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A STUDY OF THE IMPACT OF GRAPEFRUIT-DRUG INTERACTION ON THE DEMAND FOR GRAPEFRUIT JUICE

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The discovery that grapefruit can affect the metabolism of certain medicines came about, like many medical findings, largely by accident. A team of researchers at the University of Western Ontario in Canada wanted to find out whether the blood pressure medicine felodipine (Plendil) would interact with alcohol. Canadian researchers used grapefruit juice to hide the taste of alcohol in a drug interaction study. They found that after taking the tablets, the subjects became dizzy, flushed, and experienced a rapid heartbeat, regardless of whether they had drunk plain or spiked grapefruit juice. Blood levels of felodipine, which affects the cardiovascular system, turned out to be much higher than expected. Taking the tablets with water produced no such side effects. In a report in The Medical Post, David Bailey, one of the Ontario researchers said when grapefruit juice was given with a blood pressure drug, one tablet was equal to three tablets taken with water. One of the very first newspaper headlines on grapefruit-drug interaction appeared in the Toronto Star in May 5, 1990 (Lexis-Nexis).

Over the past decade, researchers have discovered a list of medications that are affected by grapefruit. They include the cholesterol-lowering drugs Lipitor (atorvastatin), Mevacor (lovastatin) and Zocor (simvastatin); the anti-anxiety medicine BuSpar (buspirone); the heartburn drug Propulsid (cisapride); antihistamines Seldane (since withdrawn from the market because of interaction deaths) and Hismanal (astemizole), and the epilepsy medication Tegretol (carbamazepine). Caffeine and estrogen are also affected. Grapefruit juice raises blood levels of all these compounds, although the drug company researchers and physicians may not agree that the increases are important.

Grapefruit Juice Consumption

Figure 1 shows the sales of grapefruit juice (GJ) and their corresponding retail prices for the period from July 1996 through July 2001. As shown in Figure 1, the demand for GJ started to decrease in the beginning of 1999, while at about the same time GJ retail price increased and news of drug interaction problems with grapefruit became more widespread.

In this study, per capita consumption of GJ is empirically related to economic factors and grapefruit-drug interaction information. GJ per capita consumption in this study is an average of consumption patterns over millions of consumers, based on ACNielsen data on purchases in retail stores with sales of more than $2 million per year, super centers, mass merchandisers, and drug stores.

Grapefruit-drug interaction information can be found in medical journals, newspapers, magazines, television, radio, and Internet, etc. However, it is difficult to compile a complete history of all grapefruit-drug interaction stories released through all media. The Lexis-Nexis Academic Universe provides headline contents for major US newspapers, and this study will use the number of major newspaper headlines on grapefruit-drug interaction from the Lexis-Nexis Academic Universe as a proxy to measure the intensity of this drug interaction publicity. Table 1 shows the number of major US newspaper headlines on grapefruit-drug interaction based on the Lexis-Nexis reports. As shown in Table 1, the number of grapefruit-drug interaction headlines increased from 1 in 1991 to 55 in 1998 and then decreased to 11 in 2001 (January 1, 2001 through July 25, 2001). Note that 30 of the 55 headlines in 1998 appeared in November.

This increased publicity of grapefruit-drug interactions coincides with the beginning of a declining (increasing) trend in GJ volume sales (retail price) in early 1999 (see Figure 1). It should be noted that major newspaper headlines accounted for only a portion of the total number of grapefruit-drug interaction reports by all media, and reports delivered by television, radio and other media may also be important for understanding the declining GJ sales.

Models and Analysis

It is assumed in this study that changes in per capita GJ consumption can be explained by changes in traditional demand factors and the release of information on grapefruit-drug interaction. Traditional demand factors studied include the price of GJ, the prices of GJ substitutes and/or complements and personal disposable income. In addition, there may be a time trend in per capita consumption of GJ due to changes in population composition and preferences. Formally, the relationship between per capita GJ consumption and these influencing factors can be expressed in double log form as

$$(1) \qquad \log q_t = \beta_0 + \beta_1 \log p_t + \beta_2 \log p_{st} + \beta_3 \log p_{ot} + \beta_4 \log inc_t + \beta_5 drug_t + \beta_6 t + u_t;$$

where subscript t indicates the time period of the observation (four weekly), q_t is the per capita consumption of GJ, p_t is the average GJ price, p_{st} is the average orange juice (OJ) price, p_{ot} is the average price of all other commodities, inc_t is the per capita disposable income, $drug_t$ is the number of US newspaper headlines pertaining to grapefruit-drug interaction, the β's are parameters to be estimated, and u_t is the disturbance term. The consumer price index (CPI) was used as a proxy for p_{ot} in equation (1).

Using the homogeneity restrictions, equation (1) can be rewritten as

(2) $\log q_t = \beta_0 + \beta_1 \log p_t^* + \beta_2 \log p_{st}^* + \beta_4 \log inc_t^* + \beta_5 drug_t + \beta_6 t + u_t;$

where $p_t^* = p_t/p_{ot}$, $p_{st}^* = p_{st}/p_{ot}$, and $inc_t^* = inc_t/p_{ot}$.

As shown in Figure 1, GJ consumption has demonstrated a seasonal pattern, i.e., consumption of GJ tends to peak between January and March, and bottom out in December of each year. In order to eliminate this seasonal pattern, the following logarithmic difference[1] transformation of equation (2) was used:

(3) $$Dq_t = \beta_6^* + \beta_1 Dp_t^* + \beta_2 Dp_{st}^* + \beta_4 Dinc_t^* + \beta_5 Ddrug_t + u_t^*;$$

where $Dx_t = \log(x_t/x_{t-13})$, with x representing each variable in (2) except the grapefruit-drug interaction variable. Since there are several zero values for the grapefruit-drug interaction variable, only the linear difference was used to derived the Ddrug variable in (3), i.e., $Ddrug = drug_t - drug_{t-13}$. Note that in the logarithmic difference model (3), parameter β_6^* ($= 13\beta_6$) is the time trend in GJ consumption and β_1, β_2, and β_4 are demand elasticities. The least-squares estimation results are presented in Table 2.

The results for (3) show that there was an insignificant negative time trend in GJ consumption. The own-price elasticity of GJ is –3.952, an indication that the demand for GJ is highly price elastic; i.e., a one percent increase in real price would decrease the demand for GJ by almost four percent. The cross-price elasticity between OJ and GJ is 1.780, an indication that GJ is a close substitute of OJ. The income elasticity estimate of GJ equals 2.257, i.e., a one percent increase in real income would increase per capita

[1] A linear difference model was also examined but did not fit the data as well as the logarithmic difference specification, based on the coefficient of determination.

demand for GJ by more than two percent. The coefficient estimate for the grapefruit-drug interaction variable is statistically not different from zero. The failure to find a significant impact of newspaper reports on the demand for GJ is not completely a surprise. This is because newspaper reports accounted for, perhaps, only a small portion of the total reports by all media, and growth in consumer knowledge of the grapefruit-drug interaction problem may have been correlated to some degree to the rising GJ price trend, reducing the precision of the parameter estimates. The possibility that the grapefruit-drug interaction problem may be influencing the price elasticity estimates is suggested by a comparison of the results in Table 2 with those in previous studies (Table 3)---the own-price elasticity, as well as the income elasticity, estimated in this study are much higher than those found in previous studies. It may be that the increase in knowledge about the grapefruit-drug interaction problem is affecting all parameters in model (3), a possibility that can be further examined with the present data.

A closer examination of the number of grapefruit-drug interaction news headlines reveals that there were 30 headlines in November 1998, and November 1998 marked the beginning of an increasing trend in the GJ retail price. Therefore, we suspect that these highly visible reports may have changed consumers' demand responses to price and other variables. The regression method used to study these changes is described below.

In this application, we divide the sample period into two sub-periods, the first sub-sample covers the period from August 1996 through November 1998 (18 observations after differencing) and the second sub-sample covers the period from December 1998 through July 2001 (34 observations). Consider the model

$$(4) \qquad \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} + \begin{bmatrix} U_1 \\ U_2 \end{bmatrix}$$

where Y_1 and Y_2 are vectors containing values of Dq_t in the first and second sub-samples, respectively; X_1 and X_2 are associated matrices containing the same explanatory variables as in equation (3) except the insignificant variable $Ddrug_t$, α_1 and α_2 are corresponding parameter vectors, and U_1 and U_2 are the error vectors. Model (4) is viewed as an unrestricted model with the parameter vectors for the two sub-samples allowed to be different.

The restricted model can be written as

$$(5) \qquad \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} X_2 \\ X_1 \end{bmatrix} \alpha + \begin{bmatrix} U_1 \\ U_2 \end{bmatrix}.$$

Models (4) and (5) can be used to test the hypothesis H_0: $\alpha_1 = \alpha_2$. The test statistic is

$$(6) \qquad \frac{(A-B)/k}{B/(n_1+n_2-2k)} = F(k, n_1+n_2-2k),$$

where A is the sum of squares from restricted model (5); B is the sum of squares from unrestricted model (4); and the degrees of freedom associated with A and B are $n_1 + n_2 - k$ and $n_1 + n_2 - 2k$, respectively (Chow; p. 61).

The estimates of unrestricted model (4) are shown in Table 4. The hypothesis H_0: $\alpha_1 = \alpha_2$ is rejected at any reasonable level of significance. In other words, the demand parameters after November 1998 (time period 2) are different from those found before November 1998 (time period 1). The own-price elasticity estimate of GJ for time period

1 is –2.26, which is a little higher in absolute value than those found in previous studies. However, the own-price elasticity of GJ for time period 2 is –3.83, which is more than double the estimates found in previous studies (see Table 3). Results also show that there was a negative time trend during time period 1 and a very high income GJ-demand response; however, both time trend and income GJ-demand response disappeared in time period 2. In addition, results show that OJ is a substitute for GJ in both time periods.

Table 5 shows the volume index for GJ consumers by income group. The volume index is calculated by dividing the average GJ consumption of a specific income group by the average GJ consumption of the panel. The volume indices shown in Table 5 indicate that GJ consumption for consumers who had more than $70,000 annual income was 38 percent higher than the average GJ consumer. One of the possible explanations of the structural change in GJ demand is that publicity of grapefruit-drug interaction made GJ consumers, especially those who belong to high income groups, more sensitive to price changes and less sensitive to income changes.

The analysis of this study does not rule out the possibility that omission of a complete measure(s) of the spread of knowledge on grapefruit-drug interaction from the models may be impacting the parameter estimates. For example, spread of knowledge on grapefruit-drug interaction may be correlated with the increasing GJ prices over the sample, and the estimated GJ price elasticity may be reflecting both price and drug-interaction effects (for the explanatory variables analyzed, there does not appear to be a multicollinearity problem, based on relatively low simple correlations between individual regressors and the eigen values for the full set of regressors). Future observations on downward GJ-price changes along with a continued spread of knowledge on grapefruit-

drug interaction may allow more precise identification of the price and other explanatory variable effects. Since the end of 1998, GJ price increases have not abated, and recent GJ price decreases at the FOB level need to be passed on to the retail level to be able to address this issue.

Conclusions

GJ sales have been declining in recent years, and, based on analysis of retail sales of GJ, there appears to be a structural change in the consumer demand for GJ. The change in demand may be due to publicity on drug-interaction problems related to GJ. Our estimates suggest that the own-price elasticity of GJ demand has nearly doubled, while the income elasticity may have fallen to near zero. However, the possibility that the elasticity estimates may be picking up some of the drug-interaction effect cannot be ruled out, since GJ prices tended to increase over the period studied while knowledge on GJ drug interaction was likely becoming more widespread. Future observations on how consumers respond to sustained declines in GJ prices may provide an answer to this issue.

Table 1. The number of newspaper grapefruit-drug interaction reports

Month	Number of Newspaper Reports										
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
January										1	1
February				2		1	2	9	4	1	3
March									2		1
April	1			2		1	1		2		
May						1	3	6	2		2
June					2		1		1		3
July					1						1
August						5		5			
September					2	4	1		1	3	
October					1		5	3			
November					3		1	30	1	1	
December					3		4	2			
TOTAL	**1**	**0**	**0**	**4**	**12**	**12**	**18**	**55**	**13**	**6**	**11**

Source: Lexis-Nexis Academic Universe, US newspaper headline and lead paragraph(s) of articles.

Table 2. Parameter estimates

Variable	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
		For Model (3)		
Time Trend	-0.032	0.021	-1.504	0.139
OJ Price	1.780*	0.164	10.866	0.000
GJ Price	-3.952*	0.286	-13.818	0.000
Income	2.257*	0.659	3.424	0.001
Drug	0.000	0.001	0.244	0.808
Adj. R^2	0.9010			

*Statistically different from zero at $\alpha = 0.05$ level.

Table 3. GJ elasticity estimates in previous studies

Study	Elasticity Estimate	
	Own-Price	Income
Brown, Behr, and Lee (1994)	-1.6060	1.0570
Brown, Lee, and Seale, Jr. (1994)	-1.8791	1.0070
Brown and Lee (1993)	-1.294 to –1.529	1.010 to 0.919

Table 4. Parameter estimates for (4)[a]

Variable	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
		Before December 1998		
Time Trend (1)	-0.2379*	0.0798	-2.981	0.0047
OJ Price (1)	1.9183*	0.6001	3.197	0.0026
GJ Price (1)	-2.2609*	1.0584	-2.136	0.0383
Income (1)	8.6463*	2.2045	3.922	0.0003
		After November 1998		
Time Trend (2)	-0.0183	0.01952	-0.937	0.3539
OJ Price (2)	1.8345*	0.18538	9.896	0.0001
GJ Price (2)	-3.8274*	0.4984	-7.679	0.0001
Income (2)	1.1704	1.2984	0.901	0.3723

*Statistically different from zero at $\alpha = 0.05$ level.
[a]Test statistic (5) has a value of 14.26 and the table value of $F(4,44) = 3.78$ at $\alpha = .01$ level.

Table 5. GJ purchase volume index and distributions (10/31/99 – 10/28/00)

Income Group	Eq Volume Index	Distribution of Volume	Distribution of Buyers
Total Panel	100		
Under $20,000	65	14.0	17.4
$20,000 - $29,999	95	18.1	17.5
$30,000 - $39,999	114	15.2	12.6
$40,000 - $49,999	105	12.1	12.3
$50,000 - $69,999	96	16.1	17.9
$70,000 +	138	24.5	22.3

Source: ACNielsen

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Lexis-Nexis Academic Universe, http://web.lexis-nexis.com/universe.

Figure 1 GJ Gallon Sales VS Retail Price