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The Effects of Relative Price and Health Information on Derived Demand for Sweeteners in the U.S. Food Processing Industry

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The purpose of the study is to examine the differential effects of relative prices and diet-health link information on the degree of substitution between corn and cane sugar in the U.S. food processing sector. Our results suggest that the nature of the relationship between cane and corn sugar is complementary and time-varying; and the elasticity of substitution is more responsive to changes in relative prices than to changes in health information.

Keywords: Derived Demand; Sweeteners; Relative Prices; Health Information; Trade-offs

JEL Codes: D21, I18, L66

Background

Growing consumer awareness of the link between diet and one's health status has been one of the stimuli for changes in food consumption/purchasing behaviour in recent years. Indeed, various studies have reported shifts in retail demand for different foods since the 1970s (e.g., Brown and Schrader 1990; Capps and Schmitz 1991; Anderson, 1997; Kinnucan *et al.* 1997). While some food processing firms may perceive a threat from changing consumer demand, others may view changing consumer behaviour as an opportunity. For example, in 2003, Voortman Foods in Canada cited growing consumer concerns regarding trans-fatty acids, and potential lose of market share arising from such concern, as its rationale for removing all trans-fatty acids from its food products. At the same time, decisions to change a food's ingredient mix are also driven by relative prices. Recognize, however, that for some agricultural input, prices are driven by policy instruments rather than markets.

This is especially relevant in the U.S. sugar market, where food processors generally face higher prices[1] due to government programs (Moss and Schmitz, 2002). Some economists have argued that high internal U.S. sugar prices prompted development of the high fructose corn syrup (HFCS) industry as processors substitute away (Figure 1) from expensive cane sugar (Schmitz *et al.*, 2002). Others have argued that the U.S. corn policy was the catalyst in the development of HFCS industry (Schnepf, 2006). Regardless, the US food industry has substituted away from cane sugar to relatively less expensive corn sugar inputs (Buzzanell, 1997). However, a growing amount of evidence points to HFCS as a factor contributing to rising rates of diabetes, cancer, cardiovascular disease and obesity (e.g., Bray *et al.*, 2004; Bray, 2004; Gaby, 2005; Morrill and Chinn, 2004). At the same time, some recent evidence dismiss the unique link between HFCS and health problems and conclude that 'HFCS does not appear to contribute to overweight and obesity any differently than do other energy sources' (e.g., Forshee et al., 2007; Soenen and Westerterp-Plantenga, 2007). Articulation of this mixed scientific evidence via health and medical professionals, public health agencies, and media outlets may cause some consumers to substitute away from products containing corn syrups to

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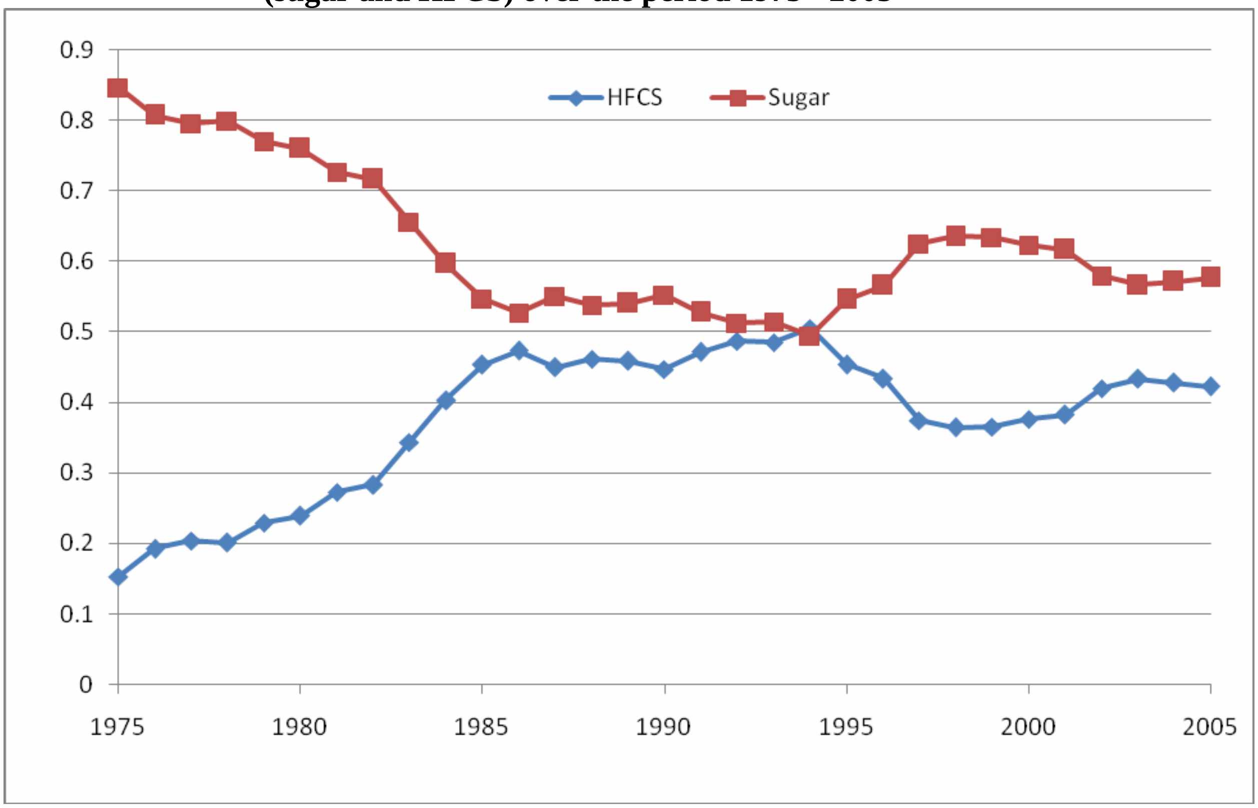
[1] For example, in 2004, the U.S. sugar price was 23.5 cents per pound, compared to the world price at 10.9 cents (USDC, 2007).

products with other sweeteners. In this light, a firm's decision to change the input mix of its food products reflects the trade-off between the cost increase associated with input substitution and the benefits of maintaining (or even increasing) market share. Furthermore, the decision by firms to change input mix has economic implications for consumers of sugar containing products (SCP), producers of corn, producers of sugar cane, sugar refinery, trade, government policy (e.g., food labelling policy) and other economic agents.

Figure 1 Market shares of HFCS and sugar as a proportion of total sweetener (sugar and HFCS) over the period 1975 - 2005



The purpose of this research is to examine the effects of relative sweetener input prices and publicly available health information on the use of sweeteners in the U.S. food processing industry. The specific objectives are to: (1) investigate the degree of substitution/ complementarity between cane sweeteners and HFCS sweeteners in the U.S. food processing industry, and (2) investigate the relative role of relative price and health information in shaping the degree of substitution/complementarity. To this end, we estimate a translog cost function and share system for the U.S. food processing industry. The estimated Allen-Uzawa partial-elasticity of substitution between cane sugar and

HFCS is then regressed on relative sweetener prices and scientific and media health information indices to determine their relative effects on substitutability between cane sugar and HFCS. The next section of the paper outlines the conceptual framework, followed by the empirical framework and data. Results are then presented and discussed. A summary and conclusion ends the paper.

Conceptual Framework

In this period of growing awareness of the link between diet and health, it is reasonable to assume that food demand is influenced by the health attributes of food products. Many retail level studies linking health information with consumption behavior have provided the necessary evidence for this argument (Capps and Schmitz 1991; Brown and Schrader 1990; Dyack 2002; Chern *et al* 1995; Burton and Young 1996). Given the strong link between diet and health, it could be argued that firms may choose ingredients that embody either enhanced or less deleterious health properties. In so responding, the firms seek to maintain or expand market share and/or sales volume. Previous studies have not explored firms' response to consumers' health concerns. The confounding issue is that consumers' health perceptions do not figure directly into the firm's cost minimization problem. It is not clear why or how the isocost line would directly reflect consumers' health perceptions in a price taking environment. However, it should be noted that the production function could reflect a quality adjustment depending on the perceived healthiness of various inputs. The production function could, therefore, be seen as a function of quality adjusted inputs. Based on the degree and direction of the impact of health concerns, the firm's perceived input quality may either be enhanced or degraded which in turn, can change the underlying input choice.

To capture this, we follow Binswanger (1974 a;b) and Lambert and Shonkwiler (1995) and assume augmented inputs and prices. For our purposes, however, we assume that the augmentation process adjusts inputs and prices for their health attributes. In particular, the health augmented input is expressed as $x_i^h = x_i h_i$ and the health augment price is expressed as $w_i^h = w_i / h_i$, where x_i is the volume of the i-th input used, h_i is the unobserved latent health factor, and w_i is the unit price of the i-th input.[2] Note that the physical properties x_i do not change, although the perceived healthiness does. Also note that expenditure on the actual input bundle and augmented input bundle is identical. Based on the above discussion, it is clear that firm's optimal choice of quality augmented input mix differs from the optimal mix of unadjusted inputs. The following Lagrange optimization problems shows the firm's cost minimization problem, subject to a production function which depends on the health quality augmented inputs:

$$\underset{x_i,\lambda}{Max} \quad L = \sum_i w_i x_i + \lambda\left(y - f\left(x_1^h, x_2^h, ..., x_N^h\right)\right)$$

(1)

The corresponding first order conditions can be written as:

$$w_i = \lambda \frac{\partial f\left(x_1^h, x_2^h, ..., x_N^h\right)}{\partial x_i^h} h_i$$

(2)

The first order conditions in (2) has relative health impacts (h_i, h_j) embedded within the production function. For any pair of inputs, the resulting optimality condition requires equality of the ratio of marginal factor costs to the health quality adjusted marginal rate of technical substitution:

$$\frac{w_i}{w_j} = \frac{f_i\left(x_1^h, x_2^h, ..., x_N^h\right)h_i}{f_j\left(x_1^h, x_2^h, ..., x_N^h\right)h_j}$$

(3)

where $f_i\left(x_1^h, x_2^h, ..., x_N^h\right)$ is the marginal productivity of the i-th input. If the perceived health impacts are identical (i.e., $h_i = h_j$), it can be shown that the optimal input choices in both the augmented and the physical cost minimizing problems are identical.

[2] The perceived quality loss due to negative health concerns may also bring about changes in the manner in which the input prices in the market are perceived by the processing firms. The motivation behind this argument is that firms' willingness to pay for the physical sweetener input may be less than the actual market price of the input.

The relative impact of the health quality augmentation indices shapes the input choices as they deviate from the neutral condition (i.e., $h_i \neq h_j$). Based on the direction of the impact of the relative health information ($h_i > h_j$ or $h_i < h_j$), the optimal quality augmented bundle may differ from the optimal physical bundle. Moreover, the substitution elasticities obtained from (3) are a function of the health information indices. However, measurement of the impact of these health information indices on and substitution elasticities for different sweeteners is complicated by several factors. First, the health augmentation indices are not easily or objectively measurable. Second, the means by which one incorporates health indices into the cost function is not clear. To circumvent these issues, we employ a two-stage approach; first, parameters used to calculate substitution elasticities are estimated from a cost function. Second, the resulting substitution elasticities are regressed on indices of health information developed in a manner similar to Brown and Schrader (1990), Kim and Chern (1997; 1999), Kinnucan *et al.* (1997) and Dyack (2002), as well as relative prices of sweeteners and a time trend. Such parsing the measurement of the health indices effect on substitution elasticities follows on Blonigen and Wilson (1999), Cranfield (2002) and Saito (2004).

Empirical Model

In order to obtain the parameters needed to calculate substitution elasticities, a cost function needs to be specified. The widespread application of the translog cost function form, its application in related studies (e.g., Goodwin and Brester, 1995; Huang, 1991), and its flexible properties make this functional form a natural choice. The translog cost function used here is:

$$\ln C_t = \beta_0 + \beta_Q \ln Q_t + \tfrac{1}{2}\beta_{QQ}(\ln Q_t)^2 + \sum_{i=1}^{n}\beta_i \ln w_{it} + \tfrac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij}\ln w_{it}\ln w_{jt}$$
$$+ \sum_{i=1}^{n}\beta_{iQ}\ln w_i \ln Q_t + \sum_{i=1}^{n}\beta_{it}\tau w_{it} + \beta_{tt}\tau^2 \qquad (4)$$

where C_t is the total cost, t indexes observations (which is time in our model), Q_t represents output at time t, w_{it} is input price of the i-th inputs (i.e., cane sugar, corn sugar, other materials, capital, labor and energy), the β's are parameters to be estimated,

τ is a trend variable and i, j =1 to n number of inputs. Applying Shephard's Lemma results in the i-th share based input demand:

$$S_{it} = \beta_i + \sum_{j=1}^{n} \beta_{ij} \ln w_{jt} + \sum_{i=1}^{n} \beta_{iQ} \ln Q_t + \beta_{it} \tau_{it} \tag{5}$$

where S_{it} is the i-th cost share and all other variables are as defined above. For theoretical consistency, the following homogeneity, adding-up and symmetry restrictions are imposed: $\sum_{i=1}^{n} \beta_i = 1$, $\sum_{i=1}^{n} \beta_{ij} = \sum_{j=1}^{n} \beta_{ij} = \sum_{i=1}^{n} \beta_{iQ} = \sum_{i=1}^{n} \beta_{it} = 0$ and $\beta_{ij} = \beta_{ji} (i \neq j)$ during estimation. Iterated seemingly unrelated regression is used to estimate the cost function and factor share equation. To do so, errors are appended to each equation, and one equation is dropped to the avoid singularity of the covariance matrix.

Once the parameters are estimated, elasticities of factor demand with respect to input prices and output, and substitution elasticities can be calculated. The price elasticities are calculated using the following formula:

$$\eta_{ij} = ((\beta_{ij} + S_i S_j) / S_i + \delta_{ij} \qquad (i \neq j) \tag{6}$$

where η_{ij} represents the price elasticity, δ_{ij} (=1, for i=j and 0 for i≠j) is Kronecker's delta and all other variables are previously defined. The elasticity of input demands with respect to output is calculated using:

$$\varepsilon_{iy} = (1/S_i) * \beta_{iQ} + \alpha_Q + \alpha_{QQ} \ln Q + \sum_{i=1}^{n} \beta_{iQ} \ln w_i \tag{7}$$

Lastly, the Allen-Uzawa elasticity of substitution is computed using:

$$\sigma_{ij}{}^{A} = \frac{\beta_{ij} + s_i (s_j - \delta_{ij})}{s_i s_j} . \tag{8}$$

To explore the relative importance of relative price and health information in explaining the degree of Allen elasticity of substitution between cane and corn based sweeteners, the second stage regression is estimated. Relative price is calculated as the ratio of cane sugar price to corn sugar price. The measure of health information associated with the cane and corn sugar inputs requires construction of proxy variables. The conventional index development, as reviewed in consumer level studies, involves classifying health information as positive, negative and neutral for the respective scenarios. A net health index is then developed from these counts (and described below in the data section). For the second stage analysis, the following model is estimated:

$$\sigma_{ij}{}^{A} = \alpha_0 + \alpha_{rp} RP + \mu_t t + \alpha_{cf}(h_{cf}) + \alpha_{sf}(h_{sf}) + \alpha_{cm}(h_{cm}) + \alpha_{sm}(h_{sm})$$
$$\alpha_{lcf}(h_{cf,t-1}) + \alpha_{sf,t-1}(h_{sf,t-1}) + \alpha_{lcm}(h_{cm,t-1}) + \alpha_{lsm}(h_{sm,t-1}) + \alpha_{\sigma_{ij}^{A}} \sigma_{ij\,t-1}{}^{A} + e_t$$

(9)

where, RP is relative price, α's are parameters to be estimated, h_{cf} is media health index associated with cane-sweetener, h_{sf} is the media health index associated with corn sugar, h_{cm} is scientific health index associated with cane sugar, and h_{sm} is the scientific health index associated with cane-sweetener. Note that lagged values of the health indices are included to allow for potential imperfections or delayed response times to publication (Doyle and Saunders, 1985) of information regarding the health impacts of cane and corn based sweeteners.

Data

The cost function and share equations are simultaneously estimated using capital, labour, energy and material data for the U.S. food and kindred products industry. Output and input expenditures and price data for all but cane and corn sugar are obtained from the *Manufacturing Industry Productivity* database (maintained by the *National Bureau of Economic Research (NBER)* and the *U.S. Census Bureau's Center for Economic Studies*: *http://www.nber.org/nberces/*) for the period 1975 to 1996, and then from the *Annual Survey of Manufacturers (ASM: http://www.census.gov/mcd/asmhome.html#)* for the *Food Processing* sector category from 1997 to 2005. Sweetener input use and prices are obtained from the *United States Department of Agriculture* (USDA:

http://www.ers.usda.gov/Briefing/Sugar/data.htm) Sugar and Sweeteners Data Tables for the period 1975-2005.[3] Output is measured as the total value of shipments deflated using a producer price index.

The U.S. retail refined sugar price was used as a proxy for cane sugar input prices (P_c). Quantity of cane sugar delivered for domestic food and beverage use is multiplied by cane sugar price to obtain cane sugar expenditure (C) data. The wholesale price for HFCS-42 (cents/ lb) in the Midwest markets proxies corn sugar input price (P_s), and is multiplied by the quantity of corn sugar used in the domestic food and beverage to obtain corn sweetener expenditure data.

Expenditure on other materials (M) reflects the total cost of raw materials apart from cane and corn sweetener. The material expenditures are obtained by subtracting energy and sweetener (both cane and corn) expenditures from the material cost in the respective dataset.[4] Note the difficulty in developing a suitable price index for other materials category, as it might include numerous baskets of food, non food inputs and resale and contract work at the two digit industry level. Goodwin and Brester (1995) used a Stone's share-weighted index to develop a price index for "other inputs." In this study, the producer price index for "intermediate materials, components and supplies" is used as the price index for other materials category.

New capital spending on permanent additions and major alterations to plant structures along with new machinery and equipment captures capital expenditures up to 1996, while total expenditures on buildings, structures and equipment is used as capital expenditures from 1996 onwards. The price of capital is measured using the producer price index for capital. Production worker wages is used as labor expenditures, while the price of labor (hourly wages) equals production worker wages (in million dollars) by the number of productive workers (in million hours). Expenditures are measured directly from respective databases, while price of energy is captured via the producer price index of energy (E).

[3] In this study, corn sweetener inputs are considered synonymous to an aggregate of corn sugar, dextrose and glucose.
[4] Material costs includes the cost of raw materials, parts and supplies put into production or used for repair, and maintenance, along with purchased fuels.

Health information indices are developed following several strands of literature which employ counts of media and scientific articles related to particular food-health outcomes (e.g., Brown and Schrader, 1990; Kinnucan *et al*,. 1997; Dyack, 2002). In particular, health indices for both cane and corn sweetener inputs are developed by classifying health information in Factiva (which covers popular media outlets) and Medline (which covers scientific publications) databases. About 10,000 authoritative media sources from a variety of sources are covered in the Factiva database. Likewise, the Medline database is a compilation by the U.S. National Library of Medicine (NLM) and published on the Web by Community of Science. Medline is the world's most comprehensive source of life sciences and biomedical bibliographic information.[5]

Both Factiva and Medline database are used to retrieve health information using keyword searches. The keywords used in retrieving articles related to cane sugar include: *'sugar' 'health' 'obesity' 'diabetes' 'cardiovascular' 'atherosclerosis' 'heart disease' 'hypertension' 'metabolism' 'bodyweight' 'cancer' 'carbohydrates' 'sucrose' 'dental caries' 'liquid sugar' 'taste' 'food' 'soft drink' and 'cane sugar'*. Keywords used in classifying articles related to corn sugar include: *'hfcs' 'health' 'obesity' 'diabetes' 'cardiovascular' 'atherosclerosis' 'heart disease' 'hypertension' 'metabolism' 'bodyweight' 'cancer' 'carbohydrates' 'fructose' 'dental caries' 'corn syrup' 'taste' 'food' 'soft drink' and corn sugar*. After reviewing the articles retrieved via this search, articles are classified into positive, negative or zero for the respective year of publication. Then, positive information is given a score of 1; negative information is assigned a numerical score of -1, and neutral or inconclusive information a score of zero. For each year, the sum of the positive, neutral and negative counts is calculated and used as a health index. This is done for both cane and corn sugar independently. Descriptive statistics of the variables used in the study are provided in Table 1.

[5] For instance, Medline contains nearly eleven million records from over 7,300 different publications from 1965 to November 16, 2005.

Table 1. Descriptive Statistics of the variables used to estimate the translog cost function for the U.S. Food and Kindred Products Industry, and in the second stage analysis explaining determinants of Allen-Uzawa substitution elasticities

Variables	**Mean**	**St. Dev**
Cane Sugar cost share	0.0157	0.0038
Corn Sugar cost share	0.0093	0.0025
Material cost share	0.8399	0.0136
Capital cost share	0.0326	0.0047
Labor cost share	0.0822	0.0083
Energy cost share	0.0200	0.0031
Cane Sugar price	35.51	3.2321
Corn Sugar Price	15.55	2.8971
Material Price	1.1897	0.2948
Capital Price	1.1712	0.3174
Labor Price	8.27	0.61
Energy Price	0.83	0.2502
Output	3.05E+11	2.83E+10
Net Count of Cane Factiva	-0.133	0.346
Net Count of Corn Factiva	-5.567	15.447
Net Count of Cane Medline	-0.100	0.305
Net Count of Corn Medline	-1.300	2.548

Results and Discussion

The translog cost function and share equations are simultaneously estimated using non-linear, iterated seemingly unrelated regression. Initial estimates suggested the presence of first order autocorrelation, so a common autocorrelation correction parameter (ρ) is incorporated into the estimated model. Table 2 reports the estimated parameters and regression summary statistics. The R^2 values range from 0.53 to 0.99, and are the lowest for the cane sweetener equation. Although the estimated parameters are not of direct interest, they do shed light on the relative importance of prices and output. For 16 of the estimated 36 coefficients, the null hypothesis that individual parameters estimate equals to zero is rejected at the ten percent significance level or better.

Table 2. Estimated translog cost function and share system parameters and standard errors

	Cost Equation	Cane sweetener equation	Corn sweetener equation	Material equation	Capital equation	
Constant	7289.40**	0.0291**	0.0050	1.7202 ***	-0.3073	-0.4257 ***
	(1.000)	(0.0367)	(0.0345)	(0.3259)	(0.2809)	(0.1261)
Cane sugar		-0.0091				
		(0.0045)				
Corn sugar		-0.0012	0.0046 ***			
		(0.0015)	(0.0015)			
Other material		0.0099	0.0044	0.0410		
		(0.0082)	(0.0061)	(0.0534)		
Capital		0.0016	-0.0064	-0.0091	0.0108	
		(0.0041)	(0.0041)	(0.0416)	(0.0394)	
Labour		-0.0008	-0.0016	-0.0444**	0.0051	0.0447***
		(0.0032)	(0.0027)	(0.0183)	(0.0116)	(0.0097)
Output	0.8143 **	-0.0349*	-0.0045	0.0625*	0.0048	-0.0234*
	(0.3501)	(0.0181)	(0.0064)	(0.0346)	(0.0172)	(0.0138)
Trend	-19.63 ***	-0.0004	0.0003	-0.0045***	0.0010	0.0032***
	(4.7369)	(0.0005)	(0.0002)	(0.0016)	(0.0010)	(0.0006)
$(\text{Trend})^2$	0.0259**					
	(0.0119)					
$(\text{Output})^2$	-0.2175					
	(0.6031)					
Rho	0.9973***					
	(0.0007)					
R^2	0.9903	0.5325	0.8815	0.8969	0.7985	0.9618

Note: *, **, *** refers to 10 per cent, 5 per cent and 1 per cent, respectively, level of significance. Figures in parentheses are standard deviations**.**

Quasi-concavity requires that the matrix of the second cross partial derivatives of the cost function be negative semi-definite. The maximum eigenvalues of this matrix is obtained for individual observations to investigate this property. The eigenvalues evaluated at the means of the data, are all negative. Thus, the model satisfies the curvature property at the means of the data. Moreover, the model shows consistency with curvature in 75 percent of the observation when evaluated at every point in the data. As well, the monotonicity property is satisfied since all of the predicted shares are greater than zero.

Table 3 shows the calculated price and output elasticity of input demand. The demand for cane sweetener and energy is elastic, while all other own-price elasticities are inelastic. In order of increasing inelasticity, the point estimates are: cane sweetener, energy, capital, corn sweetener, labour and material. The cross price elasticities between corn and cane sweeteners are counterintuitive, suggesting a complementarity relationship; an increase in the price of corn sweetener leads to a reduction in cane sweetener demand and vice-versa. One rationale for this finding might be the possibility of blending these two sweeteners in a complementary manner to maintain palatability and taste of certain food products. Further, the blending characteristic of corn sweeteners with other sweeteners has led to food manufacturers producing soft drinks, processed foods, cereals, bakery, diary and confectionary products to use these sweeteners as complements (Schorin, 2005). Energy is also found to be complementary to cane sweetener. However, the other cross price effects for cane sweetener demand are positive, suggesting a substitution relationship.

Table 3. Factor Demand Price Elasticities Evaluated at the Means of the Data

Factor Demands	With respect to the price of						Output elasticities
	Cane	Corn	Materials	Capital	Labour	Energy	
Cane	-1.7459	-0.0865	1.6663	0.1643	0.0071	-0.0052	-2.8531
Corn	-0.0915	-0.5850	1.2377	-0.5312	-0.0684	0.0385	-0.3576
Materials	0.0237	0.0166	-0.1017	0.0210	0.0229	0.0174	0.1110
Capital	0.0624	-0.1908	0.5623	-0.6269	0.2372	-0.0443	0.1906
Labour	0.0011	-0.0104	0.2594	0.1003	-0.3297	-0.0207	-0.2744
Energy	-0.0032	0.0225	0.7566	-0.0721	-0.0798	-1.3368	-0.1927

One crucial result to be noted is the impact of the price of cane sweetener on labour demand leading to substitution. The effect of cane sweetener prices on employment losses in the sweetener containing product (SCP) industries, as reported by US Department of Commerce (USDC), supports this argument. According to the Bureau of Labor Statistics, employment in sweetener containing product industries decreased by more than 10,000 jobs between 1997 and 2002 (USDC, 2007) due to closures, restructuring and relocation resulting from higher sugar prices.

The cross price elasticity between cane sweetener price and capital is positive suggesting a substitution relationship. Measures to sustain the domestic cane price at exorbitantly higher levels may have possibly led to this effect. Destinations such as Canada and Mexico where sugar prices are at world market levels have attracted the attention of the US food manufacturers. Relocation of many U.S. SCP manufacturers to lower sweetener priced countries like Canada and Mexico has increased the need for additional capital. Reports from the United States Department of Commerce substantiate this argument (USDC, 2007).

The output elasticities calculated at the means revealed mixed results suggesting mixed responses of input demands with respect to output changes. Note that the elasticity of input demand with respect to output is negative with respect to cane sweetener, corn sweetener, labour and energy (see Table 3). On the other hand, the elasticity of input demand with respect to output is positive for both material and capital.

The Allen elasticity of substitution (AES) results (see Table 4) reveal that cane sweetener is a substitute to material, capital and labour, but is complementary to corn sweetener and energy. The complementary relationship between cane and corn sweetener is contrary to the expected substitution relationship. However, as mentioned above, the blending nature of corn sweetener with other sweeteners provides opportunity for the food manufacturers to use them complementarily. Our results reveal substitutability between corn sweetener and materials and corn sweetener and energy. Corn sweetener is complement to capital and labour inputs. The coincidence between increased capital intensive characteristic of the industry and increased use of corn sweetener may be a probable reason for this effect. Connor *et al.* (1985a:b) substantiates this further by suggesting that food processing is more capital intensive than even most major industry groups. Material input is a substitute with capital, labour and energy, while capital and energy are substitutes. Our qualitative results are consistent with Goodwin and Brester's (1995) estimates of Morishma elasticities of substitution in that material input is a substitute with capital, labour and energy.

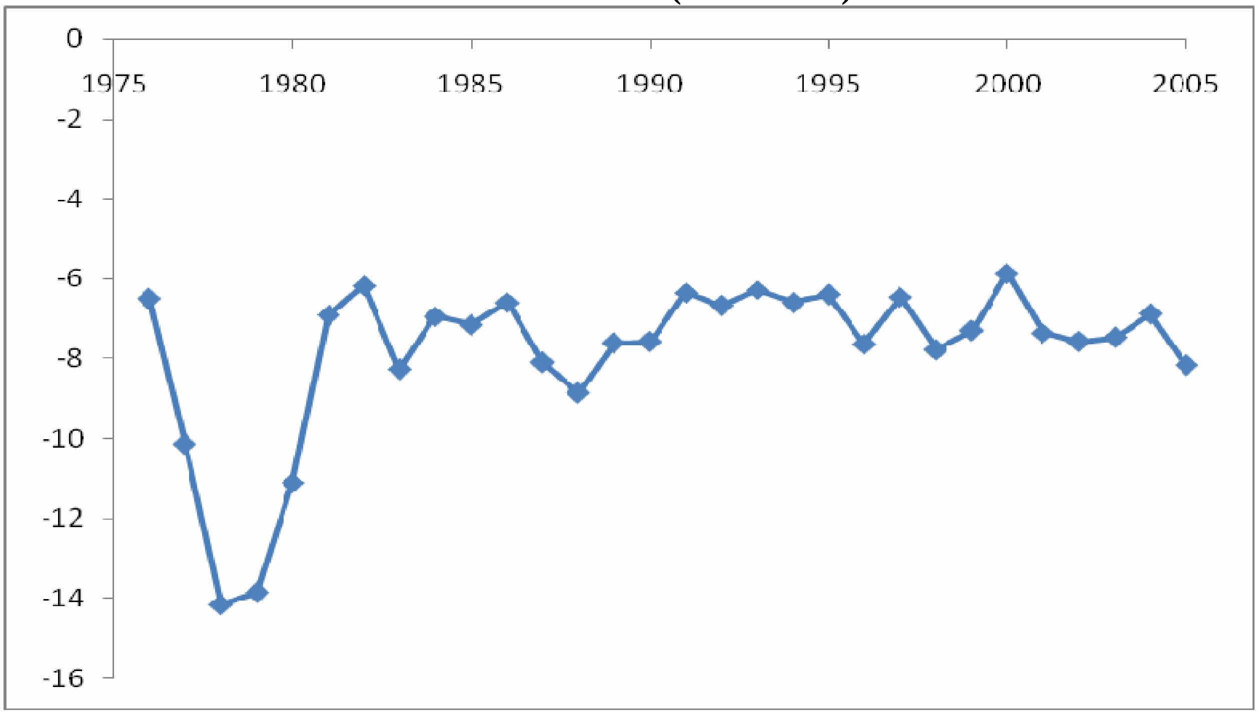
Table 4. Allen Elasticity of Substitution Evaluated at the Means of the Data

Factor Demands	With respect to the price of					
	Cane Sugar	Corn Sugar	Materials	Capital	Labour	Energy
Cane sugar	-144.387	-7.5740	1.9606	5.1666	0.0945	-0.2680
Corn sugar		-51.1930	1.4564	-16.6979	-0.9101	1.9731
Materials			-0.1197	0.6616	0.3052	0.8903
Capital				-19.7076	3.1533	-2.2665
Labour					-4.3818	-1.0608
Energy						-68.3948

Analysis of the Cane-Corn Sweetener Cross-Substitution Elasticities

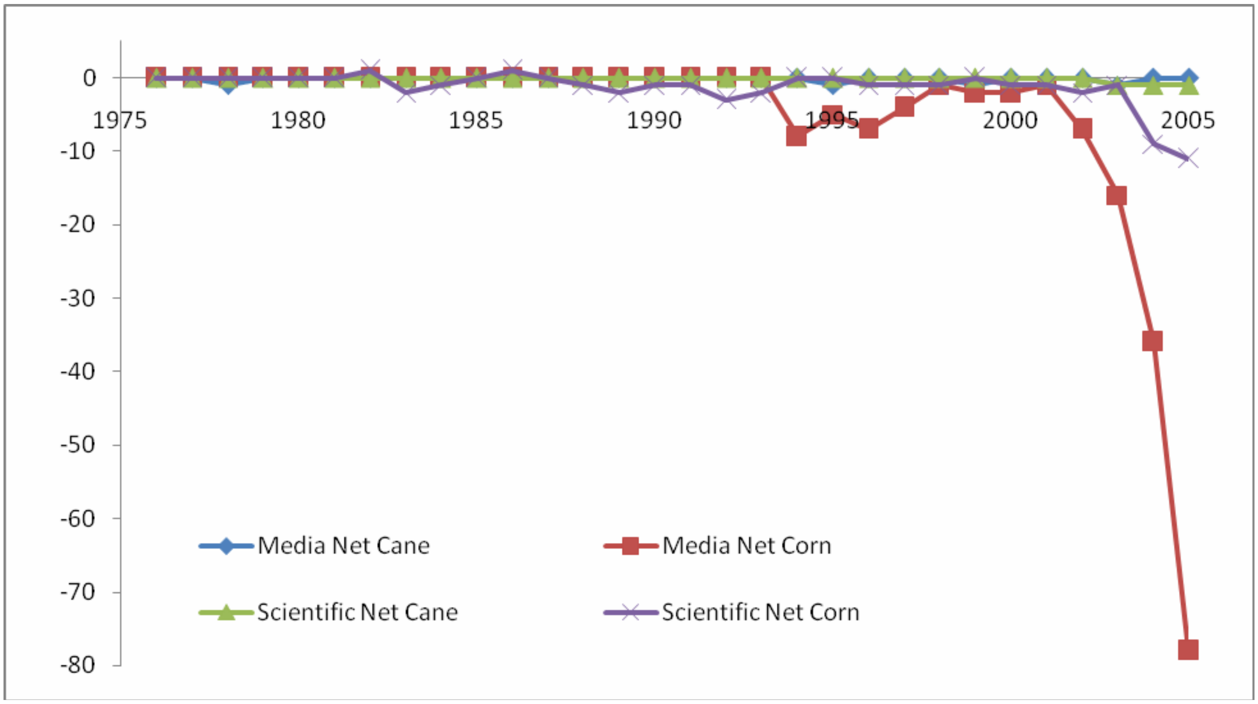
The trends in Allen elasticity of substitution is given in Figure 2. The estimated Allen elasticity of substitution (AES) excludes the influence of health concerns. The impact of relative price and health information on the estimated AES between cane and corn sugar is further explored. First, the health index developed for both cane and corn sweeteners over time are presented; estimation results concerning the relationship between the elasticity of substitution and relative price and health information is presented. Over the study period, the amount of media and medical information linking sugar and health was limited. The limited media coverage and medical publications related to health and cane sugar were negative. The negative counts for cane sweetener are observed in only a few instances during the study period. Overall, information relating cane sweetener with health issues is largely non-existent and when it does exist, is negative in nature.

Figure 2. Trends in Allen Elasticity of Substitution/Complementarity (AES) between Cane and Corn Sweetener (1975 – 2005)



To enable easy interpretation of the health counts, a scatter plot of the net counts is provided in Figure 3. The net media information concerning corn sweetener has largely been negative since 1992. Note that, since 1994, the market share for HFCS has shown a downward trend (Figure 1). Also, the net scientific information associated with corn sweetener is negative starting as early as 1980s. Increased negative association of corn sweetener with health issues compared to cane sweeter is, in itself, an interesting finding. When taken together, the volume of negative, positive and net counts support the existence of potential health concerns-sweetener type connection. A preliminary conclusion is that health information associated with corn sweeteners is largely negative and cannot be ignored.

Figure 3. Trends in Net Health Count of Cane and Corn Sweetener from Media and Scientific Articles



Having explained the health counts, the impact of the scientific and media information on the input substitution elasticities is analyzed. The second stage analysis involves the regression of the Allen substitution elasticities on relative sweetener input prices, a time trend, the level and lag of net media health count of cane sweetener, the level and lag of net media health count of corn sweetener, the level and lag of net scientific health count of cane sweetener, the level and lag of net scientific health count of corn sweetener, and the lag of substitution elasticities. Results from these second stage regressions (one using OLS, two other including a heteroscedasticity correction, and an autocorrelation correction) are presented in Tables 5. Given the large changes in the AES during the early periods of the analysis, the test for heteroscedasticity is conducted using Lagrange Multiplier (LM) heteroscedasticity test, and we fail to reject the hypothesis that error terms are homoscedastic. Thus, the analysis is corrected for heteroscedasticity (Table 5).

Table 5. Regression Estimates of the effects of relative price and health information on the degree of Allen Elasticity of Substitution

	Uncorrected (OLS)		Heteroscedasticity Corrected		Autocorrelation Corrected	
Constant	-4.830***	(-2.584)	-4.830***	(-3.808)	-5.094***	(-2.971)
Relative Price	-1.416*	(-1.874)	-1.416***	(-2.504)	-1.834**	(-2.443)
Trend	0.261***	(3.059)	0.261***	(3.999)	0.299***	(3.788)
Cane Factiva (CF)	2.158**	(2.187)	2.158**	(2.187)	1.592**	(2.271)
Corn Factiva (SF)	0.178*	(1.630)	0.178***	(3.327)	0.173***	(2.513)
Cane Medline (CM)	-0.968	(-0.512)	-0.968	(-1.060)	-0.334	(-0.248)
Corn Medline (SM)	0.630*	(1.775)	0.630***	(2.985)	0.606**	(2.479)
Lagged CF	1.124	(1.094)	1.124	(1.285)	0.696	(0.990)
Lagged SF	-0.228	(-1.282)	-0.228**	(-2.352)	-0.248**	(-2.039)
Lagged CM	-6.072	(-1.476)	-6.072***	(-3.063)	-5.515**	(-2.196)
Lagged SM	-0.148	(-0.424)	-0.148	(-0.714)	-0.141	(-0.596)
Lagged Dependent	0.340*	(1.971)	0.340**	(2.384)	0.270*	(1.936)
ρ (Rho)					0.421**	(2.217)
R^2	0.708		0.708		0.747	
R^2 adj	0.519		0.519		0.557	
LM Het Test	3.588					
Log-likelihood function	-43.539		-43.539		-41.590	

Note: *, **, *** refers to 10 per cent, 5 per cent and 1 per cent, respectively, level of significance. Figures in parentheses are t-ratios.

As expected, both relative prices and health information play a significant role in explaining trends in substitution elasticities. Higher relative prices and net health counts lead to a higher degree of elasticity of substitution (or lower degree of complementarity). However, the coefficients of health information variables provide valuable insights into the influences of health concerns on sweetener substitution behaviour. For the model estimated with OLS, current net positive cane sugar media and current net positive corn scientific information have statistically significant and positive effects on the Allen elasticity of substitution. In the autocorrelation model the same result holds, but now the net positive count of corn media information is also positive and significant. Hence, level of cane and corn sugar media information and the level of corn sugar scientific information play important roles in explaining the elasticities of substitution. Note that most lagged health variables are not statistically significant.

A broad conclusion is that the degree of substitution/complementarity between sweetener ingredients is shaped not only by relative prices of these ingredients, but also by the level of media information with respect to both cane and corn sweeteners, and the level of scientific information with regard to corn sweetener. Since media information is more accessible to consumers than scientific information (which is often targeted by the scientific community), results from the second stage analysis suggest that the food processing industry place more emphasis on consumer responses to media information than on consumer response to the scientific information.

Finally, the answer to the question about the relative impact of relative prices and health information remains. To address this question the responsiveness (elasticity) of AES with respect to relative prices and health indices is estimated (Table 6). The results indicate that AES is more responsive to changes in relative prices than changes in health information. This result may point to the relative importance of cost savings in the firm's input choice decisions to stay competitive on the world market. This result is supported by the USDC study that "the U.S. food manufacturers pay a significantly higher price than many of their foreign competitors, currently more than double, which put them at a competitive cost disadvantage" (USDC, 2007: p. 5).

Table 6. The Short and Long term Elasticities of AES with respect to relative price and health information variables (calculated at the mean values)

	Uncorrected		Heteroscedasticity		Autocorrelation	
	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
Relative prices	0.456 *	0.690*	0.456***	0.690***	0.590**	1.912
	(1.874)	(1.860)	(2.504)	(2.785)	(2.443)	(1.158)
Cane Factiva	0.038**	0.057 **	0.038**	0.057**	0.028 **	0.090
(CF)	(2.187)	(2.066)	(2.187)	(2.130)	(2.271)	(1.498)
Corn Factiva	0.130*	0.198	0.130***	0.198***	0.126 **	0.410
(SF)	(1.630)	(1.513)	(3.327)	(2.826)	(2.513)	(1.233)
Cane Medline	-0.013	-0.109	-0.013	-0.019	-0.004	-0.014
(CM)	(-0.512)	(-0.499)	(-1.060)	(-1.003)	(-0.248)	(-0.250)
Corn Medline	0.108*	0.163 *	0.108***	0.163***	0.104**	0.336
(SM)	(1.775)	(1.635)	(2.985)	(2.512)	(2.479)	(1.258)

Note: *, **, *** refers to 10 per cent, 5 per cent and 1 per cent, respectively, level of significance. Figures in parentheses are t-ratios.

Concluding Remarks

The degree of substitution between corn and cane sugar is investigated by estimating a translog input demand system using Manufacturing Industry Productivity, Annual Survey of Manufacturers and United States Department of Agriculture databases.

Time-varying Allen elasticities of substitution are estimated. Our finding suggests that the nature of relationship between cane and corn sugar is time-varying and complementary. The blending of cane and corn sweeteners to attain a certain taste may reflect the ‘complementary’ nature of our results.

The relative importance of health information and relative prices are explored through the second stage regression. Our findings suggest that AES is more responsive to changes in relative prices than changes in health information. The influence of media information may largely be a reflection of the importance of the firms’ responsiveness to consumers’ health concerns and consumers’ willingness to pay more for products with healthier ingredients. In general, both health information and relative input prices have influenced the degree of complementarity between cane and corn sugar.

The influence of media information on food input choices is an important result for the regulatory authorities, industry, consumers and policy makers. Validity of the health claims itself, as contained in the media information, may be questioned by regulatory authorities. A largely incongruent overlap between the scientific and media information, for instance, may alert regulators to monitor misrepresentation or unauthentic media reporting; consistency between the media and scientific information, on the other hand, may help regulatory authorities appreciate and even strengthen the channel of health information. Insights may be drawn for economic agents involved in regulating product labeling as well.

Putting aside the health aspect, the significance of both the own and the cross price elasticity estimates, in itself, stand alone as an important contribution. As important agricultural commodities, inferences on the nature of price responses (cane –elastic; corn-inelastic) give necessary quantitative information for policy makers. Acknowledging the high influence of policy factors in the sweetener segment, these elasticity estimates are a definite contribution in designing policy instruments.

International Trade Association (ITA) and other development departments might be benefited with cross price elasticity estimates. The Bureau of Labour Statistics (BLS), for instance, may be benefited by the cross price elasticity estimate between cane sugar and labour. Along the lines of Armington elasticities (see Saito, 2004), the elasticity estimates between cane sugar price and capital can be employed on the trade front. Significant developments in relocation of SCP industries and further deliberations on bilateral (*CAFTA*) and multilateral trade agreements (*NAFTA, WTO*) underscores the leverage of these cross price effects.

Interpreting these results to disaggregated sub-sectors within food processing is cautioned as sweetener cost shares vary significantly across these sub-sectors (see Table 7).

Table 7. The cost share of sugar as a raw material in the U.S. food processing industry by sugar containing product type in 2002

NAICS	Sugar Containing Product	Cost share of sugar (%)
311230	Breakfast cereal manufacturing	32.70
311340	Non-chocolate confectionery manufacturing	28.10
311330	Confectionery from purchased chocolate	19.10
311320	Confectionery from cacao beans	17.70
311930	Flavoring syrup and concentrate mfg	15.10
311990	All other food manufacturing	14.40
311813	Frozen cakes and other pastries manufacturing	12.40
311822	Mixes and dough	8.50
311821	Cookie and cracker manufacturing	8.40
31181A	Bread and bakery, except frozen, manufacturing	8.30
311941	Mayonnaise, dressing, and sauce manufacturing	6.00
311520	Ice cream and frozen dessert manufacturing	4.00
311514	Dry, condensed, and evaporated dairy	2.20
311942	Spice and extract manufacturing	2.10
311420	Canned fruits and vegetables	1.50
311511	Fluid milk manufacturing	0.90
311410	Frozen food manufacturing	0.50
312110	Soft drink and ice manufacturing	0.50
311111	Dog and cat food manufacturing	0.50
311211	Flour milling	0.40
311919	Other snack food manufacturing	0.40
311119	Other animal food manufacturing	0.10
312120	Breweries	0.10

Source: Economic Census (2002) and USDC (2007).

Extension of this research to the respective sub-sectors (especially to the soft drink segment) and to the firm level may comprehensively capture sector-specific effects.

An attempt to undertake a similar analysis for the Canadian food processing sector was rendered impossible due to the lack of similar data.

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