Changes in the U.S. Demand for Sugar and Implications for Import Policies

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The thrust of this paper is to identify and measure structural changes in the U.S. demand for sugar and to derive subsequent implications for import restriction policies. Empirical results indicate that changes in consumer preferences and the availability of closer and cheaper sweeteners in food processing, especially high fructose corn syrup (MFCS), are exerting a downward pressure on sugar demand. As the U.S. demand for sugar decreases and the food industry adjusts fasterto sweetener choices, the U.S. government would have to impose more restrictive import barriers to maintain prices to domestic sugar and HFCS producers. Furthermore, the welfare impact of U.S. sugar policy options on domestic consumers and food processors will be lessened.

Introduction

Government intervention in the marketplace conditions the choices of producers, consumers, and other market participants, through the mandating of price or supply-control policies. Policies which support domestic industry are ultimately paid for by the consumers in the form of higher prices. In the U.S., these policies cut across many agricultural commodities such as price support for grains; marketing order for milk, fruits and vegetables; and import restrictions on beef, cheese, and sugar. However, the impact of policies that fail to incorporate demand-side dynamics when domestic industry is supported may be highly sensitive to the changing nature of the industry. Failure to incorporate these changes may yield results that are less desirable than the objectives established by policy makers. Artificially elevated prices may stimulate the use and development of substitutes. Changes in consumers' tastes and preferences modify the effectiveness of government programs by shifting demand. The speed and ability to adjust and respond to changes in economic conditions and policies partially determine the welfare impact of policies on consumers and commodity users.

The purpose of this paper is to develop and estimate a demand model for sugar and then to derive implications for sugar import policies given the dynamics and substitutes involved on the demand side. Some novel features of the demand model ware not addressed by previous sugar demand studies (George and King, Gemmill, Young, Carman, Hassan and Johnson). These include the estimation of separate demand functions for industrial and nonindustrial sectors, comparison of periods before and after the introduction of high fructose corn syrup in industrial uses, and the incorporation of partial adjustment and the subsequent ability to measure the speed of demand adjustment.

Demand for sugar is an obvious and important component of the structure of the sweetener market. Since the demand for food commodities is, generally speaking, inelastic and the production of food commodities somewhat variable, accurate estimates of demand parameters are important inputs in the development of national price support programs, trade, and production control policies (Hassan and Johnson).

For many years the U.S. sugar industry was protected from serious competition despite the high sugar prices that were maintained primarily through important restrictions. During the past decade, however, inexpensive domestic substitutes have emerged in the food industry such as high fructose corn syrup (HFCS) introduced in the 1970s and Nutrasweet intro-

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The authors are grateful to Kay Sachtler, **Thomas Spreen,** and two anonymous **referees,** for helpful comments **on** an **earlier** draft.

New Jersey Agricultural Experiment Station, Publication No. D-02121-1-85, supported by State and U.S. Hatch Act funds.

iuced in the 1980s. Furthermore, ongoing changes in consumer preferences toward less caloric foods undoubtedly affect purchases of sugar and processed foods containing sugar. These developments have important implications for domestic and foreign sugar producers who export sugar to the U.S. consumers and food industry, and the effectiveness of the U.S. sugar policy. The U.S. imports 45 percent of its sugar needs which accounts for 25 percent of the world sugar trade.

Table 1 summarizes per capita consumption and market share trends for various sweeteners in the U.S. Between 1971 and 1983, the market share of sugar fell from 79 to 53 percent while the market share of HFCS increased from 0.7 to 30 percent. Consumption of other sweeteners, except for noncaloric, have remained fairly stable. Furthermore, the combined per capita consumption of sugar and HFCS declined slightly from 103 pounds in 1971 to 102 pounds in 1983, suggesting an approximate one-to-one substitution and no growth in combined use. Given the importance of these changes in policy analysis, it seems appropriate that an updated demand structure be estimated.

Empirical Models

The demand for sugar faced by primary suppliers is extremely complex because sugar is required for the manufacture of many products and for direct consumption. The primary sugar buyers can be broken down into two groups: industrial users (food industry), and nonindustrial users (restaurants, institutions, retailers, wholesalers, jobbers and dealers).

First, the demand by food processors is discussed. Production theory suggests that food processors use the combination of inputs that maximizes their net returns. Profit maximization conditions imply that the quantity of sugar used by food processors depends inversely on the price of sugar and the price of complements (energy, labor, etc.) and directly on the price of the processed product and price of substitutes (HFCS, noncaloric sweeteners). As important, given inflexibilities in the short run due to technological constraints, cost, managerial adjustment and time required to develop new recipes that reflect changing economic conditions, it seems appropriate to also develop an analysis of partial adjustment behavior.

The empirical model for sugar demand by the food processing sector is expressed as follows:

$$(1)\quad Q^*_t = \alpha_0 + \alpha_1 P_t + \Sigma\alpha_{2i} W_{it} + \Sigma\alpha_{3j} Z_{jt} + e_t,$$

where Q^*_t is the desired sugar use in industrial sector in period t; W_{tt} is a vector containing the price of finished product and the price of other inputs; Z_{Jt} is a vector denoting oth-

Table 1. Per Capita Consumption and Market Shares of Alternative Sweeteners in the United States for Selected Years

Year	Sugar	HFCS	Others'	Other Caloric Sweeteners[2]	Non- Caloric Sweeteners[3]	Total
	Pounds					
	(percentage)					
1971	102.1	0.9	19.9	1.4	5.1	129.4
	(78.5)	(0.69)	(15.3)	(1.08)	(3.94)	(100)
1974	95.6	3.1	22.1	1.1	5.9	127.8
	(74.8)	(2.4)	(17.3)	(-86)	(4.61)	(100)
1977	94.2	10.0	21.7	1.4	6.6	133.9
	(70.4)	(7.46)	(16.2)	(1-04)	(4.92)	(100)
1980	83.7	19.3	21.1	1.2	7.1	132.4
	(63.2)	(14.6)	(15.9)	(.90)	(5.63)	(100)
1983	71.4	30.3	21.3	1.6	9.6	134.2
	(53.2)	(22.6)	(15.9)	(1-2)	(7.15)	(100)

[1] Corn Syrup, Dextrose
[2] Honey, Edible Syrups
[3] Saccharin, Aspartame
Source: Sugar and Sweeteners Report, various issues.

er relevant variables such as seasonality, changes in technology, and consumers' preferences in the final product demand; a's are parameters; and e_t is a random disturbance. Given that food processors do not fully adjust to price changes in the short-run, partial adjustment is given by

$$(2) \quad Q_t - Q_{t-1} = \lambda(Q^*_t - Q_{t-1}) + u_t,$$

where Q_t is the sugar delivered to food processors in period t and X represents the speed of adjustment coefficient. If X = 1 then $Q^*_t = Q_t$ and instantaneous adjustment occurs. If $0 < X < 1$, then partial adjustment occurs, following Phlips, substitute (1) into (2) to obtain

$$(3) \quad Q_t = \alpha^*_0 + \alpha^*_1 P_t + \Sigma\alpha^*_{2i} W_{it} + \Sigma\alpha^*_{3j} Z_{jt} + (1 - \lambda)Q_{t-1} + \mu_t,$$

where "*" indicates the parameters of equation (1) are scaled with λ and $\mu_t = \lambda e_t + u_t$.

consumption. The direct consumption demand is conceptualized within the framework of consumer choice theory. Individual demand functions can be derived from utility maximization which can be aggregated to obtain total demand for sugar for direct consumption. Phlips argues that partial adjustment in consumer demand in the case of consumers exists due to psychological inertia that results from habit formation. An analogous procedure is followed in deriving the empirical quarterly model for the demand for direct consumption with partial adjustment. The direct consumption demand model to be estimated is expressed as follows:

$$(4) \quad Q_t = \beta^*_0 + \beta^*_1 P_t + \beta^*_2 I_t + \Sigma\beta^*_{3j} Z_{jt} + (1 + \lambda)Q_{t-1} + \mu_t$$

where Q_t is quantity purchased in period t; P_t is the price of sugar; I_t is consumers' disposable income; Z_{it} is a vector of other relevant variables; /3*'s are the demand parameters scaled by X and $/x_t$ is a disturbance.

In the specification of the models, the price of sugar is assumed to be an exogenous variable. This involves the additional limiting assumption that the locus of sugar prices and quantities traces out a demand function. This assumption is rationalized on the basis of the importance of government intervention in adjusting imports in pursuance of price objectives. Thus, government intervention, weather and a volatile international market induce significant shifts in the availability of sugar, leading to greater validity of this assumption.

Data Sources and Management

variety of federal publications for the period 1970-1984. Data sources relied heavily on *Sugar and Sweetener Reports, Sugar Market Statistics,* for sweetener prices and quantities, *Survey of Current Business* and *Wholesale Prices and Price Indexes* for processed food and **raw food products prices. Income is adjusted with the Consumer Price Index. To isolate the effect of taste and preferences (time variable), the quantity of sugar was expressed on a per capita basis. Finally, all regressors, except dummy and time variables, were converted to logarithmic terms.**

The only data available on sugar transactions are at the primary demand level, namely deliveries made by refineries. Deliveries to industrial and nonindustrial buyers are reported separately although the latter include deliveries bought by wholesalers, jobbers and dealers which account for 20 to 25 percent of all U.S. deliveries. No further classification on type of wholesalers (e.g., food service wholesalers) was reported. However, this group is classified as nonindustrial users by the USDA. Estimation of actual use in industrial and direct consumption sectors is complicated by the fact that no data exist as to how much of the sugar acquired by the wholesalers, jobbers, and dealers is rerouted to the industrial and nonindustrial sectors. Drawing from Klein's inventory demand theory, it is hypothesized that purchases of wholesalers, jobbers, and dealers (Q^w) are driven by two motives—transaction and speculation. These elements are incorporated by regressing Q^w on current industrial and nonindustrial sugar purchases from refineries (transaction demand) and the current sugar basis (speculative demand). Results are as follows:

$$(5) \quad Q^w_t = 1664135 + \underset{(1.92)}{0.14} Q^I_t + \underset{(3.86)}{0.52} Q^c_t + 376720\,(F_t - P_t),$$

$$R_2 = 0.65 \quad F = 30 \quad n = 55$$

sugar wholesalers, jobbers and dealers in quarter t; Q^I_t and Q^c_t are amounts of sugar bought by industrial and nonindustrial users

from refineries; F_t — P_t is the average basis (futures price less current spot price) in quarter t; and the t-ratios are in parentheses. Qt^1 and Q_t^c were adjusted by apportioning Q_t^w according to equation (4). The apportionment of Qt^w seems reasonable since most sugar bought by wholesalers goes to direct consumption outlets although there is no record as to this proportion. Furthermore, USDA reports sugar wholesalers under nonindustrial users.

Empirical Results

The ordinary least squares (OLS) parameter estimates for the industrial and nonindustrial demand functions are presented in Table 2. For the industrial demand, the total period was split into two overlapping subperiods— before and after the introduction of HFCS type 55 which is a closer substitute than its predecessor HFCS type 42. This was done to obtain better information about the second subperiod. Furthermore, the 55 HFCS is the one which has substantially replaced sugar in the food industry. A Chow test was employed to test the hypothesis that industrial sugar demand parameters have changed after the introduction of HFCS. The corresponding F-ratio was significant at a = 0.05 level, and hence, we fail to reject the hypothesis of no structural change.

In contrast to adaptive expectation models which have moving average disturbances, partial adjustment models produce consistent OLS estimates if the error terms are not autoregressive (Judge et al.). The coefficient of the lag dependent variable in the nonindustrial model was highly insignificant. To test serial correlation in 1970—76 industrial model, the Durbin-h statistic for lagged dependent variable models was used. Since this statistic could not be computed for the 1977—84 model, the computed model disturbances were re-

Table 2. Estimated Coefficients and Selected Statistics for the Industrial and Nonindustrial Demand for Sugar

Dependent Variable: Log of Per Capita Sugar Quantity

Explanatory Variables	Parameter Estimates (Standard Errors)		
	Industrial		Nonindustrial
	1970-76	1977-84	1970-84
Intercept	4.92**	8.32**	12.58**
	(2.10)	(2.67)	(1.51)
Log of Sugar Price	-0.15**	-0.04**	- 0.16**
	(0.06)	(0.05)	(0.05)
Log of HFCS Price		0.02	
		(0.03)	
Log of Output Price	0.28	0.37	
	(0.31)	(0.22)	
Log of Raw Food Price	0.02	-0.20	
	(0.20)	(0.15)	
Spring	0.17**	0.05**	0.13**
	(0.04)	(0.02)	(0.05)
Summer	0.19**	0.09**	0.29**
	(0.04)	(0.03)	(0.04)
Fall	-0.05	-0.07**	0.27**
	(0.05)	(0.03)	(0.04)
Trend	-0.0085**	-0.012**	-0.0023**
	(0.0020)	(0.003)	(0.0011)
Lag Dependent Variable	0.51**	0.28	- 0.11
	(0.17)	(0.16)	(0.13)
R- square	0.87	0.95	0.75
F ratio	15	40	25
n	27	31	58

** Indicates significant at a = 0.05 level

gressed against the regressors of the model and lagged estimated disturbances, and serial correlation tested on the coefficient of lagged disturbances. In both cases, we fail to reject the null hypothesis of no autoeorrelated disturbances at a = 0.05 level.

In general, the results seem plausible and consistent with theory. The estimated coefficients were robust as they were insensitive to model specification. In the nonindus-trial sector, the lagged dependent variable and income effects were not significant indicating that instantaneous adjustment takes place in the direct consumption sector and that sugar is an income neutral commodity in the U.S. Insignificance of the effect of income is consistent with the findings of Young, Gemmill, and George and King. Sugar price elasticity of demand in the nonindustrial sector was estimated at —0.16 which is between the elasticity estimated by Gemmill for the U.S. (e_u = — 0.04) and the elasticity estimated by George and King (en = —0.24) on an annual basis. A strong and highly significant declining trend in consumption was found. Seasonality is a major shifter of sugar demand with peak demand occurring in the summer and the lowest demand in the winter.

Several structural shifts in the industrial demand for sugar are in evidence after the introduction of high fructose corn syrup (MFCS). Results point out that the demand for sugar has become less responsive to sugar price changes after the introduction of HFCS. Short-run own price elasticity went from — 0.15 to —0.04 and the long-run (full adjustment) own price elasticity went from —0.31 to —0.06 after introduction of 55 HFCS. The decrease in own-price elasticity can be attributed to sugar substitution taking place in the more price elastic usages such as soft drinks and canning industries (U.S. General Accounting Office). Furthermore, the speed of adjustment toward equilibrium or desired sugar use (X in equation (2)) has increased from 0.51 to 0.72 after the introduction of HFCS. Thus, the food processing industry is now quicker than they were previous to the introduction of HFCS in adjusting their sugar use. A greater rate of decline (trend) in sugar purchases is found after the introduction of HFCS. The estimated negative trend effect on industrial demand is consistent with the estimated nonindustrial demand structure which implies that consumers may be becoming more diet or weight conscious, preferring low- or non-sugar products to those with sugar added. The demand by the industrial sector is also characterized by strong seasonality. However, the effect of seasonality on quantity demanded has diminished after the introduction of HFCS.

Implications for Import Restrictions

Undoubtedly, high sugar prices have stimulated the use and development of sugar substitutes in industrial uses. Consumers are also buying less sugar and sugar-containing products due to noneconomic factors. These trends in sugar use are exerting a downward pressure on U.S. demand. Hence, if government is to continue to support the domestic sugar industry, imposition of increasingly restrictive import quotas or duties will be needed to maintain sugar prices.

To assess the direct welfare loss of the present sugar policy on sugar users, changes in consumer surplus were estimated from industrial and nonindustrial demands. Price, under unrestricted sugar imports, was assumed to be 12.5 cents/lb. less than the actual sugar price in fiscal year 1983 (October 1982 through September 1983) as estimated by the U.S. Department of Agriculture (1984). The welfare loss in the food industry was estimated at $1.69 billion while the welfare loss to nonindustrial users was estimated at $651 million, for a total welfare loss of $2.34 billion to all sugar users, or roughly $10 per capita. This represents a welfare loss of approximately $187 million per each 1 cent of price support. Additional welfare losses are borne by foreign sugar producers whose sales are limited by import restrictions.

The U.S. Department of Agriculture estimated that the premium price differential derived from import restrictions for FY 1983 yielded roughly $1.5 billion to domestic producers and processors. Additional benefits accrue to corn sweetener manufacturers who attain higher prices and market shares from high sugar prices. Consequently, the welfare loss of the program to sugar users exceeded the benefits accrued to sugar producers by about $840 million. Further data are needed to evaluate the impact of the present policy on foreign sugar producers and corn sweetener manufacturers .

When demand was projected for FY 1986 under current trends in use and population growth, the welfare loss in food processing

decreased to $1.43 billion and the welfare loss to nonindustrial users decreased slightly to $640 million. Thus, it appears that most of the decrease in demand for sugar would come from the food processing industry while total consumers' demand will be, at best, stationary.

Concluding Remarks

Consistent with the conclusions reached by Carman, the cost of continuing the present sugar policy would primarily be borne by foreign producers who export sugar to the U.S. and by the U.S. food processing industry and consumers. Furthermore, as sugar demand decreases and the food processing industry adjusts faster to the choice of sweeteners used, the welfare impact of U.S. policy options upon domestic consumers and food processors will be lessened.

Although concern has been voiced about the cost of the present sugar program to U.S. consumers (Johnson, U.S. General Accounting Office), further analysis is needed to evaluate the impact of import restrictions on domestic and foreign producers as well as domestic sugar substitutes. The case of sugar import restrictions, however, illustrates a case where policy-induced high prices to help producers, may yield opposite or at least less effective results than the objectives of policymakers. In the long-run, such policies may induce structural changes on the demand side which counteract desired policy results.

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