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OPTIMAL ALLOCATION OF FRESH GRAPEFRUIT ADVERTISING EXPENDITURE AMONG MARKETS: U.S., CANADA, AND REST OF THE WORLD

BY

Mark G. Brown

Jonq-Ying Lee

Senior Research Economists

FLORIDA DEPARTMENT OF CITRUS
Economic and Market Research Department
P.O. Box 110249
Gainesville, Florida 32611-2049 USA
Phone: 352-392-1874
Fax: 352-392-8634
Email: mgbrown@ufl.edu

www.floridajuice.com

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Executive Summary

We have made some estimates to help determine the optimal allocation of FDOC fresh grapefruit (GF) advertising expenditures among the U.S., Canada, and the rest of the world (ROW). Our criterion for making the estimates was maximization of total FOB revenue for fresh Florida GF.

The optimal allocation depends on the market sizes, prices in each market, and impacts of FDOC advertising on quantity sales in each market. Larger markets, all else equal, would receive more FDOC advertising dollars; likewise, higher price markets would receive more dollars, and markets where advertising has relatively large impacts would receive more dollars.

A simple solution when advertising works equally well in each market would be to allocate the advertising dollars according to the FOB revenue share for each market (market sizes and market prices are then the determining factors for the allocation). The average revenue shares for the past 5 seasons (1989-90 through 1993-94) are 41% for the U.S., 9% for Canada and 50% for the ROW. If advertising is equally effective across markets, these revenue shares suggest that the FDOC fresh GF budget be split 41% to the U.S., 9% to Canada, and 50% to the ROW. Instead of using the five-year averages, the revenue shares for the last season (1993-94) might be used, in which, the budget would be split 34% to the U.S., 7% to Canada, and 59% to the ROW.

Preliminary regression analysis suggests that the impact of FDOC fresh GF advertising on volume sales is greatest in the ROW, with the impact in U.S. being the next largest and Canada having the smallest impact. When these impacts are factored into our optimization scheme, the allocation of advertising dollars is 18% to the U.S., 1% to Canada, and 81% to the ROW.

Based on the above, our best guess is about 20% to 30% to the U.S., 5% to 9% to Canada, and 60% to 70% for the ROW.

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Firms, commodity groups and even countries, that advertise and promote a specific good, face the budgeting problem of how to allocate a given advertising budget for the good in question among alternative markets in the world. The amount of advertising expenditure allocated to a market has an opportunity cost, knowledge of which allows determination of the most profitable budget allocation among alternative markets competing for the limited budget (this is similar to the problem that a store has in allocating shelf space among products, as discussed by Cairns and Cox). Factors to consider in determining the optimal advertising expenditure allocation include the good's per unit profit in each market and the market demand levels which, in turn, can expected to be dependent on such factors as prices, consumer income and preferences. Preferences, in turn, may be related to such factors as advertising and demographic variables.

In this paper, we examine allocation of Florida Department of Citrus (FDOC) advertising expenditure for fresh grapefruit (GF) among the U.S., Canada and the rest of the world (ROW). The paper proceeds by examining more closely the advertising budget allocation problem using a simple mathematical model based on the objective of maximizing revenue. Then an empirical study of the FDOC GF advertising expenditure allocation among markets is made to illustrate how the model works.

Model

A revenue maximization model is used to reveal the basic aspects of the advertising expenditure allocation problem. The problem is to allocate a limited amount of advertising

expenditure among markets such that total revenue from the markets is maximized. Let A, a_i, p_i, q_i, and x_i be the total fixed advertising budget; advertising expenditure allocated to market i; price of the product in question in market i; quantity demanded of the product in market i; and a vector containing demand factors such as prices of goods (including the price of the good in question) and consumer income for market i; respectively. The maximization problem can then be written

(1) maximize $V = p'q$, subject to $A = l'a$,

where $p' = (p_1, \ldots, p_n)$, $q' = (q_1, \ldots, q_n)$, l is a nx1 unit vector, $a' = (a_1, \ldots, a_n)$, and n is the number of markets. Prices are assumed to be fixed by competitive forces. The demands for products can further be written as functions of x, i.e., $q_i = f(x_i, a_i)$. Additional constraints such as lower and upper bounds and/or nonnegativity on a_i might also be included in specifying problem (1) (e.g., see Corstjens and Doyle for the similar shelf space allocation problem).

The Lagrangian for (1) can be written as $L = p'q + \lambda(A - l'a)$, where λ is the Lagrangian multiplier, and the first order conditions are

(2a) $dL/da_i = p_i * dq_i/da_i - \lambda = 0, \qquad i = 1, \ldots, n.$

(2b) $dL/d\lambda = A - l'a = 0,$

where, in general, dy/dz is the partial derivative of y with respect z.

In this study, market demands are approximated by the double log function $q_i = m_i * a_i^{e_i}$, where e_i is the elasticity of demand for the product in question in market i with respect to advertising expenditure allocated to the market, and m_i is a function of x_i. In this case, (2a) can be written, after multiplying both sides by a_i as

(3) $B_i = \lambda * a_i$,

where $B_i = p_i * q_i * e_i$.

Summing (3) over i, the solution for the Lagrangian multiplier can be written as

(4a) $1'B = \lambda * 1'a$,

or

(4b) $\lambda = 1'B/A$,

where $B = (B_1, \ldots, B_n)$ and we have used the constraint $A = 1'a$. One can show that λ is marginal profit obtained by relaxing the advertising expenditure constraint by a unit.

Substituting (4b) into first-order conditions (3), the solution for a_i can be written as

(5) $a_i/A = B_i/1'B$.

Solution (5) indicates that the share of advertising budget A allocated to market i is that market's share contribution to the revenue term $1'B$. The term B_i can be interpreted as revenue resulting from changing product i's allocation of shelf space from zero to a_i, i.e., $B_i = p_i * q_i * e_i$ or $B_i = p_i * (dq_i/da_i) * a_i$, and $1'B$ is the overall profit of advertising A.

Solution (5) is not in reduced form as the a_is are embedded in the q_is on the right side of the solution. To obtain an explicit closed-form solution, further structure needs to be given to the problem. For example, suppose advertising is equally effective across markets such that all e_i are the same, i.e., $e = e_i$. In this case, the advertising allocation solution can be written as $a_i/A = p_i * q_i/(\Sigma_i p_i * q_i)$ or the share of the advertising budget going to market i equals the share of dollar business (across markets) accounted for by market i (this solution is still not in reduced form but a closed-form solution exists; e.g., see Brown and Lee). We assume that the advertising elasticities are in the zero-one interval ($0 < e$

< 1), assuring that the second order conditions are meet.

Although not in reduced form, (5) can be used to find a solution for a_i, using some iterative procedure (we assume the advertising elasticities are in the zero-one interval --- 0 < e_i < 1 --- assuring that the second order conditions are meet). For example, initial values for the a_is can be substituted into the right-hand-side of (5) to obtain updated a_is which can then be substituted into (5) to obtain further updates. This procedure can be repeated until convergence is achieved, i.e., the values of a_i are the same on both sides of (5).

Application

Fresh grapefruit shipment information was provided by the Florida Agricultural Statistical Services; the FOB prices for fresh grapefruit shipped to U.S. domestic markets were obtained from the Citrus Administrative Committee; average export prices were from the U.S. Department of Commerce (see Table 1); and FDOC fresh grapefruit consumer advertising expenditures were obtained from the FDOC annual financial reports (see Table 2). Exchange rates were obtained from the International Monetary Fund. The data cover the period from the 1978-79 through 1993-94 seasons.

For each market, a demand equation, relating fresh GF shipments to the FDOC fresh GF advertising expenditure level for the market, the market price for fresh GF, and a time trend, was estimated by ordinary least squares. The ordinary least squares method was used to select the functional form of the demand function for each market or destination. Based on t-statistics and goodness of fit, semi-log functions were used in the final estimation; i.e.,

(6) $$q_{ust} = \alpha_1 + \beta_{11} \log p_{ust} + \beta_{12} \log Ad_{ust} + \beta_{13} \log t + \epsilon_{1t};$$

$$q_{ct} = \alpha_2 + \beta_{21} p_{ct} + \beta_{22} \log Ad_{ct} + \beta_{23} t + \epsilon_{2t};$$

$$\log q_{ot} = \alpha_3 + \beta_{31} p_{ot} + \beta_{32} Ad_{ot} + \epsilon_{3t};$$

where

q_{it} = total fresh grapefruit shipped to destination i during season t;

p_{it} = average FOB or export price for fresh grapefruit shipped to destination i during season t;

Ad_{it} = FDOC fresh grapefruit consumer advertising expenditures in market i during season t;

t = a time trend variable, t=1 for the season 1977-78, and so on;

ϵ_{it} = disturbance term for market i and season t;

subscripts us, c, and o denote U.S. domestic market, Canadian market, and other offshore markets (e.g., Asian and European markets), respectively; and αs and βs are parameters to be estimated. Results are presented in Table 3.

For determining the optimal allocation of the FDOC fresh GF advertising budget, we focus on the (market specific) coefficient estimates for FDOC advertising. These coefficient estimates were used to derive corresponding market-specific advertising elasticity estimates (at sample means), i.e., the e_is in equations (3) through (5) in the model section. The largest advertising elasticity estimate was for the ROW at 0.33, with the U.S. having the next largest estimate at 0.19 and Canada having the smallest at 0.03.

The advertising elasticity estimates derived above were used to solve equation (5) to further estimate the optimal allocation of the FDOC advertising budget for 1993-94 and the average budget for the past five seasons. Factors other than advertising were keep at historic levels. The solution to (5) for the 1993-94 season indicates that optimal advertising

budget shares for maximizing FOB fresh GF revenue would be 16% for the U.S., 1% for Canada and 83% for the ROW. As mentioned above, if advertising is equally effective across markets, the advertising budget share for each market is the same as its share of dollar business or revenue share. Market FOB revenues and revenue shares are shown Table 4. The average revenue shares for the past 5 seasons (1989-90 through 1993-94) are 41% for the U.S., 9% for Canada and 50% for the ROW. If advertising is equally effective across markets and past budget allocations were optimal, these revenue shares suggest that the FDOC fresh GF budget be split 41% to the U.S., 9% to Canada, and 50% to the ROW. Instead of using the five-year averages, the revenue shares for the last season (1993-94) might be used. In this case, the advertising budget in 1993-94 would be split 34% to the U.S., 7% to Canada and 59% to the ROW. Based on the above, our best guess is about 20% to 30% to the U.S., 5% to 9% to Canada, and 60% to 70% for the ROW.

Table 1. Historical shipment and prices

Season	U.S.	Canada	Other	Total	U.S.	Canada	Other
		Shipment (1,000 cartons)				Price ($/carton)	
1978-79	24,301	2,999	10,523	37,823	3.77	5.01	5.91
1979-80	23,383	3,182	9,950	36,515	4.31	5.44	6.75
1980-81	19,318	2,767	10,238	32,323	4.89	6.83	7.21
1981-82	18,887	2,840	9,932	31,659	4.53	7.06	7.52
1982-83	22,212	2,863	9,543	34,618	4.38	7.00	7.31
1983-84	18,236	2,609	9,694	30,539	4.83	7.62	7.12
1984-85	21,325	2,646	5,657	29,628	5.65	8.35	8.27
1985-86	24,469	3,144	11,079	38,692	5.49	9.24	8.85
1986-87	22,764	2,940	15,472	41,176	6.11	8.21	8.92
1987-88	21,339	3,191	20,668	45,198	6.26	8.47	9.43
1988-89	19,482	3,313	23,568	46,363	5.73	9.74	9.35
1989-90	14,290	2,178	9,241	25,709	7.56	11.08	10.72
1990-91	23,469	3,616	19,352	46,437	8.28	9.26	11.66
1991-92	22,244	2,982	18,637	43,863	7.50	10.42	10.62
1992-93	22,903	3,809	17,482	44,194	5.80	9.59	9.64
1993-94	19,455	3,206	20,365	43,026	5.90	7.98	9.87
		Quantity Share (%)				Price Ratio (%)	
1978-79	64.25	7.93	27.82	100.00	100.00	132.98	156.86
1979-80	64.04	8.71	27.25	100.00	100.00	126.11	156.48
1980-81	59.77	8.56	31.67	100.00	100.00	139.59	147.36
1981-82	59.66	8.97	31.37	100.00	100.00	155.87	166.02
1982-83	64.16	8.27	27.57	100.00	100.00	159.71	166.79
1983-84	59.71	8.54	31.74	100.00	100.00	157.75	147.40
1984-85	71.98	8.93	19.09	100.00	100.00	147.72	146.31
1985-86	63.24	8.13	28.63	100.00	100.00	168.35	161.25
1986-87	55.28	7.14	37.58	100.00	100.00	134.40	146.02
1987-88	47.21	7.06	45.73	100.00	100.00	135.36	150.71
1988-89	42.02	7.15	50.83	100.00	100.00	170.08	163.27
1989-90	55.58	8.47	35.94	100.00	100.00	146.65	141.89
1990-91	50.54	7.79	41.67	100.00	100.00	111.86	140.86
1991-92	50.71	6.80	42.49	100.00	100.00	138.90	141.57
1992-93	51.82	8.62	39.56	100.00	100.00	165.44	166.30
1993-94	45.22	7.45	47.33	100.00	100.00	135.34	167.39
Average (90-94)	50.78	7.83	41.40	100.00	100.00	139.64	151.60

Table 2. Florida fresh grapefruit advertising expenditures

	US	Canada	Other
		dollars	
1977-78	924,100	72,796	316,859
1978-79	944,621	78,095	241,972
1979-80	1,134,482	97,040	431,165
1980-81	1,312,007	72,123	684,793
1981-82	1,235,007	56,276	575,015
1982-83	1,805,029	60,276	868,104
1983-84	2,487,110	35,314	880,201
1984-85	3,311,705	141,922	1,094,987
1985-86	5,862,059	213,976	5,318,956
1986-87	3,987,091	262,025	5,849,342
1987-88	2,863,165	327,545	7,238,470
1988-89	6,563,170	378,000	9,888,750
1989-90	2,737,145	177,447	4,978,048
1990-91	5,109,286	53,360	10,164,101
1991-92	4,281,623	434,115	7,532,819
1992-93	4,539,444	110,799	5,747,421
1993-94	2,558,110	103,224	5,816,601
Average	3,038,538	157,314	3,978,094

Source: FDOC *Annual Financial Report*, selected issues.

Table 3. Demand parameter estimates for equation (1)

Variable	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|	Demand Elasticity
		U.S. Domestic Shipment (q_{us})			
Intercept	808.12	13,298.00	0.0610	0.9525	
log p_{us}	-1,613.90	5,663.24	-0.2850	0.7805	-0.0764
log Ad_{us}	3,858.86	1,936.87	1.9920	0.0696	0.1826
log t	-3,531.89	2,420.90	-1.4590	0.1703	-0.1672
R-Square	0.2828				
Adj R-SQ	0.1035				
		Shipments to Canada (q_c)			
Intercept	4,268.03	1,146.82	3.7220	0.0029	
log p_c	-863.97	625.95	-1.3800	0.1927	-0.2863
log Ad_c	33.22	150.26	0.2210	0.8287	0.0110
log t	58.98	28.83	2.0460	0.0633	0.0195
R-Square	0.2626				
Adj R-SQ	0.0782				
		Shipments to Offshore Markets (log q_o)			
Intercept	10.4302	0.3042	34.2830	0.0001	
p_o	-0.0008	0.0002	-4.6340	0.0005	-1.2389
Ad_o	4.58000e-07	1.14000e-07	4.0290	0.0014	0.2695
R-Square	0.8306				
Adj R-SQ	0.8045				

Table 4. Historical fresh grapefruit on-tree revenues

Season	U.S.	Canada	Other	Total
		Revenue ($1,000)		
1978-79	91,557	15,025	62,191	168,773
1979-80	100,868	17,310	67,163	185,341
1980-81	94,518	18,899	73,816	187,232
1981-82	85,548	20,050	74,689	180,288
1982-83	97,352	20,041	69,759	187,152
1983-84	88,088	19,881	69,021	176,990
1984-85	120,538	22,094	46,783	189,415
1985-86	134,299	29,051	98,049	261,399
1986-87	139,057	24,137	138,010	301,205
1987-88	133,522	27,028	194,899	355,449
1988-89	111,565	32,269	220,361	364,194
1989-90	107,966	24,132	99,064	231,162
1990-91	194,274	33,484	225,644	453,403
1991-92	166,866	31,072	197,925	395,863
1992-93	132,765	36,528	168,526	337,820
1993-94	114,712	25,584	201,003	341,299
		Revenue Share (% of Total Revenue)		
1978-79	54.25	8.90	36.85	
1979-80	54.42	9.34	36.24	
1980-81	50.48	10.09	39.42	
1981-82	47.45	11.12	41.43	
1982-83	52.02	10.71	37.27	
1983-84	49.77	11.23	39.00	
1984-85	63.64	11.66	24.70	
1985-86	51.38	11.11	37.51	
1986-87	46.17	8.01	45.82	
1987-88	37.56	7.60	54.83	
1988-89	30.63	8.86	60.51	
1989-90	46.71	10.44	42.85	
1990-91	42.85	7.39	49.77	
1991-92	42.15	7.85	50.00	
1992-93	39.30	10.81	49.89	
1993-94	33.61	7.50	58.89	
Average (90-94)	40.92	8.80	50.28	

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