A SIMULATION MODEL OF THE FLORIDA ORANGE INDUSTRY

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Abstract. **A quantitative economic model of the Florida orange industry was developed and then used to simulate the effects on industry performance of alternative inventory, pricing, advertising and supply control policies. The model was composed of ten interrelated sectors, extending from tree planting through consumer demand.**

Policy simulation results were examined from the viewpoints of producers, handlers and consumers. Policies that reduced long-run supplies of orange products caused substantially higher aggregate grower profits, lower storage costs and higher retail prices. They also reduced risks for orange producers, but not for handlers and consumers.

The characteristic which dominated policy analysis was the presence of conflicts of interests among growers, handlers and consumers. In almost every instance, in order for one group of participants to gain, another was placed in a less desirable position.

The Florida orange industry has been characterized by large variations in orange prices and supplies. Individual producers have sometimes benefited from short supplies and high prices; however, high prices allow the introduction of competitive products such as synthetic orange beverages and induce the establishment of new orange groves which increase supplies and reduce profits in future periods (7, p. 1). The instability of the orange industry may be detrimental to the long-run interests of growers, handlers and consumers. Supply stabilization would introduce greater certainty into the decision environment of producers and handlers. Consumer interests may also be best served by stable supplies.

The effects of alternative industry policies on the system as a whole and on the grower, handler and consumer components merit investigation. The dynamic and interdependent economic mechanisms operating within the Florida orange industry may dampen or amplify the effectiveness of a policy more than static partial analysis and intuitive judgment would indicate. The construction of a dynamic model provides a method of studying the effectiveness of policy decisions within an environment generated by a computer. Experiments conducted on the model provide guidance to decision makers without the cost and risk of policy changes in the industry.

Objectives

The specific objectives of the study were to:

1. Identify the system of the structure underlying the orange industry's dynamic behavior.
2. Construct a quantitative economic model of the orange industry.
3. Develop measures of performance which reflect the interest of growers, processors and consumers.
4. Evaluate the effects on the three major industry groups of policies designed to improve the performance of the orange industry. These policies included:
   a. Supply control policies as follows:
      i. Curtailment of new tree plantings when grower profits were above specified levels.
      ii. Elimination of fully productive trees when grower profits fell below specified levels.
   b. Changes in the end of year carry-over of orange products.
   c. Alternative pricing strategies.
   d. Changes in the Florida citrus industry's generic advertising budget.

Previous Work

In 1962, under a grant from the Minute Maid Corporation, Jarmain (2) developed a first generation industrial dynamics model of the Florida frozen concentrated orange juice (FCOJ) industry. Jarmain's study indicated that a larger carry-over of FCOJ from one season to the next would

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reduce price variability and improve the grower's position. Raulerson (11) revised and expanded Jarmain's work in a second generation model in order to appraise the effectiveness of alternative supply control policies in stabilizing and raising grower profits. Emphasis was placed on the lack of knowledge in the area of supply response of oranges—particularly during the periods of low prices. Both Jarmain and Raulerson used average grower profits as a basis for evaluating the performance of the frozen concentrated orange juice subsector. These studies provided a basis for the current study.

Models of the type used in this study require large amounts of information and it is helpful when this information is summarized in relatively efficient forms. Information for this model was available from several sources. The following studies were particularly useful.

A study completed by Polopolus and Black (7) in 1966 concluded that shifts in the quality and supply of orange juice due to periodic freezes have fostered the entry and proliferation of synthetic and partially natural citrus flavored drinks.

Weisenborn (13) completed a study in 1968 in which he estimated price-quantity relationships for major Florida orange products at the FOB level. These estimates provided the information necessary for the construction of net marginal revenue functions which were used to optimally allocate oranges among product markets for various size crops.

Priscott (9) carried Weisenborn's study of the export market a step further in a 1969 study of the European demand for processed citrus products. In general, the study indicated that the demand for citrus products in West Europe was elastic and showed development potential.

McClelland, Polopolus and Myers (3) used time series data to estimate the response of consumer sales to changes in generic advertising expenditures. These estimates were then used to allocate advertising funds. Information from the study provided the basis for specifying the influence of advertising on product demand in the economic model used in this study.

In a 1971 study, Hall (1) estimated consumer demand in retail grocery stores for frozen concentrated orange juice, chilled orange juice, canned single strength orange juice, and canned single strength grapefruit juice for ten geographic regions of the United States. The analysis indicated that consumer demand functions for these products differ by region.

Myers and Liverpool (5) in 1972 empirically estimated cross elasticities of demand for major orange juice products orange drinks and synthetic orange flavored beverages. From these estimates, the demand equations for frozen concentrated orange juice, chilled orange juice, and canned single strength orange juice in the retail market were developed.

Parvin (6) used yield estimates and standard regression techniques to estimate weather effects on early-midseason and Valencia orange production for eighteen Florida counties. These estimates provided a basis for the construction of a weather index for total Florida orange production.

The Model

A simplified flow diagram of the subsector is presented in Figure 1. Raw oranges move from the growing activity into the processing-packing sector where they are converted into processed orange products. From processed inventory, orange products move into wholesale or institutional inventories and eventually consumption. Dotted lines in the diagram represent information flows between various system components. Information may be in the form of order rates or prices. Associated with information flows are various delay factors. These delays represent the time lags required for information to move through the system. Information passed through the marketing system is the basis for management decisions.

Several allocation problems must be solved by the market mechanism. The rate at which fruit flows from the growing activity into the processing sector must be controlled. This control is recognized in Figure 1 by hourglass shaped symbols. The solid lines represent physical flows. Raw fruit must also be allocated among alternative products.

The allocation process as visualized in Figure 1 shows the processor-packer sector as a major decision point. Processor-packers receive information concerning inventory levels and the rates of flow of various products from inventory. If inventories are larger than desired or if the demand for a particular product changes, processors adjust FOB prices. These price signals pass through the marketing system and eventually affect consumption rates. As consumption rates change, signals are passed back through the system in the form of orders. Processors receive information on the adjusted movement from inventories and evaluate the effects of their pricing policies. If the ef-

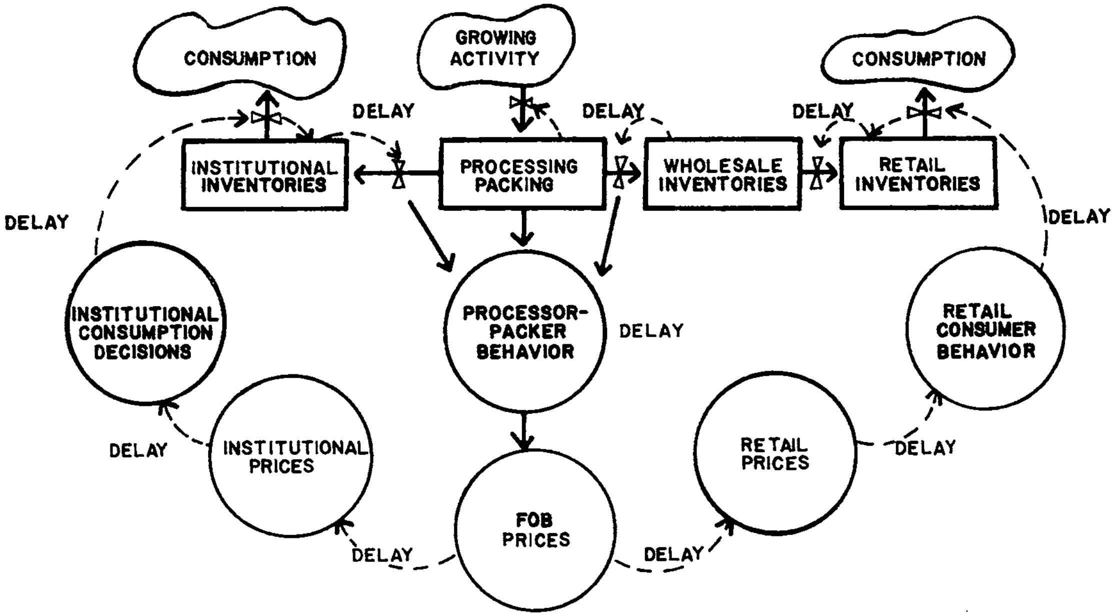

Fig. 1. Simplified flow diagram of the orange subsector.

fects of the pricing policy are not those desired, a new FOB price will be forthcoming. An equilibrium price will probably never result from this process. Consumers react to new prices over a period of time while decision makers are considering new pricing policies.

For a detailed flow diagram and verbal description of the industry see Powe (8). The industry description was translated into a mathematical simulation model.

The model was written in DYNAMO II simulation language (10) and consisted of over 300 equations (8, pp. 127-141). The equations can be grouped into ten interrelated sectors of the industry. These sectors were named: tree numbers, weather effects, crop size, grower profit, processor disappearance, advertising, FOB price, inventory and sales, retail and institutional price, and demand.

After the equations of the model were developed, the internal consistency of the model was examined. The model was then validated on the basis of its ability, when given empirical estimates of weather conditions, to reproduce the behavior of the orange subsector over the 1961-71 period. Theil's (12) inequality coefficients were used to measure the correspondence between simulated and empirical data. Calculated values of the coefficients ranged from .55 to .98 and indicated that predictions were better than those that would have been realized with the model $p_t = a_{t-1}$, where a_t and p_t represent actual and predicted values at time t.

After the model had been accepted as an adequate representation of the structure of the orange industry, a base simulation was made to establish a benchmark to compare the policies considered in the study. Comparable results for a variety of conditions were obtained by replicating each simulation with five randomly selected weather patterns. Simulations were started with initial values corresponding to conditions that existed at the beginning of the 1961-62 season and covered a twenty-five year period. Results were examined from the viewpoints of three major groups of industry participants: orange producers, handlers and consumers. The interests of these groups were evaluated on the basis of the present value and variance of grower profits, crop size and average FOB price, respectively. The utility of a particular group was assumed to be an increasing function of the level of its respective variable and a decreasing function of its variability. These measures along with estimated storage costs were computed from model output to evaluate alternative policies.

Simulated Policies and Results

Policy 1 prevented the establishment of new tree plantings whenever grower profits exceeded specified levels. Three levels were examined in the study—$1.25, $1.50 and $1.75 per box. In the simulations, the policy increased the present value of grower profits. It also reduced crop size and caused an increase in the prices paid by consumers. The associated changes in the variance of the performance variables were a reduction for growers, an increase for handlers and an increase for consumers. Consequently, restricted tree plantings during periods of high prices were beneficial from the viewpoint of orange producers but not from the viewpoints of handlers and consumers. Table 1 lists the direction of the change in performance variables for the alternative policies considered.

Policy 2 abandoned fully productive orange trees whenever calculated grower profits fell below two levels—$.15 or $.25 per box. The tree abandonment policy caused an increase in grower profits, reduction in crop size and an increase in consumer prices. However, in all cases the variability was decreased—a beneficial result from the viewpoint of all three groups. Whether this policy would be favored, however, would depend on how processors and consumers made trade-offs between the present value and variance of their respective performance variables. Because of our inability to measure these trade-offs and to make inter-group comparisons of well-being, there was no attempt to determine if the "gainers" from a particular policy could compensate the "losers."

Policies 3, 4 and 5, respectively, increased carry-overs from eight to sixteen weeks of average consumer demand, restricted adjustments in the FOB price and placed a floor on prices. Growers and handlers would benefit from increased expected values but experience greater variability. The gains from policies which increased end-of-year carry-over were offset by increased storage costs. Consumers would suffer in both cases.

Policy 6 limited increases in acreage whenever grower profits were above $1.50 per box and also placed a lower limit on prices. The small gains from this policy, when compared to the planting restriction alone, probably would not justify the administrative costs of the price floor.

Policy 7 altered the collection and expenditure of advertising funds (4). In the base model, advertising was funded by a constant tax per box of oranges. In the policy procedure, the tax per

Table 1. Direction of change in performance measures relative to base model.

	Growers		Handlers		Consumers	
Policy	Expected value	Variability	Expected value	Variability	Expected value	Variability
Restricted tree planting	+	+	-	-	-	-
Abandonment of productive trees	+	+	-	+	-	+
Increase in carry-over	+	-	+	-	-	
Price floor	+	-	+	-	-	+
Change in advertising budget	-	-	-	+	-	

[z]Plus sign indicates preferred direction. A reduction in variability would be shown as a plus. Negative sign indicates non-preferred direction. No entry indicates no change.

box increased with higher prices. The procedure also allowed a large proportion of advertising funds to be spent when there was a large crop to be sold. In addition, the policy increased the average amount spent on advertising by 66 percent. Given the advertising response functions in the model, the additional advertising was unprofitable. Thus, the policy was undesirable from the viewpoints of all three interest groups. No attempt was made in the study to determine the most profitable level of advertising or whether or not one of the procedures was preferable to the other. The poor results of the policy were associated with the level of advertising rather than the changed pattern of expenditure. Had the level of advertising been lower in the simulations, the performance of the policy would have improved.

In conclusion, the policies that reduced orange supplies caused substantially higher grower profits, lower storage costs and higher retail prices. They also reduced risks for orange producers, but not necessarily for other industry members. The alternative advertising proposal did not prove to be beneficial because of the advertising response functions in the model and the much higher level of advertising expenditure. Small gains from policies that failed to alter the long-run behavior of the subsector were partially or completely offset by increased storage costs. Consumers suffered by higher prices in all cases. The presence of conflicts of interests among industry groups dominated the policy analysis. In almost every instance, in order for one group to gain, another was placed in a less desirable position. Some of the policies simulated must be considered more realistic than others. However, the results provide insights in costs and returns and their distribution among industry members.

Plans are underway to update the basic equations of the model to reflect changes in the demand for the products and advertising policies. The model has potential usefulness in the continuing evaluation of alternative policies; since, as specific proposals develop in the orange industry, the model provides a means of studying their effectiveness and obtaining insights into potential problems. We plan to alter the model so that it can be utilized to simulate the behavior of the industry with a FCOJ reserve pool. Hopefully, the results will provide information on the effects of a pool on the interests of the growers, processors and distributors, and consumers.

Literature Cited

1. Hall, L. W. 1971. An Analysis of the U.S. Regional Demands and Marketing Costs for Selected Florida Processed Citrus Products. Master's thesis, University of Florida.
2. Jarmain, W. E. C. 1962. Dynamics of the Florida Frozen Orange Concentrate Industry. Master's thesis, Massachusetts Institute of Technology.
3. McClelland, E. L., Leo Polopolus and Lester H. Myers. 1971. Optimal Allocation of the Florida Citrus Industry's Generic Advertising Budget. *Univ. of Fla. Ag. Econ. Report* 20.
4. Myers, Lester H. 1969. *Proposal for Funding the State of Florida Department of Citrus.* Fla. Dept. of Citrus, Gainesville.
5. ———— and Leslie Liverpool. 1972. Demand Interrelationships Among Orange Beverages. *Fla. Dept. of Citrus ERD Report* 72-1.
6. Parvin, E. W., Jr. 1970. Effects of Weather on Orange Supplies. Ph.D. dissertation, Univ. of Fla.
7. Polopolus, Leo and W. E. Black. 1966. Synthetics and Substitutes and the Florida Citrus Industry. *Fla. Citrus Commission Report* No. FCC-ERD-66-4.
8. Powe, C. E. 1973. A Model for Evaluating Alternative Policy Decisions for the Florida Orange Subsector of the Food Industry. Ph.D. dissertation, Univ. of Fla.
9. Priscott, R. H. 1969. Demand for Citrus Products in the European Market. Master's thesis, Univ. of Fla.
10. Pugh, Alexander L., III. 1970. DYNAMO II User's Manual. Massachusetts Institute of Technology Press.
11. Raulerson, Richard C. 1967. A Study of Supply-Oriented Marketing Policies for Frozen Concentrated Orange Juice: An Application of Dynamo Simulation. Master's thesis, Univ. of Fla.
12. Theil, H. 1966. Applied Economic Forecasting. North Holland Publishing Co.
13. Weisenborn, D. E. 1968. Market Allocation of Florida Orange Production for Maximization of Net Revnue. Ph.D. dissertation, Univ. of Fla.