

International Agricultural Trade  
Research Consortium

**Modeling the U.S. Sweetener Sector:  
An Application to the Analysis of Policy Reform**  
by  
**Stephen L. Haley\***

**Working Paper #98-5**

The International Agricultural Trade Research Consortium is an informal association of University and Government economists interested in agricultural trade. Its purpose is to foster interaction, improve research capacity and to focus on relevant trade policy issues. It is financed by United States Department of Agriculture (ERS, and FAS), Agriculture and Agri-Food Canada and the participating institutions.

The IATRC Working Paper series provides members an opportunity to circulate their work at the advanced draft stage through limited distribution within the research and analysis community. The IATRC takes no political positions or responsibility for the accuracy of the data or validity of the conclusions presented by working paper authors. Further, policy recommendations and opinions expressed by the authors do not necessarily reflect those of the IATRC or its funding agencies. For a complete list of IATRC Working Papers, books, and other publications, see the IATRC Web Site <http://www.umn.edu/iatrc>

\*Stephen L. Haley is an economist with the Economic Research Service of the U.S. Department of Agriculture (USDA), Specialty Crops Branch, Market and Trade Economics Division.

Correspondence or requests for additional copies of this paper should be addressed to:

Stephen L. Haley  
USDA/ERS/MTED  
1800 M Street, NW  
Washington, DC 20036-5831

August 1998  
ISSN 1098-9218  
Working Paper 98-5

**Modeling the U.S. Sweetener Sector:  
An Application to the Analysis of Policy Reform**

Stephen L. Haley  
Specialty Crops Branch  
Market and Trade Economics Division  
Economic Research Service

July 1998

Abstract

This report documents a modeling framework for the U.S. sweeteners industry developed in the Specialty Crops Branch (SCB) of the Economic Research Service (ERS). Several innovations not seen in other studies include the regional modeling of sugar processing capacity adjustments and detailed sectoral analysis of sweeteners demand, using an Almost Ideal Demand Systems (AIDS) approach. The report describes the use of the framework to evaluate the benefits and costs of the current U.S. sugar program.

**Keywords:** Beet sugar, cane sugar, economic model, fructose, sugar

**Acknowledgments:** The author appreciates the manuscript review of the following individuals: Bill Kost, Ron Lord, Tom Worth, and Glenn Zepp. Appreciation and thanks go to Vern Roningen for his modeling help in the use of his economic modeling software VORSIM.

## **Modeling the U.S. Sweetener Sector: An Application to the Analysis of Policy Reform**

The government of the United States has exercised control over the trade of sugar going back to 1789. The current program dates to 1981, and is technically scheduled for reauthorization, revision, or possible termination in 2002. Recent studies - e.g. U.S. General Accounting Office (GAO), 1993 - have emphasized the huge costs of the program in changing world and domestic sugar markets. The 1996 Farm Act ended the deficiency payment program and associated provisions for U.S. food and feed grain producers, which indicates to some the potential for significant changes to the sugar program.

The purpose of this report is two-fold. First, it documents a modeling framework for the U.S. sweeteners industry developed in the Specialty Crops Branch (SCB) of the Market and Trade Economics Division (MTED) of the Economic Research Service (ERS). The framework was developed in anticipation of requests for analysis concerning possible changes to the current program. The modeling parameters have been estimated using data from more recent periods than other efforts. The framework also includes several innovations not seen in other studies. These include the modeling of sugar processing capacity adjustments by region and detailed sectoral analysis of sweeteners demand, using an Almost Ideal Demand Systems (AIDS) approach.

The second purpose is to report on the benefits and costs of the current program. This exercise is meant to show the capabilities of the modeling system in evaluating policy alternatives. Termination of the program is the most extreme outcome. Alternatives to rapid and radical reform should be analyzed as well, even if the results of alternative outcomes are not herein discussed.

Another reason for examining the termination of the program is to provide a more detailed analysis of the costs and benefits of the program as it currently operates. Estimates of bottom-line costs and benefits are of interest to program critics and supporters alike. It is important to have estimates that can be supported, or at least the weaknesses known, through methods generally used by economists.

This report is divided into several sections. The next describes the salient features of current U.S. sugar policy. The following four sections describe modeling and estimation aspects of sugar production, demand, processing and marketing stages, and price-determination, respectively. The last section provides analysis of the effect of terminating the program. It concludes by providing welfare analysis and results, which are compared explicitly to the GAO findings.

### **The U.S. Sugar Program**

The basic mechanisms of the current sugar program were established by the Food and Agricultural Act of 1981. Subsequent modifications have been made by the Food Security Act of 1985, the Food, Agriculture, Conservation, and Trade Act of 1990, and most recently, the Federal Agriculture Improvement and Reform (FAIR) Act of 1996.

The core policy tool is the nonrecourse loan program. The intention is to provide a minimum market price to U.S. producers. Sugar from cane and beets are used by processors as collateral for loans from the U.S. Department of Agriculture (USDA). Loans can be taken for up to 9 months. Processors can then pay growers for their sugar (pending perhaps final adjustments after the sugar has been sold), typically about 60 percent of the loan. The program permits processors to store the sugar rather than sell it for lower-than-desired prices. When the sugar is sold, the loan is repaid.

The nonrecourse aspect of the program guarantees a minimum price. If the market price were insufficiently low to meet the repayment loan amount, processors could forfeit the sugar, which is the loan collateral, to the Department. The obligations of the loan would then be fully satisfied. This mechanism effectively provides a price floor, which must be high enough to meet the loan repayment, including interest and other costs involved in the sale of sugar.

A unique aspect of the program is that it is meant to operate at no-cost to the U.S. government. The implication is that USDA must have the authority to limit imports in order for the price to be high enough to prevent forfeiture, thereby incurring program costs. Because the world price of sugar is typically below the unit loan repayment amount, import control is an active part of the program. Total imports vary yearly to meet the price targets. Originally a quota system was used that allocated import shares to source countries on the basis of their averaged exports to the United States for the period 1975-81, excluding high and low years. The quota system was replaced by a tariff-rate quota (TRQ) system that still allocates the shares. It specifies a 16 cent a pound tariff on all over-quota shipments.<sup>1</sup> This amount is sufficiently high to cap exports at the USDA-assigned levels.

The current program operates under the FAIR Act. The raw cane loan rate is set (as before) at 18 cents a pound, and the beet loan rate is 22.9 cents a pound. The FAIR Act introduced some revisions to the program. If the TRQ is at 1.5 million tons or below, loans become recourse loans.<sup>2</sup> This provision allows USDA to demand cash repayment of the loan, regardless of the price. When the TRQ is set above 1.5 million tons, the loans are nonrecourse. Processors are assigned penalties on forfeited sugar, 1 cent a pound for cane and 1.07 cents a pound for beet processors.

### **Modeling Raw Sugar Production**

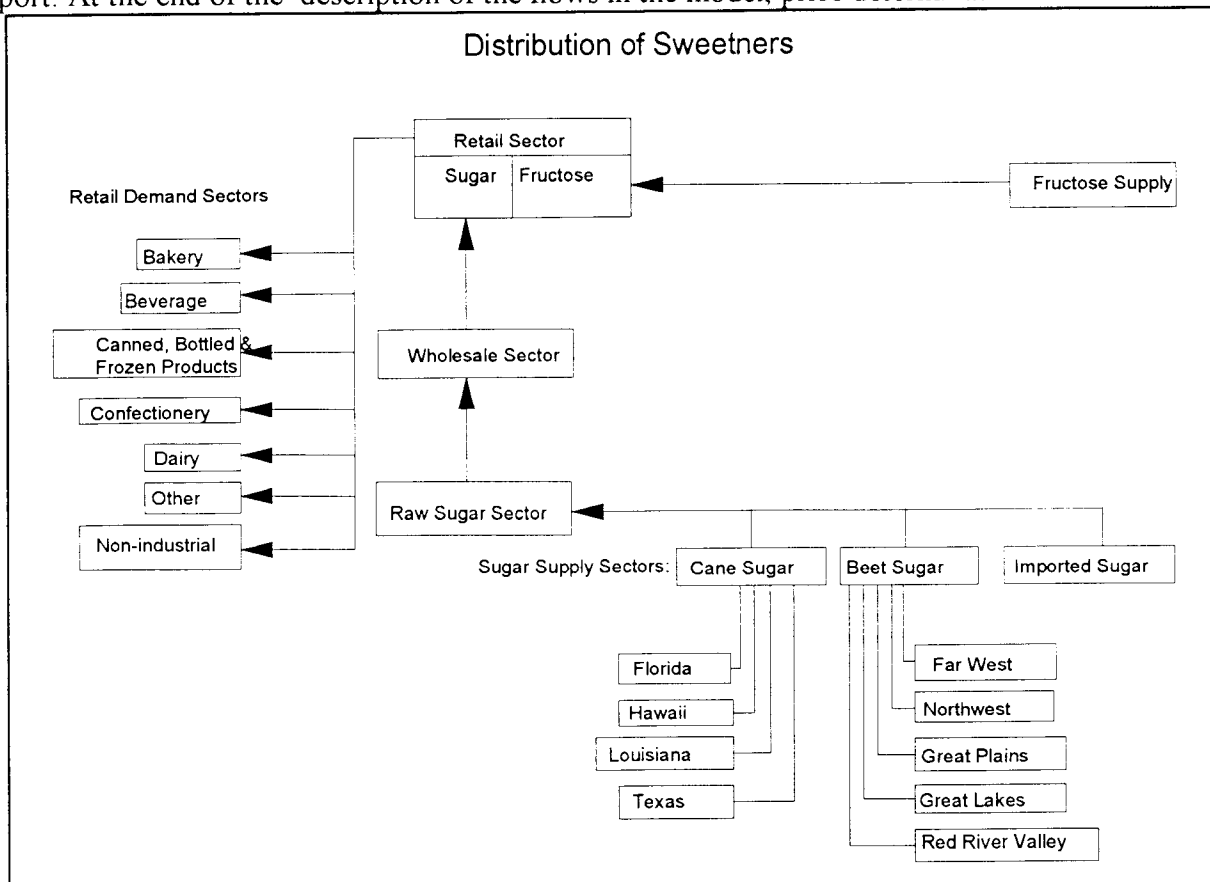
An overview of the sweetener modeling structure is provided in Figure 1. The bottom right area shows the sourcing of sugar from domestic producing regions (cane and beets) and from imports. Retail demanders are shown in the left portion. There are 6 industrial demand sectors and 1 non-

---

<sup>1</sup>See Lord (1995) for details on U.S. sugar imports of the provisions of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) and of the North American Free Trade Agreement (NAFTA).

<sup>2</sup>In this report, U.S. sugar estimates are presented in short tons, equal to 2,000 pounds. All estimates are expressed in raw value, unless otherwise specified. One ton of refined sugar is equivalent to 1.07 ton of sugar, raw value.

industrial sector. The marketing chain from raw to wholesale to retail is shown in the middle. Fructose supply and demand are in the top, right portion. Each of these divisions are discussed in this report. At the end of the description of the flows in the model, price determination is discussed.

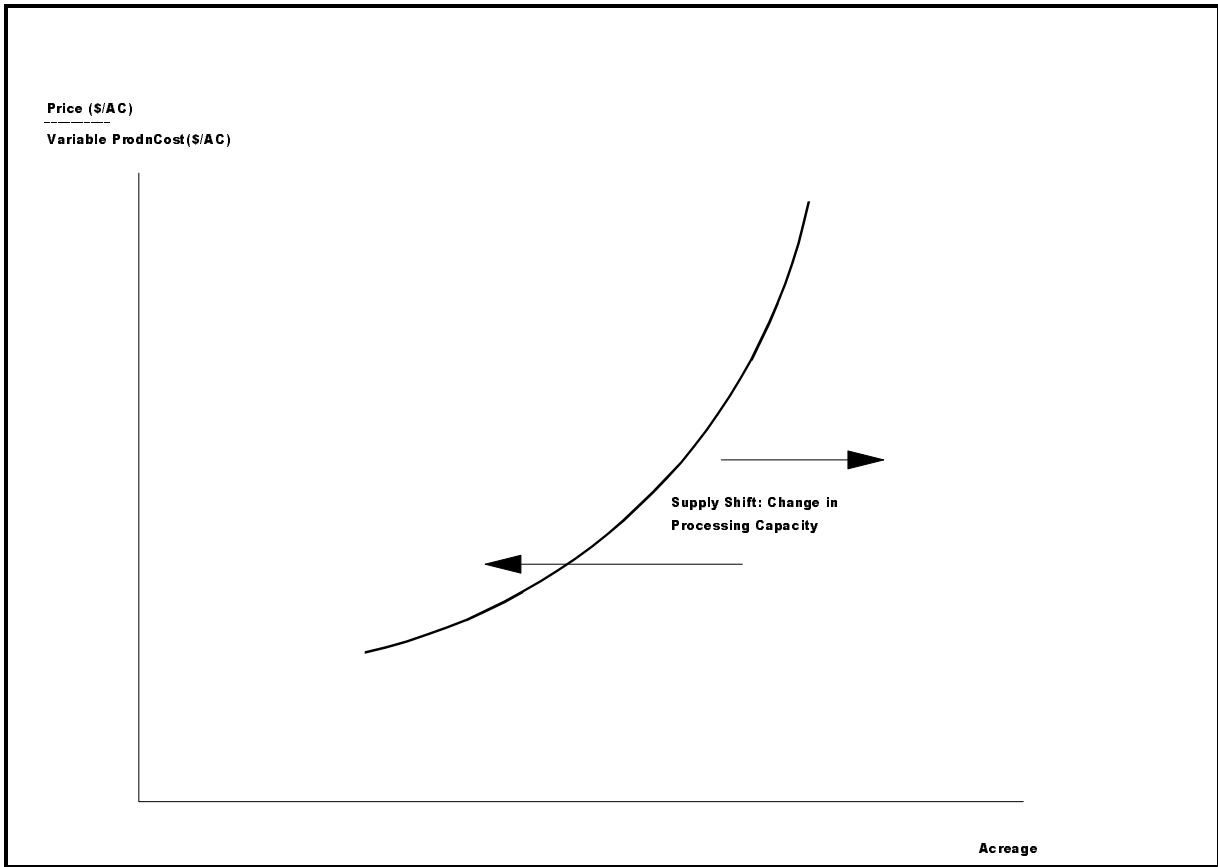


**Figure 1 - Distribution of Sweeteners**

U.S. produced sugar comes from two primary crops: sugar beets and sugarcane. Over the crop year periods 1992/93 through 1995/96, sugar from beets has averaged 4,210 thousand tons (about 55 percent of the total), and sugar from cane has averaged 3,513 thousand tons. For this study, beet and cane production areas are grouped according to how the cost-of-production data are reported. For beets, there are 5 regional aggregations. They are: (1) Far West - California; (2) Northwest - Idaho, Oregon, and Washington State; (3) Great Plains: Northern - Montana, northern Wyoming, and northwestern North Dakota; Central - Nebraska, Colorado, and southeastern Wyoming; and Southern - Texas and New Mexico; (4) Great Lakes - Michigan and Ohio; and (5) Red River Valley - Minnesota and eastern North Dakota. Cane production comes from state-based producing regions: Florida, Hawaii, Louisiana, and Texas.

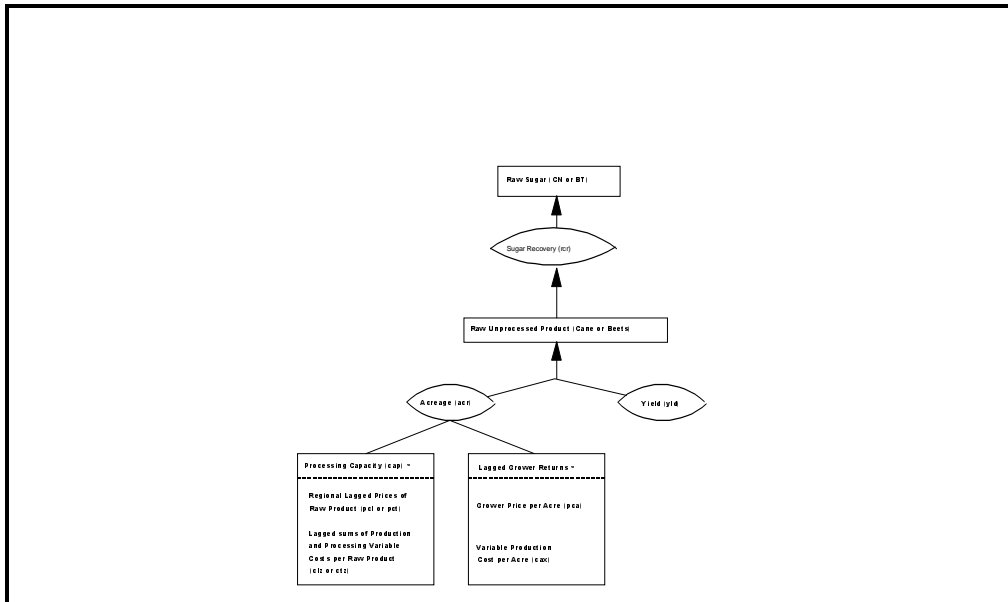
Cane and beets are distinguished from other agricultural crops in that they retain very little use or economic value until processed into a raw (cane) or refined (beets) state. The primary producers'

In figure 2, an acreage supply schedule is shown as function of the ratio of the real price of growing cane or beets (dollars/acre) to the variable costs of production. The supply schedule shifts either



**Figure 2 - Regional Acreage Supply Schedule**

rightward or leftward, depending on positive or negative changes, respectively, in processing capacity. In figure 3, processing capacity and lagged grower returns are shown to contribute to acreage allocation. Acreage times exogenous yield is the amount produced of either cane or beets. This amount multiplied by an exogenously-determined sugar recovery ratio is the region's raw sugar production.



**Figure 3 - Raw Sugar Production**

Table A-1 in the appendix to this report is a more formal presentation of the model equation structure. For estimation purposes, capacity is approximated by the maximum of the last three years' level of cane or beet production. Changes in the amount of capacity depend on processors' expected returns from investment or expected profitability. For this study, expected profitability is assumed to be a lagged function of real product prices and lagged sums of variable costs of production and processing. These lagged changes are specified to extend back in time 5 years.

Acreage is a dual function of available processing capacity and the expected returns from growing beets or cane. Expected returns are assumed to be functionally related to the ratio of real sugar price (expressed in terms of dollars/acre) to variable production costs. The lag is initially allowed to extend back 5 years.

Yield and the sugar recovery rate are assumed exogenous. For cane, each region has its own rate. For beets, a national average rate is used because the regional rates are not available. The product of acreage, yield, and recovery rate is the amount of sugar from a region.

The variable cost of production data needed to estimate these equations are available back only through 1981 and forward to 1995. Given the number of explanatory variables specified for capacity (i.e., 10) and acreage (i.e., 11) equations, there are unlikely to be sufficient degrees of freedom associated with each estimation to generate much confidence in the results. To deal with this problem, the ratio of the price to variable cost is calculated and used (at least initially) in equations. This restriction means that the value of the cost coefficient will be restricted to equal the inverse of the price coefficient. Also, a polynomial distributed lag (pdl) specification is used to further conserve the degrees of freedom. In all cases where pdl is successfully used, a second-degree specification gave

the best estimation results.

Tables A-2, A-3, A-4, and A-5 in the appendix estimation results for, respectively, cane capacity and acreage, and for beet capacity and acreage. All data are from the Economic Research Service (ERS). Statistically, estimation results are generally, but not uniformly, good. Thirteen of the eighteen equations have adjusted r-squared values above 0.80. Serial correlation presents problems in only 3 equations. The reported coefficients have theoretically correct signs and are mostly statistically significant at high confidence levels.

The processing equation results for cane (table A-2) show that capacity adjustments are fairly elastic with respect to price (all regions) and variable costs (except for Louisiana). The sum of price coefficients for each region are: Florida, 2.02; Hawaii, 2.31; Louisiana, 2.80; and Texas, 1.26. Except for Louisiana, the sum of the cost coefficients are of the same magnitude but opposite sign. The sum for Louisiana is -0.20.

The cane acreage equations (table A-3) show that acreage allocations are tied very closely to processing capacity. Only the Florida equation shows allocations being influenced by the price to variable production cost ratio. Even in that case, it is relatively inelastic, 0.29, with lower significance on each of the coefficients than seen in the processing equation results.

Beet processing equations (table A-4) show less elastic responsiveness to price and variable costs. The sum of the price elasticities for the regions are: Far West, 1.02; Northwest, 0.28; Great Plains, 0.72; Great Lakes, 0.77; and the Red River Valley, 1.54. Except for the Red River region, variable costs are of the same magnitude but opposite sign. No significant relationship between capacity and variable costs could be discerned for the Red River Valley.

Beet acreage equation results (table A-5) are mostly similar to those for the cane areas. In the two eastern regions (Great Lakes and Red River) only the capacity variable is statistically significant. In the Northwest, only the acreage price variable lagged 3 years (0.45) is significant in addition to the capacity variable. In the Great Plains the price-to-variable cost ratio with a 3-year lag is 0.43 and significant.

The Far West acreage equation provides the most contrary results. There the capacity variable is indistinguishable from zero and two of the price-to-variable cost ratio coefficients are significant. The third coefficient is shown as insignificant but there is likely a collinear relationship with the other lagged variables that cause the t-statistic to be understated. The sum of these coefficients is 1.55.

In summary, estimation results show the importance (except for the Far West beet region) of capacity adjustments in influencing production outcomes. Results indicate that cane production is more elastic than beet production with respect to real price and cost-of-production changes. An implication for any sort of domestic price-lowering reform scenario is that cane producers will more affected than will be beet producers.



## Modeling Sweetener Demand

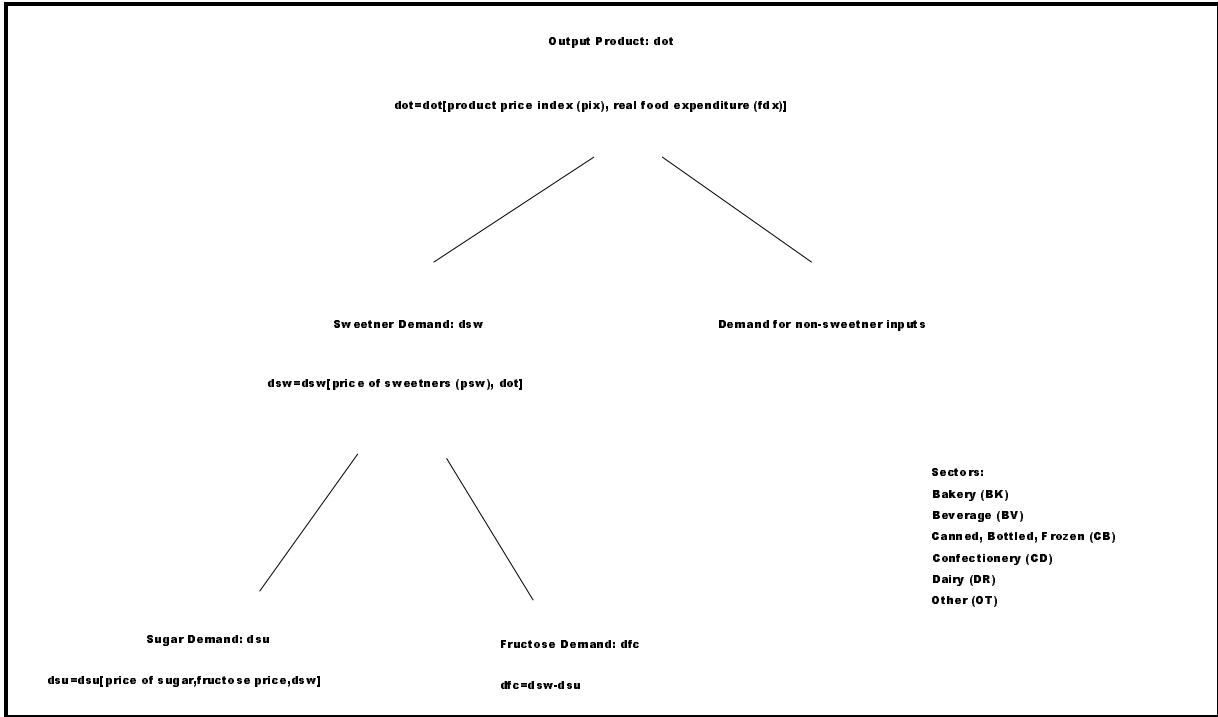
According to the GAO (1993), most econometric evidence regarding the demand for sugar and sweeteners is that it is fairly inelastic. In its own analysis of the cost of the U.S. sugar program, the GAO used a value of -0.05 for the overall demand elasticity with respect to price. Since then, Uri (1994) has argued that measurement errors have tended to bias downward measurements of the relationship between sugar demand and its own price. In his analysis, Uri stressed differences in sector demands for sugar, especially between beverage and non-beverage demanders. His results indicate that the value of the sugar demand elasticity has varied according to the periods where high fructose corn syrup (HFCS) has been replacing sugar in the beverage industry. In the most recent period, he argues, the elasticity is in the neighborhood of -0.50. An implication, Uri notes, is that the GAO has very likely overstated the cost of the U.S. sugar program due to its assumption of the low demand responsiveness to price changes.

In this section, the demand for sweetener, sugar, and fructose is examined and elasticities estimated for 6 industrial users (intermediate demanders) and for the non-industrial sector (final demanders). For both sets of demanders, elasticities are estimated using an Almost Ideal Demand Systems (AIDS) approach. For industrial users, this approach emphasizes differences between sectors in the substitutability between sugar and fructose. For non-industrial users, the approach emphasizes differences between the direct purchase and use of sugar, and consumption of products containing sugar and fructose.

### Sectoral Demand for Sweeteners

ERS tracks sugar and fructose (through 1995) deliveries to 6 industrial users: bakeries, beverage producers, processed products (canned, bottled, and frozen foods), confectionery producers, dairy uses (e.g. ice cream), and other food and non-food users. The degree to which sugar and fructose substitute for each other varies in each use. In the beverage industry, fructose has almost totally replaced higher-priced sugar. In the confectionery industry, fructose demand is not significant.

Figure 4 illustrates a three-stage analytical framework utilized in this report. In an initial stage, there



**Figure 4 - Sector Demand for Sweeteners**

is demand for the output product which is a function of a real consumer price index and real food expenditure. In the first stage, producers demand both sweeteners and non-sweetener inputs. The demand for sweeteners is function of the real sweetener's price and the level of production of output. In the second stage, the choice of how much sugar and fructose to use to satisfy first-level sweetener demand is determined.

Table A-6 in the appendix shows stages 1 and 2 more formally. The sweetener's price is a combination of real sugar and fructose prices weighted by their use-shares in each sector. It, along with how much final output is to be produced, determines the sectoral demand for sweeteners. Sugar's share of sweetener's demand is a function of its real price, the real price of fructose, and the level of overall sectoral demand for sweeteners. The demand share of fructose is shown as residually determined.

First stage estimation results for the 6 sectors are shown in Table A-7. Estimation results are generally good, with reasonably high adjusted r-squares and satisfactory Durbin-Watson statistics. Four of the sectors show responsiveness to real price changes: bakery, -0.41; beverages, -0.33; confectionery, -0.27; and dairy, -0.11. All except dairy are highly significant (the dairy coefficient being significant at  $\alpha=0.14$ ). Results show that demand for sweeteners expands at the same rate as the demand for the output for the bakery, beverage, and Other Use industries. The expansion is less than proportional for confectionery (0.67), dairy (0.54), and canned, bottled and frozen foods (0.35).

Second stage estimation is based on the Almost Ideal Demand system (AIDS) developed by Deaton and Muellbauer (1980). Sugar's share of total sectoral sweetener demand is regressed on the logs of real prices for sugar and fructose and on the log of the quantity of sweetener demanded in each sector. Unlike other equations discussed in this report, estimated coefficients are not themselves elasticities. They are used to calculate the elasticities, which are variable from year-to-year. Equation results for the bakery, canned, bottled and frozen foods, dairy, and Other Uses are shown in Table A-8. Estimation for the confectionery sector is not needed because the sector makes little use of fructose. Specification and results for the beverage sector are discussed below.

Results for the bakery and for canned, bottled, and frozen uses are good - high adjusted r-squares and satisfactory Durbin-Watsons. The Other Uses results are somewhat less satisfactory but not bad (adjusted r-square = 0.56). The dairy results are the least satisfactory but still usable (t-statistic on the quantity variable indicating significance, and an adjusted r-square of 0.24).

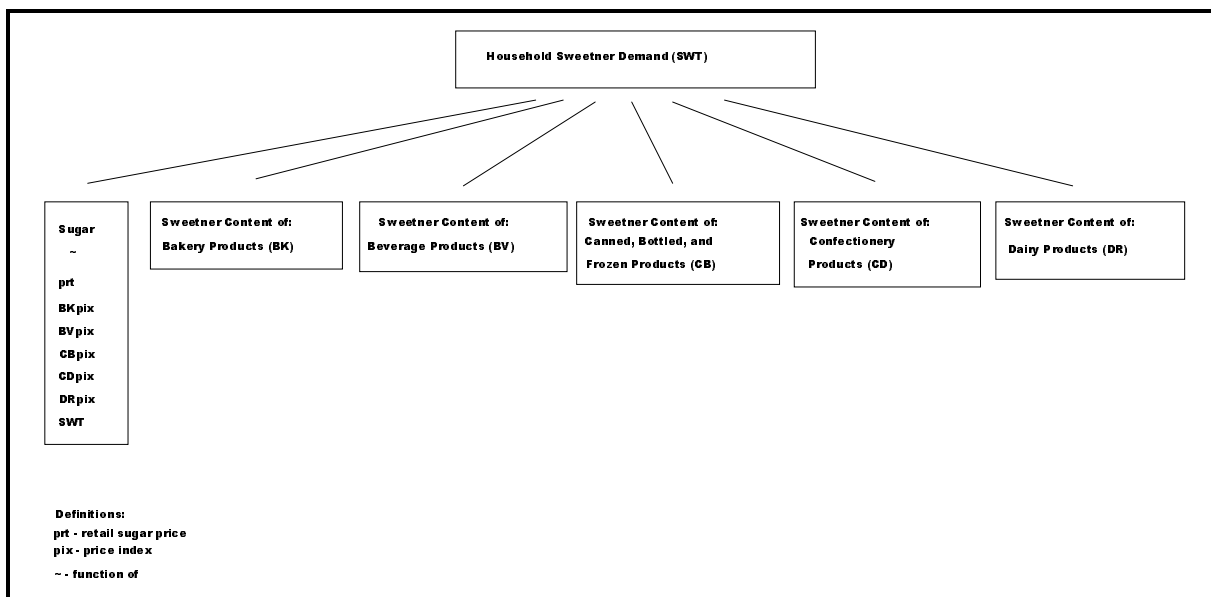
The AIDS framework is modified for beverage equation. The reason is that this sector experienced dramatic structural change in its sweeteners use during in the estimation period. In the early period (1975-76) sugar satisfied nearly all the sectoral sweetener demand. Over the period 1977-84, sugar use was being largely replaced by fructose, especially HFCS-55. From 1985 onward, the sector's use of sugar has been very marginal.

The modified framework and results are shown in Table A-9. The modification follows that made by Moschini and Meilke (1989) in their examination of structural change in meat demand, which in turn is based on the modification more generally developed by Ohtani and Katayama (1986). The revision involves the use of an interaction variable  $h$ . The variable takes a value of zero for the period of sugar's sectoral dominance (1975-76) and a value of one for the period where fructose is clearly dominant (1985-95). During the transition period, yearly values for  $h$  grow proportionally from 0 to 1, as shown in the table. The  $h$  variable interacts multiplicatively with the customary price and quantity variables in the AIDS modified model. The formulas showing the modified elasticity calculations are reported in Moschini and Meilke. The estimation results shown in the table are very good. The adjusted r-square is over 0.99 and the Durbin-Watson is 2.22. Most t-statistics on the individual coefficients are highly significant.

Table A-10 shows the elasticity estimates implied by the estimation. The first two columns of results repeat the first stage results already seen. The next three columns show the second stage elasticities. Because the elasticities vary from year-to-year, averages over the estimation period are reported. The revealed own-price elasticities are shown to be fairly elastic: bakery, -1.07; beverage, -3.43; canned, bottled, and frozen foods, -0.88; dairy, -0.75; and Other Uses, -1.13. Homogeneity conditions (elasticities summing to zero) are largely maintained except for the beverage sector where the quantity elasticity seemed hard to interpret due to the structural change over the estimation period.

### Non-industrial Demand for Sugar

Households consume sugar in a variety of products. These products are either (1) purchased already containing sweeteners or (2) are prepared by the consumer who mixes or adds refined sugar purchased separately. Figure 5 shows the two-stage sweetener demand process. In the first stage



**Figure 5 - Non-industrial Sugar Demand**

households demand sweeteners, independent of explicit form. In the second stage, the manifested form of the sweetener demand is determined. The second stage incorporates implicitly the rates of substitution in consumption between the various sweetener-containing products and refined sugar.

Table A-11 shows a more formal specification of households' sweetener demand. There are 6 sectors: sugar; bakery; beverages; canned, bottled and frozen foods; confectionery products; and dairy. Sweeteners embedded in each sector are a combination of the sector's demand for sugar and fructose. Total sweetener use is the summation of the sectors' uses. First-stage demand is assumed to be a function of an aggregate, sector-weighted sweetener's price and the real expenditure on food. Second-stage household demand for a sector's sweetener product is assumed to be a function of real prices and the total amount of sweeteners demanded.

First-stage demand is estimated with a correction for serial correlation. The adjusted r-squared is 0.9724 and the Durbin-Watson is 2.03. The coefficient of the constructed sweetener's price index could not be statistically differentiated from zero. The coefficient on real food expenditure is 1.5217, with a highly significant t-statistic of 11.8096. These results indicate that household sweetener demand is completely inelastic with respect to price but has been expanding at 50 percent greater rate than real food expenditure.

A system of equations is estimated (Seemingly Unrelated Regression with theoretical restrictions on coefficients) for the second stage. Table A-12 shows the systems results for non-industrial sugar demand. There are shown two versions of the equation. The first includes a squared term for the

sweetener quantity variable, and the second has instead a time trend variable. Because results from the first equation are slightly better (higher adjusted r-squared and a Durbin-Watson closer to 2.00), they are used to calculate elasticities. The second version is included for explanatory purposes because the time trend coefficient is easier to interpret than the squared quantity term and the coefficient values in both versions are close.

Both versions have an adjusted r-squareds higher than 0.80, but have lower than ideal Durbin-Watsons in the range 1.08-1.12. Coefficients are significant on the bakery and beverage price coefficients, on the sweetener quantity variables, and on the time trend in version 2. The coefficient on the dairy price is restricted so that homogeneity across the price variables holds. Version 2 results indicate that, all else constant, the non-industrial's share of the total sweetener use is declining at a rate of -0.0136 over the estimation period.

The lower panel shows the implications of version 1 estimation results for non-industrial demand elasticities. Because in the AIDS specification elasticities vary yearly, elasticities averaged over the estimation period are shown. The results show the own-price demand elasticity is fairly high, -0.78. Given that non-industrial sugar demand does not seem to grow as overall demand for sweeteners grows (elasticity with respect to quantity = 0.03), any expansion in household sugar demand will have to be price-induced.

### **Modeling Processing Stages**

The price that consumers pay for sugar is not the same as that received by wholesalers or raw sugar producers and importers. There are margins between retail, wholesale, and raw sugar prices that reflect the contribution of marketing inputs in transforming sugar from raw to retail states. Marketing inputs are constituted by many factors, such as transportation, packaging, advertizing expenses, labor

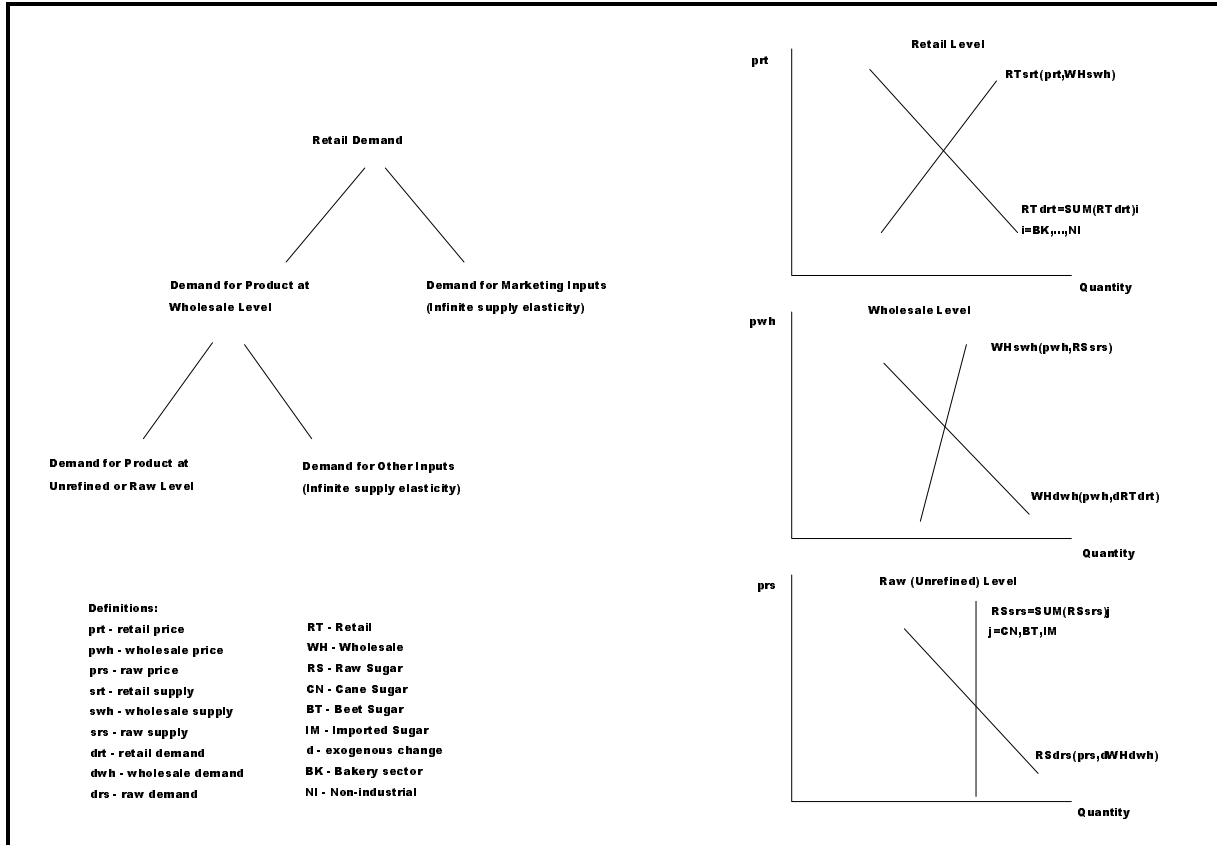


Figure 6 - Structure and Modeling of Processing Stages

inputs, etc.

Figure 6 shows the stages. The left panel shows the tree diagram arrangement, and the right panel shows the stages in a demand-supply context. The retail sector demands sugar from wholesalers, and the sugar is combined with marketing inputs before final sales are executed. The marketing inputs are assumed to be available at set prices (infinite supply elasticity). Likewise, wholesalers demand raw sugar (cane) or refined sugar (beets) from on-site production or importing locations. Marketing inputs, also assumed available at set prices, assist in getting the sugar to the wholesale level.

In the top right panel, retail demand ( $RT_{drt}$ ) is a summation of demands from individual sectors. Retail supply ( $RT_{srt}$ ) is a function of wholesale supply, and the retail price. A non-zero own-price supply elasticity reflects substitution possibilities between sugar and marketing inputs. If the wholesale sugar price increases and the quantity demanded by the retail sector remains unchanged by assumption, assumed-available substitution possibilities imply the increased use of marketing

inputs. Increased usage of the inputs, with the same level of wholesale demand, implies an increase in retail supply, but at the same time a decrease in the marketing inputs' marginal productivity. Declining productivity requires an increase in the retail sugar price to compensate for revenue which now falls short of increased expenses. Thus, increased retail supplies become available only if the retail sugar price increases; that is, the retail sugar schedule must be upward sloping with respect to own price.

The wholesale level is shown in the right, middle panel. Wholesale supply is understood in a way analogous to retail supply. Wholesale demand reflects demand for the final product and substitution possibilities with marketing inputs. If there were no substitution possibilities between marketing inputs and wholesale sugar, wholesale sugar would constitute a constant proportion of the retail sector costs, implying that the wholesale price is a fixed proportion of the retail price. On the other hand, if there were substitution possibilities, wholesale sugar demand could compensate for changes in marketing input prices, implying greater elasticity in wholesale sugar demand.

The raw level is in the bottom, right panel. The demand for raw sugar comes from the wholesale level. It is understood in a way analogous to wholesale demand being a function of retail demand. Supply is a summation of supplies from domestic cane and beet sectors, and from imports.

Table A-13 in the appendix shows the between-level supply-demand relationships in algebraic terms when the supply of marketing inputs is assumed infinitely elastic (Muth, 1964). The derived demand specification is the first equation in the table, and the supply specification is the second equation. The derived demand elasticity specification shows derived demand as function of higher stage demand (share of costs multiplied by the higher-stage elasticity value) and of substitution possibilities (elasticity of substitution multiplied by the marketing cost share proportion). The second equation shows that upward sloping supply depends on a non-zero substitution elasticity.<sup>3</sup>

Estimation of relevant parameters follows procedures developed by Wohlgenant and Haidacher (1989). They were interested in linking farm price changes to retail level price changes for several agricultural commodities. They took Muth's system (Table 13) as a starting point and systematically developed an econometric specification that would permit an estimate of a lower-stage demand elasticities and of the elasticities of substitution between farm-level commodities and marketing inputs.

Equations in the table 14 show higher-level (retail and wholesale) and lower-level (wholesale and raw, respectively) prices as functions of marketing costs (W), demand shift variables (Z), and the quantities demanded as inputs ( $Q_{WH}$  and  $Q_{RS}$ ), respectively. In this report, the total marketing cost index from the ERS publication, Food Cost Review, is used as "W". Retail demand shifters Z are calculated sector by sector based on the demand equations estimated earlier for this study. They measure the effect of all changes due to non-sugar price variables. The sector effects are summed and used as the

---

<sup>3</sup>The input supply elasticity  $e_j$  equals zero because supply is a function of lagged prices, that is, inelastically supplied with respect to the current price.

independent, explanatory variable  $Z$  in the equations. Expected coefficient signs are positive for  $Z$  and negative for  $Q$ . The sign on  $Z$  is theoretically ambiguous. Other conditions, such as constant returns to scale and symmetry conditions, can be examined as well.

Table 15 shows estimation results (top panel) and implications for elasticities (bottom panel). In all three equations, the signs on the retail demand shift variables and quantity variables are of the correct sign and highly significant. Adjusted  $r$ -squares are 0.775 for the retail price equation (good result), 0.679 for the wholesale price equation (good result), and 0.297 for the raw price equation (could be better). Durbin-Watson values are all acceptable.

Elasticity calculations are dependent on the estimate for retail demand, which is calculated outside the estimation system. In the table it is shown equal to -0.86, which is a weighted-average of the sectoral and non-industrial elasticities estimated earlier. The wholesale demand elasticity is the inverse of the wholesale sugar coefficient in the wholesale price equation, -1.30. These two values imply an elasticity of substitution between wholesale sugar and marketing inputs equal to 1.56. This value in turn implies a retail supply elasticity equal to 0.56. The raw demand elasticity is the inverse of the raw sugar coefficient in the raw price equation, -0.89. The ratio of the raw to the wholesale elasticities is about equal to the ratio of raw to wholesale prices. This equality implies that there are no substitution possibilities between raw sugar and marketing inputs; therefore, the wholesale supply elasticity is zero.

### **Modeling System Closure**

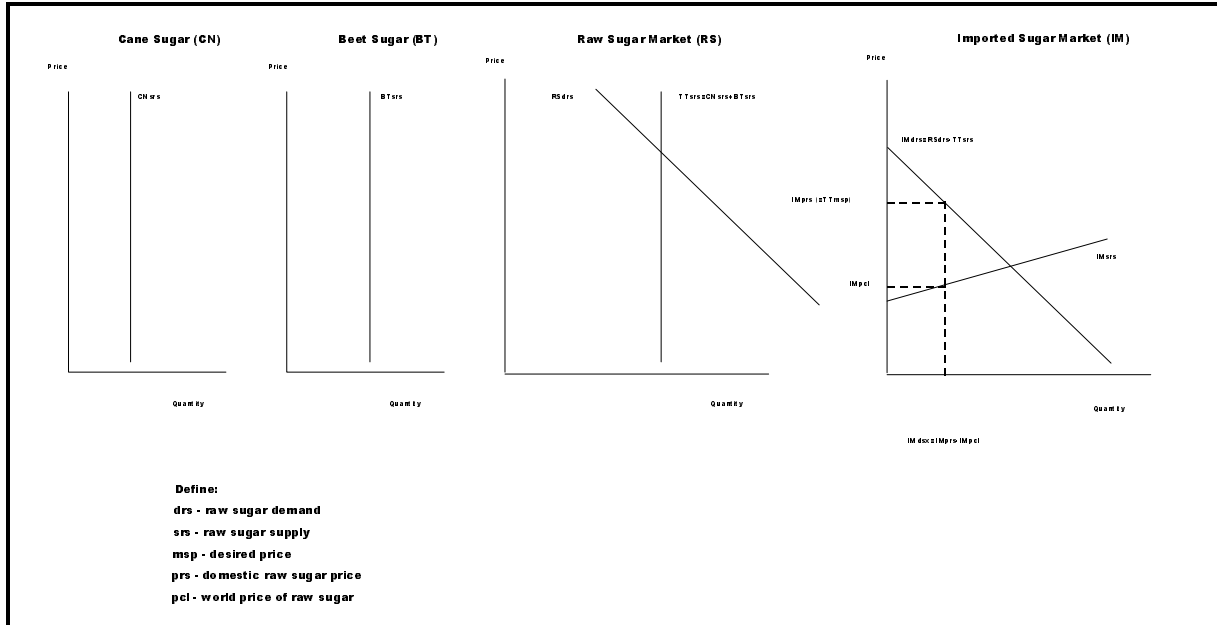
Price determination within the system requires a closure mechanism. In the generic, small country trade model, trade is the difference between production and consumption, with adjustments made for stock changes. The domestic price may be imperfectly linked to the world price. Differences between the two prices constitute price wedges, portions of which may be specified to represent policy-induced tariff-like or export subsidy-like distortions. World price changes may be specified to have muted domestic price effects through imperfect price transmission mechanisms.<sup>4</sup>

---

<sup>4</sup>For example, the specification of zero price transmission could mimic the workings of a variable levy system. The link between domestic and world prices is effectively severed by making tariffs adjust endogenously to fix the domestic regardless of world price changes.



Although the modeling system described in this report is more complex than most, price-determination is dealt with in similar ways. The United States imports raw sugar but attempts to control the amount to achieve a desired domestic price. Figure 7 shows the workings of the system. Domestic sugar comes from cane (CN) and from beets (BT). In the chart, their supply schedules are



**Figure 7 - Sugar Import Determination**

shown as perfectly inelastic because production has been specified as a function of lagged real prices and variable costs. Sugar summed from the two sources constitute domestic supply (TTsrs in the third panel). Demand comes from the wholesale sector (RSdrs). If the United States were a closed market, the intersection of these two curves would determine the market-clearing price. However, because the United States imports sugar, the price at which the two intersect determines the vertical intercept of the excess demand schedule IMdrs in the fourth panel. This schedule slopes downward as imports increase, the distance between it and the axis being equal to the distance between RSdrs and TTsrs in the third panel.

Supplies available for import into the United States are represented in the fourth panel as IMsrs. The curve is shown here sloping upward, indicating that increased imports into the United States can only result by higher prices being paid to divert sugar from other customers. If the world price were not affected by the level of U.S. imports, the schedule would be shown as perfectly elastic or diagrammatically, as a horizontal line at the world price. In an undistorted trade equilibrium, the level of imports and the price would be determined at the intersection of IMdrs and IMsrs.

The presumed ability to map a level of imports to a desired price via the IMdrs schedule closes the system. Import levels fluctuate yearly to meet price targets. The vertical distance between the domestic price IMprs and the world price IMPcl is an endogenously determined tariff-like price wedge.

## Two Additional Modeling Assumptions

Two elements currently missing from the discussion to this point are a specification of the fructose production sector and the degree to which increased U.S. sugar imports may affect the world price of raw sugar. Specification and estimation of a fructose producing sector has not been attempted in this research. Because it derives from corn in the wet-milling process, which produces other products like corn gluten feed and meal, a reasonable modeling effort would likely add costly complexity without assuring a corresponding increase in benefits. The simpler approach taken here is to specify a unitary elastic supply correspondence between the price of fructose and resulting level of production. Essentially this specification says that a one-percent reduction in the price of fructose leads to a one-percent reduction in the amount supplied. Although this relationship may seem somewhat arbitrary or restrictive, the advantage lies in the ease of performing sensitivity analysis to other responsiveness-levels.

The model used for this analysis focuses exclusively on demand and supply relationships within the United States. Because levels of sugar imports have been strictly controlled by policy makers, the closed-economy specification of the sweetener sector has not been inappropriate for analysis. Opening the sector to more world-wide developments surely changes previously assumed relationships. One way to deal with the change is to assume that the United States is a "small-country" when it enters into the world market. Although this specification would be the simplest to deal with (that is, there are no effects on the world price of sugar as the United States imports more), it does not seem very realistic. A currently-used "rule of thumb" is that a 1 million ton increase in world sugar excess demand leads to a 1.5 cent a pound increase in the world price. Translated into modeling terms, this means that for the initial level of U.S. imports of about 2.5 million tons in 1995, the resulting world excess supply elasticity would be about 2.5. This elasticity-value is about equal to that estimated by Hammig et al. (1982) and used by Leu et al. (1987), but may be low according to Marks (1993). It is used for this analysis. Other values and even lagged responses can be specified as alternatives for sensitivity analysis.

### **Liberalization of U.S. Sugar Policy**

The model that has been described is used to draw out the economic implications of reform of the U.S. sugar policy. Although unlikely in the real work, the current policy is assumed totally and immediately eliminated in the modeling experiment described in this paper. The goal is to focus on the worst-case scenario for the producing sector. The results are useful in estimating the cost of the program to the U.S. economy.

In order to perform this experiment, two modeling scenarios are run. The first assumes that current policy remains in force for the ten-year period over which the model simulates. This scenario is called the "base" and serves as a standard to which to compare the reform scenario. This first scenario assumes that the real domestic price of raw sugar is maintained at 18.42 cents a pound over the ten-year period. Imports are specified to adjust in order that demand and supply exactly balance each other at this price.

The second scenario captures the effects of abandoning the policy. There is no longer assumed to be a price wedge separating the levels of the domestic and world prices. The greater availability of raw sugar at lower prices would be expected to be rapidly absorbed by increased demand. The domestic producing sectors would take more time in adjusting to reduced prices, however. For this reason, the comparison of results focuses on the last year of the ten-year period.

Results: Supply

Tables T-1, T-2, and T-3 show final-year results for the reform and base scenarios for prices, production quantities, and demand quantities, respectively. As more imported sugar enters, domestic and world raw prices converge. The domestic raw price falls by 4.3 cents a pound (about 23 percent) to 14.2 cents a pound. Refined and wholesale prices decrease by somewhat less, 3.6 cents a pound, which is a reduction in the 14-17 percent range. Fructose prices fall by 1.2 cents a pound, or by 7.6 percent.

<b>Table T-1 - Predicted Outcomes for Sugar Program Elimination: Price</b>				
<b>Prices: Cents per pound</b>				
Type of Price	Base	Reform	Difference	Percentage
Refined	27.24	23.62	-3.62	-13.3%
Wholesale	21.75	18.12	-3.63	-16.7%
Raw	18.43	14.16	-4.32	-23.4%
World	7.32	14.51	7.19	98.2%
Fructose	15.99	14.76	-1.22	-7.6%

Domestic cane production falls by 38 percent compared to the base. The biggest regional losses are in Louisiana (55 percent) and in Hawaii (50 percent). Production from Florida suffers relatively less although the production level is down by over 500,000 tons. After reform, over 60 percent of the cane crop is centered in Florida, up from 51 percent in the base.

Decreases in beet production are much less than in cane. The overall loss is over 900,000 tons, which is a reduction of under 19 percent. The Far West region, mainly California, experiences the greatest

**Table T-2 - Predicted Outcomes for Sugar Program Elimination**

**1,000 tons**

Source	Base	Reform	Difference	Percentage
Cane	4,100	2,542	-1,558	-38.0%
Florida	2,100	1,547	-553	-26.3%
Hawaii	719	361	-357	-49.7%
Louisiana	1,104	490	614	-55.6%
Texas	177	144	-33	-18.6%
Beets	4,856	3,943	-913	-18.8%
Far West	872	613	-259	-29.7%
Northwest	965	816	-149	-15.4%
Great Plains	788	671	-117	-14.8%
Great Lakes	471	395	-76	-16.2%
Red River Valley	1,759	1,448	-311	-17.7%
Imports	1,142	6,317	5,174	452.9%
Raw Sugar	10,098	12,802	2,704	26.8%
Fructose	8,628	7,968	-660	-7.6%

percentage loss (almost 30 percent). Percentage losses for the 4 other regions are in the 15-18 percent range.

In the base, domestic production covered 89 percent of domestic deliveries: 48 percent for beets and 41 percent for cane. In the reform scenario, domestic production covers only 51 percent, with cane covering 20 percent and beets, 31 percent. The United States, therefore, is much more dependent on imports, but still produces a sizable portion of what it consumes.

Results: Demand

Demand for refined sugar increases by over 1.5 million tons or 17 percent over the base. About 70 percent of this growth comes from industrial or intermediate demand, and 30 percent from non-industrial or final demand. The industrial demand growth is about 20 percent higher than in the base, and non-industrial growth is about 12 percent higher.

**Table T-3 - Predicted Outcomes for Sugar Program Elimination: Demand**

**1,000 tons**

Type of Demand	Base	Reform	Difference	Percentage
Industrial	5,244	6,295	1,051	20.0%
Bakery	1,689	2,205	515	30.5%
Beverage	256	341	115	51.2%
Processed Foods	294	333	38	13.0%
Confectionery	1,390	1,459	69	5.0%
Dairy	479	550	71	14.9%
Other	1,136	1,407	271	23.9%
Non-industrial	3,663	4,095	432	11.8%
Total	8,878	10,390	1,512	17.0%

Among industrial users of sugar, the largest volume growth comes from the bakery sector (515,000 tons), then the Other Uses sector (271,000 tons), and then the beverage sector (115,000 tons). In terms of percentage growth, the beverage sector growth is the highest (51.2 percent), then bakery (30.5 percent), and Other Uses (23.9 percent). Although the beverage demand growth sounds impressive, the effect on that sector's use of fructose is only marginal. In the tenth year of the base, sugar comprises 3.37 percent of that sector's sweetener use. In the same year of the reform scenario, it rises only to 4.95 percent. There is no reversal of the switch to fructose.

There are cost savings to industrial and non-industrial users as a result of reform. By the tenth year, industrial sugar users are paying about \$393 million less on sweeteners (both sugar and fructose) than in the base. This amount is a 7.8 percent cost savings. Consumers of refined sugar are saving about \$61 million; that is, buying more sugar at a lower price and still expending less in total, 3.1 percent.

#### Welfare Effects

The cost of the U.S. sugar program can be estimated by summing the consumer gains from reform

with the producer losses. The net benefit reflects the "dead-weight" cost imposed by the program on the U.S. economy. Many studies have used these standard welfare measures of "consumer surplus" and "producer surplus" for welfare evaluation. Because it is the most recent study, results from the GAO study tend to be quoted the most, especially by critics of the current program. They show consumer losses in the early 1990's of about \$1.4 billion a year. The loss is offset by gains to sugar producers of \$561 million and fructose producers of \$548 million. The "deadweight" loss is the remainder, or \$291 million a year.

The current study is different from the GAO. The GAO assumed a very reduced-form, simplified structure in making their estimates. The current study is much more detailed. Both studies rely on econometric evidence, although the GAO synthesizes the work of others at arriving at consensus elasticity values.

The most obvious difference between the two studies is that the current one has a much more elastic demand structure. (Both studies assume similar upward sloping excess supply (ES) schedules from import suppliers.) The implications for differing welfare results can be illustrated by Figure 8. In the diagram, the demand schedule D1 is assumed more elastic than D0. With the same supply schedule

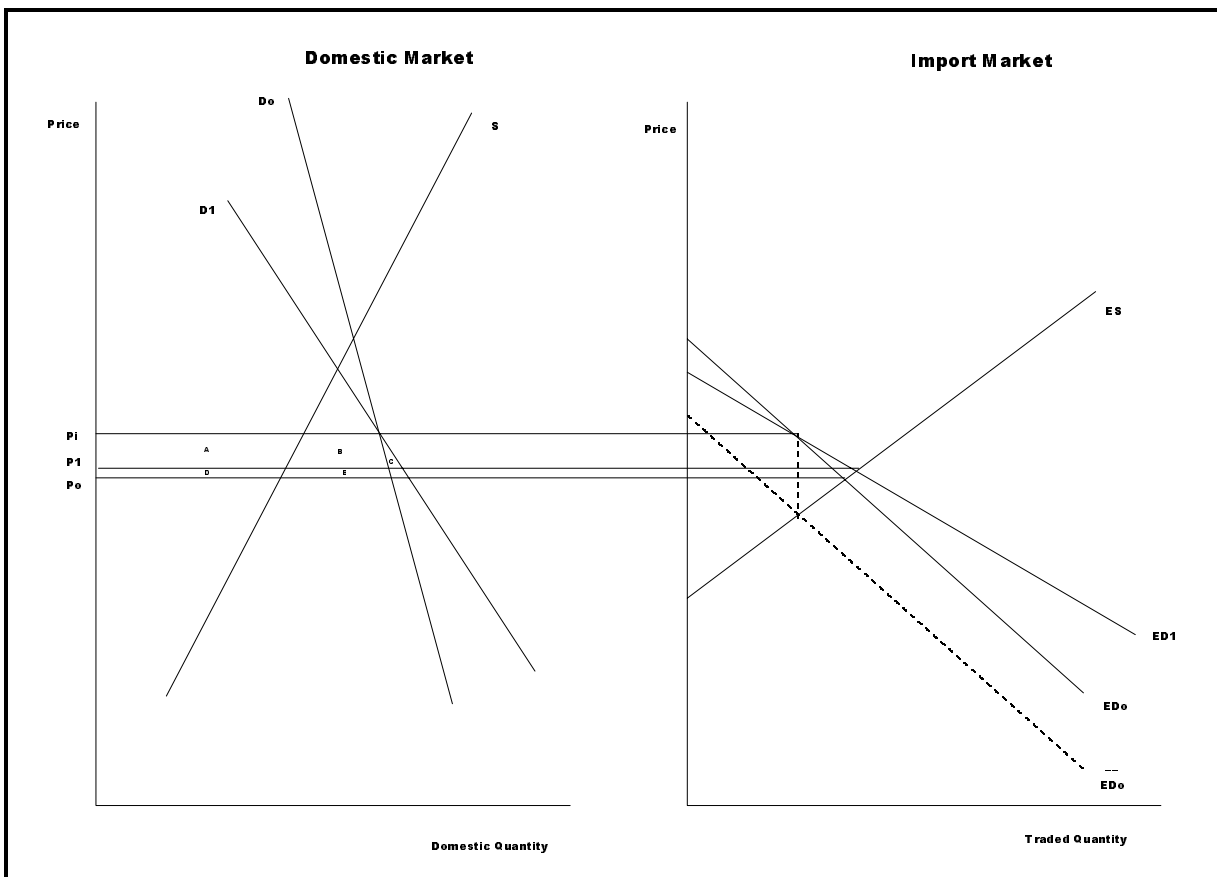


Figure 8 - Welfare

S, differing domestic demand elasticities imply differing excess demand elasticities (ES1 more elastic than ESo) in the world market shown in the right panel. Assuming a common initial price of  $P_i$  and a common tariff-equivalent representing the effect of the program, differential effects of reform can be traced out. With more elastic demand, more is demanded domestically and the world price must decrease by less ( $P_1$  compared to  $P_0$ ) in order to draw in more imports. With more elastic demand, the change in producer surplus is area  $-A$  and the change in consumer surplus is  $A+B+C$ , for a net effect of  $B+C$  (there is no, or at least very minimal, tariff revenue to consider). For the more inelastic specification, the producer loss is  $-(A+D)$  and the consumer gain is  $A+B+D+E$ , for a net gain of  $B+E$ . A comparison depends on the size of  $C$  relative to  $E$ . Therefore, a welfare comparison becomes an empirical matter, unresolved by theory.

The current study differentiates intermediate and final demand. Consumer surplus for final demand is summed with sweetener cost reductions for the intermediate sectors to produce a total benefit of \$673.7 million of the reform (Figure 9). On the producer side, the regional processed price of sugar

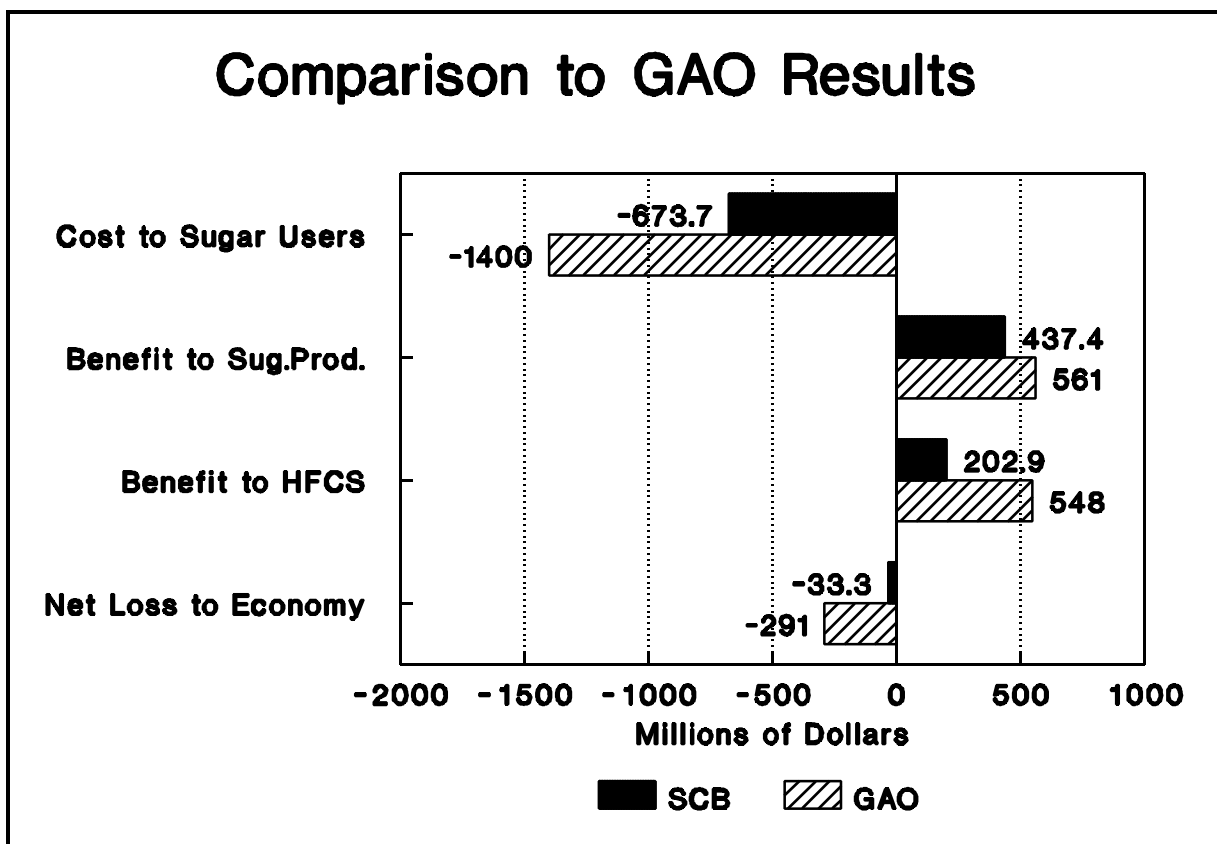


Figure 9 - Costs of Sugar Program

less the sum of unit production and processing costs is calculated and multiplied by production levels to yield a net return to fixed factors. These amounts are summed across producing regions for the base and reform scenarios in the tenth year. The difference represents the total change in return to fixed factors in the production and processing of sugar. This amount equals \$437.4 million. The loss

to fructose producers is calculated as the change in producer surplus; that is, \$202.9 million. Subtracting producer losses from consumer gains indicates a "deadweight" loss of \$33.3 million, an amount substantially less than that indicated by the GAO (\$291 million). These results suggest a greater efficiency in supporting sugar and fructose producers and processors by the current program than what is seen in other studies.



## References

- Deaton, A., and J. Muellbauer. (1980) "An Almost Ideal Demand System," American Economic Review. Vol. 70, pp 312-26.
- Hammig, M., R. Conway, H. Shapouri, and J. Yanagida. (1982) "The Effects of Shifts in Supply on the World Sugar Market," Agricultural Economics Research. Vol. 34, pp 12-18.
- Leu, G., A. Schmitz, and D. Knutson. (1987) "Gains and Losses of Sugar Program Options," American Journal of Agricultural Economics. Vol. 69, pp 591-602.
- Lord, Ron (1995) "U.S. Sugar Import Duties," Sugar and Sweetener Situation and Outlook Yearbook. Econ. Res. Serv., U.S. Dept. Agr., SSSV20N4, December, pp16-17.
- Marks, S.V. (1993) "A Reassessment of Empirical Evidence on the U.S. Sugar Program," in The Economics and Politics of World Sugar Policies. S.V. Marks, and K.E. Maskus (eds), Univ. of Michigan: Ann Arbor, Michigan.
- Moschini, G., and K.D. Meilke. (1989) "Modeling the Pattern of Structural Change in U.S. Meat Demand," American Journal of Agricultural Economics. Vol. 71, pp.253-61.
- Muth, R.F. (1964) "The Derived Demand for a Productive Factor and the Industry Supply Curve," Oxford Economic Papers. Vol. 16(2). pp 221-34.
- Ohtani, K., and S. Katayama. (1986) "A Gradual Switching Regression Model with Autocorrelated Errors," Economic Letters. Vol. 21, pp 169-72.
- Uri, N. (1994) "A Re-Examination of the Demand for Sugar in the United States," Journal of International Food and Agribusiness Marketing. Vol 6(2), pp 17-43.
- U.S. Department of Agriculture, Economic Research Service. Sugar and Sweetener Situation and Outlook Report. various issues, Washington, DC.
- \_\_\_\_\_. (1996) Food Consumption, Prices, and Expenditures, 1996. Stat. Bull. No. 928, Washington, DC.
- \_\_\_\_\_. (1996) Food Cost Review. AER No. 729, Washington, DC.
- U.S. General Accounting Office. (1993) Sugar Program: Changing Domestic and International Conditions Require Program Changes. GAO/RCED-93-84. Washington, DC.
- Wohlgemant, Michael K., and Richard C. Haidacher. (1989) Retail to Farm Linkage for a Complete Demand System of Food Commodities. Econ.Res.Serv., U.S. Dept. Agr., Technical Bulletin No. 1775.

**Table A-1 - Supply Equation Structure**

Definitions

Capacity	
proxy (CP):	Maximum of previous 3 years of cane (CN) or beet (BT) production
acr:	Acreage Harvested
yld:	Average yield per region (exogenous)
rcr:	Recovery rate (percentage of sugar from cane or beets) (exogenous)
srs:	Supply (s) of raw sugar (rs)
pcl:	Price (pc) per pound (l)
pct:	Price (pc) per ton raw product (t)
clx:	Cost (c) per pound (l) of production (x) (exogenous)
cly:	Cost (c) per pound (l) of processing (y) (exogenous)
clz:	Cost (c) per pound (l) of the sum (z)
ctx:	Cost (c) per ton raw product (t) of production (x)
cty:	Cost (c) per ton raw product (t) of processing (y)
ctz:	Cost (c) per ton raw product (t) of sum (z)
cax:	Cost (c) per acre (a) of production (x)
":#":	variable lagged # periods

Equations

Capacity proxy definition:

$$CP_{CN} = \text{MAX}(CN:1, CN:2, CN:3)$$

$$CP_{BT} = \text{MAX}(BT:1, BT:2, BT:3)$$

Cost Equations:

$$\begin{aligned} clz &= clx + cly \\ ctx &= clx * (rcr/100) * (2000lb/tn) * (\$/100cents) \\ cty &= cly * (rcr/100) * (2000lb/tn) * (\$/100cents) \\ ctz &= ctx + cty \\ cax &= ctx * yld \end{aligned}$$

Estimable Capacity equation:

$$CP_{CN} = CP(pcl:1, \dots, pcl:5; clz:1, \dots, clz:5)$$

$$CP_{BT} = CP(pct:1, \dots, pct:5; ctz:1, \dots, ctz:5)$$

Estimable Acreage equation:

$$ACR_{CN} = ACR(CP_{CN}; pca:1, \dots, pca:5; cax:1, \dots, cax:5)$$

$$ACR_{BT} = ACR(CP_{BT}; pca:1, \dots, pca:5; cax:1, \dots, cax:5)$$

Sugar Production:

$$CN_{SRS} = ACR_{CN} * YLD_{CN} * RCR$$

$$BT_{SRS} = ACR_{BT} * YLD_{BT} * RCR$$

**Table A-2 - Processing Capacity Equations: Cane**

Variable/ Equation Stat	Florida	Hawaii	Louisiana	Texas
Constant	-0.7533 (0.3516)	-1.8622 (0.9789)	2.1687 (0.9539)	0.1290 (0.0958)
Indicator Variable*	-	-	0.0708 <sup>1</sup> (6.2085)	-
pcl:1	-0.2421 (1.3627)	0.8804 (6.3213)	0.5619 (1.7154)	0.3105 (5.7575)
pcl:2	0.2567 (2.2185)	0.6713 (7.6127)	0.5614 (2.1322)	0.2808 (6.2182)
pcl:3	0.7554 (6.5358)	0.4621 (5.6790)	0.5609 (2.7145)	0.2510 (5.7211)
pcl:4	1.2542 (7.0680)	0.2530 (2.0042)	0.5603 (3.3846)	0.2213 (4.3667)
pcl:5	-	0.0439 (0.2321)	0.5598 (3.6535)	0.1915 (3.0411)
clz:1	0.2421 (1.3627)	-0.8804 (6.3213)	-0.0817 (2.3529)	-0.3105 (5.7575)
clz:2	-0.2567 (2.2185)	-0.6713 (7.6127)	-0.0674 (2.1082)	-0.2808 (6.2182)
clz:3	-0.7554 (6.5358)	-0.4621 (5.6790)	-0.0530 (1.0603)	-0.2510 (5.7211)
clz:4	-1.2542 (7.0680)	-0.2530 (2.0042)	-0.0387 (0.5151)	-0.2213 (4.3667)
clz:5	-	-0.0439 (0.2321)	-	-0.1915 (3.0411)
Adjusted R-squared	0.8436	0.8638	0.9748	0.8211
Durbin- Watson	2.10	1.58	2.67	1.89

\* See referenced footnotes for specification of indicator variables.

1. Time trend.

Table Notes: T-statistics are in parentheses immediately below the coefficient. PCL is price per pound, and CLZ is the sum of production and processing variable costs per pound. The ":#" refers to the #-period lag. Coefficients

corresponding to PCL and CLZ were derived from a second-degree polynomial distributed lag (pdl) specification. The ratio of PCL to CLZ was used initially as the independent variable. When estimation results were not satisfactory, each of the variables were used by themselves in the pdl specification.

**Table A-3 - Acreage Equations: Cane**

Variable/ Equation Stat	Florida	Hawaii	Louisiana	Texas
Constant	0.6688 (0.6757)	-6.0889 (8.0239)	-4.2132 (1.3734)	-0.8664 (0.3119)
Indicator	-	0.2115 <sup>1</sup> (3.7134)	-	-
Capacity	0.3651 (4.5946)	1.1574 (13.7360)	1.1100 (3.2028)	0.6284 (1.5917)
pca:1	0.1374 (1.7963)	-	-	-
pca:2	0.1080 (1.8516)	-	-	-
pca:3	0.0492 (0.4611)	-	-	-
cax:1	-0.1374 (1.7963)	-	-	-
cax:2	-0.1080 (1.8516)	-	-	-
cax:3	-0.0492 (0.4611)	-	-	-
Adjusted R-squared	0.8263	0.9340	0.3981	0.5195
Durbin- Watson	2.20	1.93	1.81	1.88

\* See referenced footnotes for specification of indicator variables.

1. 1994.

Table Notes: T-statistics are in parentheses immediately below the coefficient. PCA is price per acre, and CAX is production variable costs per acre. The ":#" refers to the #-period lag. Coefficients corresponding to PCA and CAX were derived from a second-degree polynomial distributed lag (pdl) specification. The ratio of PCA to CAX was used initially as the independent variable. When estimation results were not satisfactory, each of the variables were used by themselves in the pdl specification.

**Table A-4 - Processing Capacity Equations: Beets**

Variables/ Equation Stat	Far West	Northwest	Great Plains	Great Lakes	Red River Valley
Constant	3.5404 (2.3501)	6.6961 (12.1303)	5.0781 (9.7533)	3.6500 (3.2761)	3.5678 (1.7206)
Indicator*	0.1691 <sup>1</sup> (3.8302)	0.0431 <sup>2</sup> (12.4518)	-	0.0515 <sup>3</sup> (9.3804)	-
pct:1	0.5191 (2.8251)	-	0.0786 (1.8956)	0.4130 (2.8772)	0.6357 (1.5086)
pct:2	0.3396 (3.2642)	-	0.1112 (3.8643)	0.2581 (3.5777)	0.5140 (2.6808)
pct:3	0.1601 (0.8989)	-	0.1438 (6.8282)	0.1032 (0.7524)	0.3924 (2.0543)
pct:4	-	0.2818 (2.5213)	0.1763 (7.4128)	-	-
pct:5	-	-	0.2089 (6.0417)	-	-
ctz:1	-0.5191 (2.8251)	-	-0.0786 (1.8956)	-0.4130 (2.8772)	-
ctz:2	-0.3396 (3.2642)	-	-0.1112 (3.8643)	-0.2581 (3.5777)	-
ctz:3	-0.1601 (0.8989)	-	-0.1438 (6.8282)	-0.1032 (0.7524)	-
ctz:4	-	-0.2818 (2.5213)	-0.1763 (7.4128)	-	-
ctz:5	-	-	-0.2089 (6.0417)	-	-
Adjusted R-squared	0.8780	0.9500	0.8760	0.9030	0.4492
Durbin- Watson	1.69	2.08	2.67	1.88	1.24

\* See referenced footnotes for specification of indicator variables.

1. 1988-90. 2. Time trend. 3. Time trend.

Table Notes: T-statistics are in parentheses immediately below the coefficient. PCT is price per ton, and CTZ is the sum of production and processing variable costs per ton. The "#:" refers to the #-period lag. Coefficients corresponding to PCT and CTZ were derived from a second-degree polynomial distributed lag (pdl) specification. The ratio of PCT to CTZ was used initially as the independent variable. When estimation results were not satisfactory, each of the variables were used by themselves in the pdl specification.

**Table A-5 - Acreage Equations: Beets**

Variable/ Equation Stat	Far West	Northwest	Great Plains	Great Lakes	Red River Valley
Constant	-0.8228 (0.3128)	-3.6049 (3.1963)	0.7476 (0.8819)	-2.8769 (3.8149)	-1.3305 (1.2201)
Indicator*	-	-	0.0150 <sup>1</sup> (3.4036)	-0.2721 <sup>2</sup> (3.8181)	-
Capacity	-0.2221 (0.6750)	0.6905 (10.0670)	0.2754 (2.7924)	0.9983 (10.5659)	0.8311 (6.9114)
pca:1	0.8176 (2.6794)	-	0.4339 (3.5494)	-	-
pca:2	0.5171 (2.3230)	-	-	-	-
pca:3	0.2165 (0.8059)	0.4459 (3.0752)	-	-	-
cax:1	-0.8176 (2.6794)	-	-0.4339 (3.5494)	-	-
cax:2	-0.5171 (2.3230)	-	-	-	-
cax:3	-0.2165 (0.8059)	-	-	-	-
Adjusted R-squared	0.8079	0.9093	0.6140	0.9223	0.7696
Durbin- Watson	2.04	1.71	2.00	1.23	1.15

\* See referenced footnotes for specification of indicator variables.

1. Time trend. 2. 1982.

Table Notes: T-statistics are in parentheses immediately below the coefficient. PCA is price per acre, and CAX is production variable costs per acre. The ":#" refers to the #-period lag. Coefficients corresponding to PCA and CAX were derived from a second-degree polynomial distributed lag (pdl) specification. The ratio of PCA to CAX was used initially as the independent variable. When estimation results were not satisfactory, each of the variables were used by themselves in the pdl specification.

**Table A-6 - Sectoral Retail Demand Equation Structure**

Definitions

SU	Sugar
FC	Fructose
SWT	Sweetener
$\omega$	Share parameter
P	Price
$Q_i$	Production in sector i

Sectors BK: Bakery; BV: Beverage; CB: Canned, Bottled, and Frozen; CD: Confectionery; DR: Dairy; OT: Other

Equations

Sweetener Price

$$P_{SWT_i} = \omega_{SU,i} * P_{SU} + \omega_{FC,i} * P_{FC}$$

Sectoral Demand for Sweetener

$$SWT_i = SWT_i (P_{SWT}, Q_i)$$

Demand Share of Sugar in Sweetener Demand

$$\omega_{SU,i} = \omega_{SU,i} (P_{SU}, P_{FC}, SWT_i)$$

Demand Share of Fructose in Sweetener Demand

$$\omega_{FC,i} = 1 - \omega_{SU,i}$$



**Table A-7 - First Stage Retail Demand Estimation**

	Coefficient and T-Stat				Equation Statistics		
Sector	Constant	Indicator Variables*	Real Price: Sweetner	Quantity of Sector Output	Adjusted R-Squared	Durbin-Watson	Estimation Method
Bakery (1986-95)	-1.0149 (0.7359)	0.0659 <sup>1</sup> (2.1824)	-0.4122 (2.2015)	0.9860 (8.9918)	.9368	1.97	OLS
Beverage (1987-95)	0.2373 (0.5543)	-	-0.3257 (6.1649)	1.0090 (20.3511)	.9810	2.51	OLS
Canned, Frozen, and Bottled (1980-95)	5.8324 (15.3840)	-0.1771 <sup>2</sup> (3.9591)	-	0.3464 (4.3244)	.6983	1.48	OLS
Confectionery (1982-95)	2.2537 (5.1653)	0.0721 <sup>3</sup> (4.5307)	-0.2652 (4.3590)	0.6697 (18.9096)	.9808	1.85	OLS
Dairy (1981-95)	2.7267 (2.7888)	-0.1129 <sup>4</sup> (4.0769) -0.1128 <sup>5</sup> (4.8212)	-0.1088 (1.6060)	0.5365 (5.8771)	.8839	1.97	Auto-Regressive
Other (1981-95)	2.1166 (1.4014)	-	-	1.0705 <sup>6</sup> (3.2714)	.5890	2.10	Auto-Regressive

\* Years to which indicator variables equal 1 are footnoted in sector cell.

1. 1994 2. 1986 3.1987 4.1983 5.1988

6. Sector Output = Index of Food Production

**Table A-8 - Second Stage Retail Demand Estimation**

Sugar's Share of Sector's Sweetner Demand	Coeffi-cient and T-Stat					Equation Sta-tistic		
Sector	Constant	Indicator Variable*	Real Price: Sugar	Real Price: Fructose	Quantity of Sweetner	Adjusted R-Squared	Durbin-Watson	Esti-mation Method
Bakery (1980-95)	0.2862 (2.1246)	0.0247 <sup>1</sup> (6.9282)	-0.0130 (0.9471)	0.0372 (2.7496)	0.0559 (4.1371)	.8159	2.41	OLS
Canned,Frozen& Bottled (1978-96)	2.8333 (5.2604)	-0.0166 <sup>2</sup> (8.0024)	-0.0682 (2.1127)	0.0682 (2.1127)	0.4173 (1.6462)	.9727	1.93	Auto-Regress., with linear restriction
Dairy (1981-95)	2.4682 (3.2820)	-	-	-	-0.2486 (2.3536)	.2448	1.45	OLS
Other (1981-95)	-0.2984 (0.7054)	-0.0740 <sup>3</sup> (3.0085)	0.0053 (1.4290)	-0.0053 (1.4290)	0.1383 (2.3726)	.5556	1.51	OLS, with linear restriction

\* Years to which indicator variables equal 1 are footnoted in sector cell.

1. 1988, 1989, 1990 2. time trend 3. 1985

**Table A-9 - Second Stage Retail Demand for Beverages**

Modified AIDS specification

$$\omega_{it} = \alpha_i + v_i * h_t + \sum_j \beta_{ij} * \log(P_{jt}) + \sum_j \delta_{ij} * h_t * \log(P_{jt}) + \beta_i * \log(Q_t) + \delta_i * h_t * \log(Q_t)$$

Structural change period: 1977 - 1984

Structural change variable: h

Values h(t) = 0 for t=1975,1976

h(t) =(t-1977)/(1984-1977) for t=1977,....,1984

h(t) = 1 for t=1985,....,1995

Variable	Coefficient	T-Statistic
$\alpha$	-8.4826	5.8704
v	10.6994	7.0869
$\beta_{su,su}$	0.2316	2.4318
$\beta_{su,fc}$	0.0786	0.6250
$\delta_{su,su}$	-0.3625	2.8550
$\delta_{su,fc}$	-0.1270	0.8208
$\beta_{su}$	1.0759	6.4376
$\delta_{su}$	-1.2676	8.1271

Adjusted R-Squared: .9984; Durbin-Watson: 2.22

**Table A-10 - Industrial Demand Elasticities for Sectors**

	First Stage		Second Stage		
Sector	Real Price: Sweetner	Product Quantity	Real Price: Sugar	Real Price: Fructose	Sector Sweetner Quantity
Bakery	-0.41	0.99	-1.07	0.03	1.07
Beverage	-0.33	1.01	-3.43	2.67	-
Canned, Bottled, & Frozen	-	0.35	-0.88	0.48	0.40
Confectionery	-0.27	0.67	-	-	-
Dairy	-0.11	0.54	-0.75	0.11	0.65
Other	-	1.07	-1.13	-0.10	1.23

**Table A-11 - Non-industrial Demand for Sugar**

---

Definitions

SWT	Sweetener
FC	Fructose
Q	Quantity Demanded
$\omega$	Share parameter
P	Real Consumption Price
FEX	Real Food Expenditure
i	Sector index

Sectors SU: Sugar; BK: Bakery; BV: Beverage; CB: Canned, Bottled, and Frozen; CD: Confectionery; DR: Dairy.

Equations

Sector Demand for Sweetener

$$SWT_i = Q_{SU, i} + Q_{FC, i}$$

Total Sweetener Use

$$SWT = \sum_i SWT_i$$

Sectoral Shares

$$\omega_i = \frac{SWT_i}{SWT}$$

Sweetener Price

$$P_{SWT} = \sum_i \omega_i * P_i$$

Demand for Sweeteners (1st Stage)

$$SWT = SWT(P_{SWT}, FEX)$$

Sectoral Demand (2nd Stage)

$$\omega_i = \omega_i(P_{SU}, P_{BK}, P_{BV}, P_{CB}, P_{CD}, P_{DR}, SWT)$$

**Table A-12 - Second Stage Retail Demand for Non-industrial Sector**

Estimation

Variable/ Equation Statistic	Version 1: Coefficient	T-Statistic	Version 2: Coefficient	T-Statistic
Constant	68.8632	7.6381	-2.7566	2.7446
1992	0.0113	2.4516	0.0088	1.6836
Real Price: Sugar	-0.0115	0.4884	0.0261	0.9864
Real Price Index (RPI): Bakery	0.0333	3.0542	0.0428	2.7754
RPI: Beverage	-0.0518	2.4217	-0.0772	2.7593
RPI: Canned,etc.	0.0091	0.9551	0.0087	0.7912
RPI: Confectionery	0.0027	0.2673	-0.0153	1.3142
RPI: Dairy	0.0182	-	0.0149	-
Sweetner Consumption (SC)	-14.2102	7.4877	0.3289	3.0419
SC - squared	0.7354	7.3635	-	-
Time Trend	-	-	-0.0136	5.3587
Adjusted R- squared	0.8506	-	0.8115	-
Durbin-Watson	1.12	-	1.08	-

Observations: 1978-95.

Elasticities

	Real Price: Sugar	RPI: BK	RPI: BV	RPI: CB	RPI: CD	RPI: DR	Quantity of Sweetner
Household Demand for Sugar	-0.78	0.26	0.08	0.11	0.10	0.12	0.03

**Table A-13 - Processing Stage Sugar Elasticities**

---

Definitions

- $\sigma$  = elasticity of substitution between sugar and other inputs  
 $\eta$  = higher stage demand elasticity for sugar  
 $e$  = sugar supply elasticity  
 $d$  = demand  
 $s$  = supply  
 $S$  = distributive input share of sugar in processing/marketing of higher stage sugar  
 $j$  = index for raw sugar (RS), wholesale sugar (WH), retail sugar (RT)  
 $k$  = index:  $k=WH$  when  $j=RS$ , and  $k=RT$  when  $j=WH$

Equations

Derived Demand for Wholesale and Raw Sugar

$$d(Q_j^d)^* = [(1-S_j) * \sigma + S_j * \eta] d(P_j)^* - \eta * \left( -\frac{1}{\eta} * d(Q_k^d)^* + d(P_k)^* \right)$$

Wholesale and Retail Sugar Supply Elasticities

$$d(Q_k^s)^* = \left[ \frac{(1-S_j)}{S_j} * \sigma + \frac{e_j}{S_j} \right] * d(P_k)^* - e_j * \left[ -\frac{1}{e_j} * d(Q_j^s)^* + d(P_j)^* \right]$$

---

**Table A-14 - Processing Stage Estimation Specification**

---

Define:	Z -	demand shift variable
	W -	marketing cost index
	P -	price
	Q -	quantity
	RT-	retail
	WH-	wholesale
	RS-	raw sugar
	su-	sugar
	fc-	fructose
	swt-	sweetner
	i -	sector index (BK=bakery, BV= beverage, CB= canned, bottled, and frozen processed products, CD= confectionery, DR= dairy, OT= other, NI= non-industrial)

Sector demand shift

$$Z_i = Q_i (\overline{P_{su}}, P_{fc}, Q_{swt}^i)$$

Total demand shift

$$Z = \sum_i Z_i$$

Retail-Wholesale Linkage Equations

$$\log(P_{RT}) = \alpha_0 + \alpha_W * \log(W) + \alpha_Z * \log(Z) + \alpha_Q * \log(Q_{WH})$$

$$\log(P_{WH}) = \beta_0 + \beta_W * \log(W) + \beta_Z * \log(Z) + \beta_Q * \log(Q_{WH})$$

Wholesale-Raw Linkage Equations

$$\log(P_{WH}) = \gamma_0 + \gamma_W * \log(W) + \gamma_Z * \log(Z) + \gamma_Q * \log(Q_{RS})$$

$$\log(P_{RS}) = \delta_0 + \delta_W * \log(W) + \delta_Z * \log(Z) + \delta_Q * \log(Q_{RS})$$



**Table A-15 - Processing Stage Equations (1981-95)**Equations

Equation	Constant	Marketing Cost Index(W)	Demand Shifter (Z)	Sugar Quantity(Q <sub>w</sub> <sub>HRS</sub> )	Adj. R-squared	Durbin-Watson
Retail Price	10.354 (12.321)	-0.835 (5.894)	0.299 (5.181)	-0.635 (10.083)	0.775	1.70
Whole-sale Price <sup>1</sup>	2.365 (1.620)	0.321 (2.208)	0.678 (7.611)	-0.772 (4.417)	0.679	2.27
Raw Price	10.028 (7.178)	0.274 (1.706)	0.219 (2.458)	-1.119 (6.471)	0.297	2.35

Note: T-statistic in parentheses below the coefficient value.

1. Indicator variable for 1988-89 has coefficient value of 0.114 with a t-statistic of 12.138.

Elasticities

Processing Level	Demand	Supply
Retail	-0.86 (computed)	0.56
Wholesale	-1.30	0
Raw	-0.89	-