the error is reduced to zero over time and that equation 3 is the appropriate error specification [8, p. 327; 10, p. 57; 11, p. 395].

Because the error term for each observation associated with a particular firm contains μ_i , there is a correlation among errors of the same firm. A generalized least squares approach was used to correct for the correlated errors. Given the assumption of the variance component model, the variance in equation 3 is:

$$\sigma^2 = \sigma_\mu^2 + \sigma_v^2$$

The portion of total variation due to differences in firms is given by the ratio $\rho = \sigma_\mu^2 / \sigma^2$. A maximum likelihood procedure similar to that of Maddala [7, p. 345] was used to estimate ρ which was used to correct for correlated errors.

Data were collected from 29 Florida citrus packinghouses⁴ for three seasons (1973-74 to 1975-76). These firms packed more than 100,000 1 3/5 bushel boxes and accounted for 43 percent of the total Florida fresh fruit shipped in 1975-76. Even though there were 167 packinghouses in operation during the 1975-76 season, only 82 firms shipped more than 100,000 1 3/5 boxes. These 82 firms accounted for 95 percent of the total fresh fruit shipments. Therefore, this study is relevant to the portion of the citrus packinghouse industry that packs more than 100,000 boxes annually.

INDUSTRY AND FIRM ANALYSES

Equation 2 and several variations were estimated.⁵ Coefficients for two of the specifications are shown in Table 1. All coefficients are of the expected sign. The standard error of the capacity squared coefficient in Model A is large in comparison with the coefficient. The

TABLE 1. MODELS

Explanatory Variables	Model A		Model B	
	Standard		Standard	
	Parameter	Deviation	Parameter	Deviation
<u>Capacity Variables^{a/}</u>				
Capacity [LnC]	--	--	-.1573	.0648
Capacity [C]	-.0040	.0017	--	--
Capacity Squared [C ²]	.000008	.000005	--	--
<u>Managerial Ability Variables^{a/}</u>				
Capacity Utilization [LnCU]	-.4022	.0809	-.4006	.0808
Packout [LnPO]	-.2524	.1287	-.2867	.1301
Supply Variability [S]	.0461	.1309	.0480	.1310
<u>Operating Characteristics Variables</u>				
Oranges/Grapefruit [LnO]	-.0509	.0180	-.0509	.0191
Pack Variability [Pk]	.0031	.0017	.0027	.0017
<u>Physical Plant Variables^{b/}</u>				
Modernization 2 [M2]	.1586	.0733	.1488	.0782
Modernization 3 [M3]	.1140	.0888	.0923	.0940
Location [L1]	-.2759	.0950	-.2749	.1014
<u>Season Variables</u>				
1974 [Y1]	-.2939	.0334	-.2960	.0331
1975 [Y2]	-.0729	.0299	-.0759	.0296
Intercept	3.5788	.5461	4.1414	.5538
Observations	87		87	
Number of Packinghouses	29		29	
ρ	.62		.66	
Standard Error of Model	.176		.183	

^aData on which capacity, capacity utilization, and supply variability were based came from the Division of Fruit and Vegetable Inspection, Florida Department of Agriculture and Consumer Services, Winter Haven.

^bSincere appreciation is extended to Dr. William Grieron, Dr. Will Wardowski and Dr. William Miller of the Agricultural Research and Education Center, Institute of Food and Agricultural Sciences, Lake Alfred, for developing the categories of modernization used in this study and for categorizing almost all packinghouses in Florida according to these categories. Without their assistance, this study could not have been undertaken.

coefficients are nearly equal between Models A and B. Model A was used in the empirical analysis instead of Model B because of a lower standard error of the model, a graphic plotting of average costs and capacity which suggested decreasing returns to size, and informed industry opinion that the larger packinghouses are not realizing an increased return to size.⁶

⁴The data were collected from citrus packinghouses willing to participate in an annual cost study performed for many years by the Food and Resource Economics Department at the University of Florida.

⁵When supply variability was dropped from the equation and when packout percentage and capacity utilization were not in logarithmic form, the parameters and their respective standard deviations changed very little. However, when the ratio of oranges to grapefruit was introduced in non-logarithmic form, the location coefficient changed dramatically from .28 to .10 in nonlogarithmic form. Thus, multicollinearity is present between the location variable and the ratio of oranges and grapefruit.

⁶The subjectivity involved in choice of functional form is thoroughly discussed by Stollsteimer et al. [9].

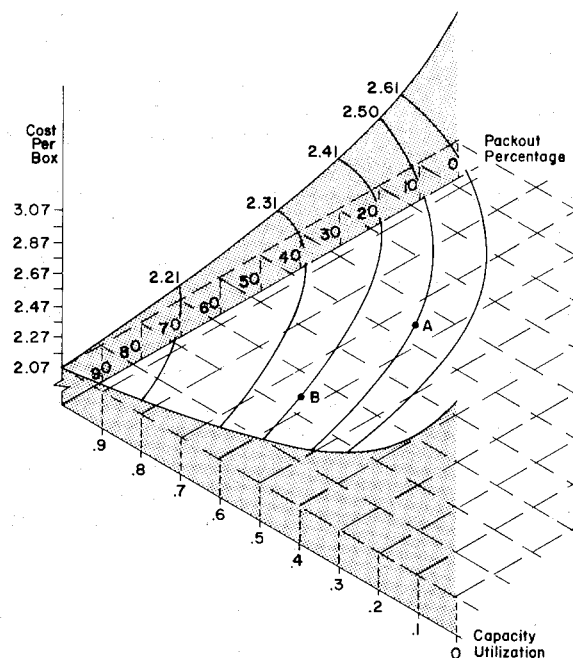
The cost function that was chosen subjectively shows increasing and decreasing returns to scale (Model A). The minimum cost occurs at 2.5 million boxes for all levels of modernization which is below the maximum sample plant capacity of 3.0 million boxes. The expected cost savings for a firm moving from the sample mean capacity of 1 million boxes to 2.5 million boxes would be 18 cents (7.2 percent). This result quantifies one of the reasons why there has been a decline in packinghouse numbers and an increase in the size of new and remodeled packinghouses.

Some of the largest and smallest plants are operating at a size disadvantage. In the short term, managers can manipulate the managerial ability⁷ variables of capacity utilization, packout percentage, and supply variability to reduce costs. Consider a firm with the average sample figures of a 1.0 million box capacity and a capacity utilization of .5. If capacity utilization were to increase to .9, packing cost would decrease 23 cents (9.6 percent). The total effect of moving from the sample average capacity and capacity utilization is a total cost reduction of 42 cents (16.7 percent). However, should the firm maintain a constant volume packed (capacity utilization would decrease to .2), and increase capacity from 1 million to 2.5 million boxes, average packing cost would increase by 19 cents (7.6 percent).

Adequate volume from high quality groves to utilize packinghouse capacity is unlikely. The cost tradeoff between capacity utilization and packout percentage is critical. A firm with a 1 million box capacity that operates at the sample averages of capacity utilization and packout percentage (Point A, Figure 2) could hold cost constant by moving along the isocost curve (a tradeoff between variables) or could decrease cost by 8 cents (3.2 percent) by increasing packout to .88 and holding capacity utilization constant, a movement from A to B (Figure 2). The high standard error of the coefficient for supply variability indicates that firms are able to make resource adjustments so that variability of supply does not materially affect costs. Most workers work on a piece rate or hourly basis and are not paid when fruit is not available.

The operating characteristics, pack variability and the proportion of oranges to grapefruit packed, depend on the package type and fruit type desired by wholesale buyers. Pack variability among the sample firms ranges from 0 to 83 percent with a mean of 26 percent. Some firms packed all of their product in standard

FIGURE 2. ISOCOST CURVES FOR ALTERNATIVE CAPACITY UTILIZATION AND PACKOUT PERCENTAGE COMBINATIONS



cartons and others packed as much as 83 percent in nonstandard packages. The cost differential between the two extremes was 25 cents (10 percent). Packinghouses with a high proportion of oranges were found to have lower costs than houses packing a high proportion of grapefruit.⁸ Grapefruit are shipped in heavier, more expensive cartons. The cost differential between the minimum and maximum values in the sample was 41 cents (16.3 percent). These variables are consumer dependent and the packinghouse manager will adjust them in order to increase profit, not necessarily to decrease costs.

The modernization variables, M1, M2, and M3, represent the degree of packinghouse mechanization. Packinghouses in category 1 are least mechanized. The more mechanized houses have higher costs than the least mechanized houses. This difference is due in part to lower capital costs in earlier years when a low degree of mechanization was used by packinghouses.⁹ A packinghouse at a 1 million box capacity and .5 capacity utilization would need to increase capacity utilization to .66 in order to achieve the same expected costs with M3 rather than M1 technology.

Constraints other than the manager's ability may partially control these variables. However, a good manager will improve degree of control by modifying the constraints.

⁷These results must be discounted because of the multicollinearity between the orange/grapefruit variable and the location variable (see footnote 5).

⁸Fixed assets were valued at cost rather than market value. The results may have been different if the market value had been used.

CONCLUSIONS

The study results indicate to firm managers the potential for industry structural adjustments and the form in which the adjustments are likely to occur. In the short term, desire to improve capacity utilization and packout percentage may increase competition among Florida citrus packinghouses. In the longer term, average plant capacity may increase as the advantage of lower cost will make it increasingly difficult for small plants to remain cost competitive. Large plants can realize the same cost savings available through increased capacity utilization and packout percentage as small plants.

Managers will be compensated if they improve capacity utilization and packout percentage in relation to those of other packinghouses. A premium can be paid for the fruit based on reduced costs. Even though additional fruit may not improve packing percentage, the reduced costs from increased capacity utilization must be contrasted with the increased cost from a deteriorating packout percentage. Because many standards by which fruit is graded are related to exterior appearance and not necessarily to eating quality or shipping perishability, development of consumer acceptance and markets for fruit that would not meet current exterior quality standard could lead to lower packing costs.

Firm modernization and expansion must be approached with caution. Recent modernization does not appear to have increased the cost savings between plants of comparable size with different degrees of modernization. If a plant is contemplating modernization without expansion, per box cost may be higher after

modernization. A packinghouse is not necessarily cost inefficient solely because it uses less mechanized equipment. Careful analysis must be performed before drawing conclusions about the cost efficiency of packinghouses based on degree of mechanization.

Packinghouses may become larger in the future; however, all plants currently in the industry will not be able to increase capacity and maintain average capacity utilization at or above .5 (see footnote 1). Expansion plans with committed fruit should be considered in the near future to maintain capacity utilization.

Structural adjustments toward the optimum levels of all variables could reduce average processing cost by 9.7 percent (\$8, 712, 193, in 1975-76). The adjustments would include an increase in capacity (from 1 million to 2.5 million boxes) and an increase in capacity utilization from .5 to .6 (see footnote 1), a 20 percent improvement. The improvement in technical efficiency will be slow, however. Underutilization of capacity is present. Packinghouses with a low mechanized technology have an 11¢ lower packing cost. If labor remains available at reasonable costs, the older houses will continue to operate for several years.

Cost functions estimated by statistical techniques represent a sample average managerial efficiency. Thus, statistical studies are not a good substitute for economic engineering studies which are better suited to examining differences in technologies. However, statistical cost analysis does empirically measure how the sample firms are operating in the real world. Other objectives such as increasing market share, maximizing total revenue, and maximizing profits must be evaluated in conjunction with minimization of costs.

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