Estimating the U.S. Demand for Sugar in the Presence of Measurement Error in the Data

Noel D. Uri

Abstract. *Inaccuracy in the measurement of the price data for the substitute sweeteners for sugar is a problem encountered in the estimation of the demand for sugar Two diagnostics are introduced to assess the effect that this measurement error has on the estimated coefficients of the sugar demand relationship The regression coefficient bounds diagnostic is used to indicate a range in which the true price responsiveness of consumers to changes in the price of sugar substitutes lies The bias correction factor is computed to evaluate the magnitude of the overestimation of the responsiveness of the quantity of beverage sugar and nonbeverage sugar demanded to a change in the price of sugar*

Keywords. *Sugar demand, random measurement error, price responsiveness, beverage sugar, nonbeverage sugar*

Both policy analyses such as that found in General Accounting Office (1993)[1] and the studies cited therein and forecasting efforts such as that found in Economic Research Service (various issues) rely on estimates of the demand for sugar The implicit assumption in these efforts is that the sugar demand relationships are accurately estimated and that the responsiveness of the quantity demanded to changes in the price of sugar is adequately calibrated In what follows, this presumption will be examined by looking at the impact that errors in the measurement of one of the explanatory variables has on the estimated relationships of the demand for sugar The implications of this for sugar policy analyses and forecasting will be assessed

There are a variety of reasons why the estimates of the demand elasticities for agricultural commodities are frequently tenuous Foremost among these are the differences in economic and institutional conditions reflected in the data and the differences in estimation procedures applied to the data to derive the estimates Differences associated with the data are frequently easy to identify and comprehend Estimates vary between studies because the magnitudes of the variations in the data and the behavior of the observed variables are different

Differences that arise due to the variations in the estimation procedure are more difficult to identify Well conceived empirical studies of demand begin with the same basic economic notions That is, they are all based on conventional neoclassical microeconomic theory It is the functional specification and estimation procedure that produces divergence A choice must be made about the type of model to use, the sorts of data that are appropriate, and the estimation procedure to be employed in fitting the data to the model In making these choices, a number of estimation problems are either explicitly or implicitly addressed These include how data are aggregated across individuals, the choice of the functional form(s) considered, the nature of the dynamic relationship between price and quantity demanded, and the way the influences impacting demand are separated (Griliches, 1986, explores these and other issues in greater detail)

One concern that encompasses both the differences in economic and institutional conditions reflected in the data and the differences in estimation procedures, and one that has received little attention in previous attempts to model the demand for agricultural commodities, involves the presence of random errors associated with the measurement of the variables needed to properly estimate a demand relationship Random measurement error occurs when the measured values of a variable are sometimes greater than and sometimes less than or equal to the true or accurately measured value With random measurement error, the economic and institutional conditions that should be reflected by the data are inaccurately portrayed This, in turn, has consequences for the actual estimates These will be explored Before doing so, however, a demand model, which will be used to assess the impact of random measurement error, is presented Sugar is the commodity used in the analysis

Modelling the Demand for Sugar

Overview

In the short run, the demand for sugar is presumed to follow a flow-adjustment process of

Uri is an agricultural economist with the Commodity Economics Division, ERS He thanks the anonymous referees for helpful suggestions

[1]Sources are listed in the References section at the end of this article

the Houthakker-Taylor type (Houthakker and Taylor, 1970) In this sort of model, the tastes of consumers and considerations such as the availability of substitutes, the degree of substitutability of alternative sweeteners for sugar and health and nutrition factors are assumed to be fixed in the short run and consumption of sugar is presumed to be entirely a function of normal economic influences such as prices and disposable personal income In this situation a classical adjustment model can be used Assume that there is a desired demand Q_t^* for sugar by consumers at time t This demand is a function of the price of sugar and a vector of other relevant economic and institutional variables, X_t

In general functional form,

$$Q_t^* = f(P_t, X_t) \quad (1)$$

This level of demand is reached only in conditions of long run equilibrium A simple adjustment process is assumed whereby

$$(Q_t - Q_{(t-1)}) = a\,(Q_t^* - Q_{(t-1)}) \quad (2)$$

where the adjustment parameter a is between zero and one (The choice of this specification for the adjustment process will be discussed below) Hence, actual demand for sugar in the current period, Q_t, is given by

$$Q_t = a\,(Q_t^*) + (1-a)\,(Q_{(t-1)}) \quad (3)$$

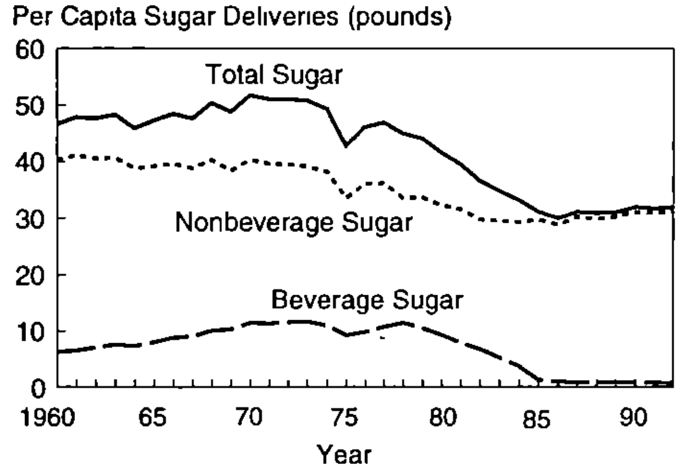
Demand Specification

The empirical analysis will focus on just two categories of sugar demand—beverage sugar and nonbeverage sugar [2] The quantity of sugar demanded per capita by these two categories over the period 1960-1992 is shown in fig 1 [3]

Beverage sugar demand is a derived demand That is, the demand for beverage sugar is not based on any intrinsic desire for the sugar itself, but rather on the need to use the sugar to sweeten the beverages which are in turn sold to final consumers or to wholesalers and retail establishments who then sell them to final consumers [4] This means that the demand for beverage sugar is determined in the final markets by the demand and supply for the beverage products being sold Thus, the derived demand for sugar is indirectly based on the elements which generate the supply and demand for the final beverage products In a properly specified demand model for beverage sugar, these factors must be either explicitly or implicitly taken into account

Nonbeverage sugar is a fairly heterogeneous category Some components of this demand are derived and some consist of demand by final consumers Thus, for example, the demand for sugar for ice cream and dairy products, canned, bottled and

Figure 1
Per Capita Quantity of Sugar Consumed in the United States in Pounds: 1960-1992



[2]Two separate categories of sugar consumption are considered here sugar used in beverages (primarily soft drinks) and sugar for nonbeverage uses, including bakery, cereal, and allied products confectionery and related products, ice cream and dairy products, canned bottled, and frozen foods This disaggregation is necessitated because sugar used for beverages has been the major contributor to the observed erratic behavior in aggregate sugar consumption Between 1960 and 1969, beverage sugar accounted for around 25 percent of total [per capita] sugar consumption In fact, the growth in beverage sugar consumption accounted for all of the aggregate growth in sugar consumption since the average nonbeverage sugar consumption per capita over the period was essentially static (that is no statistically significant growth trend is evident) During the period 1970 to 1978, while per capita beverage sugar consumption exhibited, on average, no change from one year to the next the decline in nonbeverage per capita sugar consumption accounted for the decline in aggregate per capita sugar consumption Next, the big decline in total per capita sugar consumption between 1978 and 1985 is primarily an artifact of the precipitous decline in per capita beverage sugar consumption Over this period, beverage sugar consumption declined at an average annual rate of 25 58 percent Since 1985, per capita beverage sugar consumption has continued to decline but this has been more than offset by the increase in consumption of nonbeverage sugar of approximately 0 90 percent per year This resulted in the modest growth in aggregate per capita sugar consumption between 1985 and 1992

[3]Per capita sugar consumption is the focus here since it is this unit of measure that has served as the basis of the analysis of many of the U S sugar demand studies performed (some of these are cited below) and it is also the common unit on which industry assessments of trends in sugar consumption are based (for example, F O Lichts, 1991-B, Morris 1980, and Page and Friend, 1974) Finally, it is a convenient basis on which to forecast the demand for sugar since changes in sugar consumption are inexorably tied to changes in the population size (for example, Blamberg, 1992)

[4]Stigler (1966) explores the nature of derived demand

frozen foods, and bakery, cereal, and allied products are, in general, all derived demand[5] On the other hand, the nonbeverage demand for sugar via retail and wholesale grocery sales is a final demand by consumers[6] It was decided not to consider each of these components of nonbeverage sugar separately because their respective shares of the total quantity of sugar demanded have, unlike beverage sugar demand, been relatively stable over the period 1960 through 1992 and because there is a dearth of different objective explanatory variables available for each of the components That is, each of the separate components is specified to be a function of the same set of explanatory variables (for example, disposable personal income and population) While it might be of interest to know, for example, how the demand for sugar by confectionery and related products responded to a change in the price of sugar relative to how retail grocery sales responded, this does not aid in the objective of this study of explaining the aggregate variability in the demand for sugar

Given the foregoing considerations for beverage sugar and nonbeverage sugar, the specification of the desired demand per capita, Q_t^*, for beverage sugar and nonbeverage sugar separately are given as

$$Q_t^* = C_0 + C_1 (P_{at}) + C_2 (P_{ot}) + C_3 (ECON_t) + (V_t) \qquad (4)$$

where Q^* denotes the per capita desired quantity demanded for beverage sugar (nonbeverage sugar) by consumers,

P_a denotes the average price of sugar consumed,

P_o denotes an average composite price of substitute sweeteners for sugar,

ECON denotes a proxy variable for economic activity designed to capture the effects of changes underlying the derived demand and final demand on the desired quantity demanded (per capita soft drink sales for beverage sugar and disposable personal income for nonbeverage sugar),

V denotes the error term,

t denotes the time period, and

C_0, C_1, C_2, and C_3 are parameters to be estimated

Combining relationship 4 with relationship 3, the equation to be estimated becomes

$$Q_t = a\ C_0 + (1\text{-}a)\ (Q_{t-1}) + a\ C_1\ (P_{at}) + a\ C_2\ (P_{ot}) + a\ C_3\ (ECON_t) + V_t \qquad (5)$$

The coefficient on the sugar price term, P_{at}, should be negative (following conventional neoclassical demand theory) indicating that an increase in the price will result in a decrease in the quantity of either beverage sugar or nonbeverage sugar demanded Since other types of sweeteners are ostensibly substitutes for sugar in both beverage and nonbeverage uses, the coefficient estimate on the price of the other sweetener should be positive indicating that it is a substitute good for sugar The coefficients on the soft drink sales (in the case of beverage sugar) and disposable personal income (in the case on nonbeverage sugar) should be positive suggesting that an increase in soft drink sales or disposable personal income will be associated with an increase in the consumption of sugar[7]

Data

The specific time period used in the estimation covers 1960 through 1992 because comprehensive and consistent (that is, consistently measured) sugar consumption and price data are available for this period The data are national aggregate annual time series The data were obtained from a variety of sources Data on the quantity of sugar consumed and the wholesale sugar price[8] were taken from the *Sugar and Sweetener Situation and Outlook Report* (Economic Research Service, various issues) and its predecessor publications (variously titled) and the *U S Sugar Statistical Compendium* (Angelo and others, 1991), all of which were published by the Economic Research Service of the United States Department of Agriculture (USDA) The composite price of substitute sweeteners for sugar is computed as a weighted average of the prices of glucose corn

[5]In 1992, this category of nonbeverage sugar demand accounted for approximately 52 percent of the total quantity of sugar consumed in the United States (Economic Research Service, March 1993)

[6]The quantity of sugar demanded by these sources accounted for approximately 45 percent of total sugar consumption in the United States in 1992 (Economic Research Service, March 1993)

[7]Disposable personal income is a commonly used measure of consumer purchasing power and purchasing propensity in empirical analyses A complete assessment of the relevant issues can be found in Intriligator (1978, Chapter 7) and in Phlips (1974)

[8]Both the wholesale and the retail sugar price were used in preliminary analyses The empirical results exhibit no statistically significant difference at the 5 percent level when one price is used in deference to the other The results when the wholesale price of sugar was used in the estimation are reported here

syrup, dextrose, and high fructose corn syrup (both 42 percent and 55 percent)[9,10] This price series was computed based on data obtained from various issues of *Sugar and Sweetener Situation and Outlook Report* and its predecessor publications The data on soft drink sales were obtained from Moore and Buzzanell (1991) while the data on disposable personal income and population were obtained from the Economic Report of the President (1993) Per capita soft drink sales were computed by dividing total soft drink sales by the population All of the price and income data are in constant 1987 dollars The real values of these variables were obtained by deflating their respective nominal values by the gross domestic product implicit price deflator This deflator was obtained from the Economic Report of the President (1993) as were the population data

Preliminary Analyses

Before presenting the estimation results for the model developed here, several issues need to be addressed The first factor to be considered involves the demand model formulation In the model formulation, an adjustment specification is used for the desired quantity demanded whereby the difference between the desired quantity demanded in the current period and the actual quantity demanded in the previous period is hypothesized to adjust at some specific rate a An obvious question is whether this specification is supportable based on the data Additionally, an additive specification is used in deference to others that are available (for example, a multiplicative specification) Is there any reason to prefer one specification over another? Each of these issues was examined in preliminary analyses using a statistical test suggested by Davidson and MacKinnon (1981) First, the issue of whether there is an adjustment over time of the desired quantity demanded was examined This was accomplished by defining the null hypothesis to be the specification where there is no adjustment parameter and the alternative to be the specification where there is an adjustment parameter The results of the Davidson-MacKinnon J-test strongly suggest that there is in fact a lag of one period[11] in the adjustment between the desired quantity demanded and the actual quantity demanded for both beverage sugar and nonbeverage sugar demand[12] This means that consumers do not completely adjust their consumption of beverage sugar and nonbeverage sugar within the current period to changes in sugar prices, the price of sugar substitutes, soft drink sales, and disposable personal income

Next, the null hypothesis that the appropriate specification is a linear specification versus a linear-in-logarithms (which was the alternative hypothesis) was investigated The test indicated for beverage sugar and nonbeverage sugar that the null hypothesis could not be rejected[13] Consequently, the linear specification was used in the estimation for both beverage sugar and nonbeverage sugar

A second factor considered concerns whether there is an identifiable substitution of other types of sweeteners for sugar To investigate this, a test for directional causality was used[14]

To determine whether changes in the composite price of other types of sweeteners impacted the quantity of beverage sugar and nonbeverage sugar demanded, current period consumption of beverage sugar (nonbeverage sugar) was regressed on eight lagged values of beverage sugar (nonbeverage sugar) consumption (corresponding to consumption in six previous periods) This gave the restricted estimates used in performing the causality test Subsequently, current period consumption of bev-

[9]Measuring the price of a representative sugar substitute is very difficult The degree of substitutability between glucose corn syrup, dextrose, and high fructose corn syrup (HFCS) is, for some uses, relatively low Thus for example, in the case of soft drinks, glucose and dextrose are not equivalent to high fructose corn syrup as sugar substitutes However, using the price of a HFCS in the beverage sugar demand equation has its problems HFCS (42 percent) was only introduced in 1967 while HFCS (55 percent) was introduced in the late 1970s Consequently, the available series on HFCS do not cover the period of this study The alternative is to use a shorter time period in the estimation This, however, presents another set of shortcomings because the underlying structural demand relationships changed over time In order to handle the peculiarities associated with this, the use of the longer time series is required Uri (1993) explains and explores this in detail

[10]It would also be desirable to include a price or price index for noncaloric sweeteners thereby providing an indication of the extent to which sugar is a substitute for non-caloric sweeteners Unfortunately, no consistent and comprehensive data series over the period of this study (1960 to 1992) exist on the price of the various noncaloric sweeteners Hence, they are omitted from consideration

[11]Longer lags were also considered but they proved to be statistically insignificant Also, lags on the various explanatory variables of up to four periods were considered In no instance was a distributed lag of any of the explanatory variables indicated

[12]The computed J-test statistic for a linear-in-logarithms specification was 4 34 while for a linear specification it was 5 23 for the beverage sugar demand equation Corresponding values for the nonbeverage sugar demand equation were 4 33 and 5 41, respectively The critical chi-square value at the 5 percent level is 3 84

[13]The computed J-test statistic for the beverage sugar equation was 2 46 and the computed J-test statistic for the nonbeverage sugar equation was 3 08 The critical chi-square value at the 5 percent level is 3 84

[14]A general discussion of the technique is contained in Uri and Boyd (1990)

erage sugar (nonbeverage sugar) was regressed on eight lagged values of beverage sugar (nonbeverage sugar) consumption (corresponding to consumption in six previous periods) and six lagged values of the price of the substitute sweeteners. This gave the unrestricted estimates. The relevant partial F-statistics were then computed. For the beverage sugar equation, the computed value was 7.33 while for the nonbeverage sugar equation the computed value was 6.81. The critical value at the 5 percent level is $F(6, 26) = 2.47$. Hence, it is possible to identify from the data being used in the estimation the substitution of other sweeteners for beverage sugar and nonbeverage sugar (separately). Thus, for example, there is an indication that in response to changing relative sugar and other sweetener prices (however slight that change might have been) that beverage sugar (nonbeverage sugar) was substituted for one of the other sweeteners when the relative price change favored sugar over the other sweeteners.

The demand equations for beverage sugar and nonbeverage sugar were fit to the time series data previously discussed. Ordinary least squares was used with correction for first order serial correlation (which was present (not surprisingly since time series data were used) for both equations) using the approach of Beach and MacKinnon (1978).[15,16] An instrumental variable was used for the lagged dependent variable (Bowden and Turkington (1984)). The instrument was defined to be a linear function of the average price of sugar, the average composite price of the substitute sweeteners for sugar, and the proxy variable for economic activity (soft drink sales for beverage sugar and disposable personal income for nonbeverage sugar) all in the current period. Lagged values of these variables did not enhance the fit of the relationship.

The initial estimation results were very poor. There were few statistically significant coefficient estimates and the coefficient of determination was below 0.50 for both the beverage sugar and the nonbeverage sugar demand equations. One of the reasons for this lack of acceptable results is that the demand for beverage sugar and the demand for nonbeverage sugar destabilized over the sample period. This destabilization coincided with the introduction of high fructose corn syrup (HFCS) as a new and relatively high intensity sweetener during the period of study.[17]

Estimation Results

The developments in the HFCS industry over the past 20 years or so coupled with the price advantage of HFCS over the domestic price of sugar[18] lead to HFCS having a destabilizing effect on the demand for beverage sugar as well as nonbeverage sugar in the United States.[19] Uri (1993) has shown that both the demand for beverage sugar and the demand for nonbeverage sugar destabilized around 1978. This corresponds to the period just after which HFCS-55 was introduced and when HFCS (both HFCS-42 and HFCS-55) was making large initial inroads into the sweetener market as a substitute for sugar (Vuilleumier, 1981, 1989). The demand for beverage sugar destabilized again in 1985. This corresponds to the first full year in which both the Coca-Cola Company and PepsiCo permitted 100 percent substitution of HFCS for sugar in their respective soft drink brands (Vuilleumier, 1989).

To account for the instability in the underlying demand relationships and its impact on the parameter estimates, a combination of dummy variables and the various explanatory variables was introduced into the specification for both the demand for beverage sugar and the demand for nonbeverage sugar. Preliminary analyses were undertaken to determine which of the variables to retain in the final specification. Those variables included are indicated in table 1.

The results of the stability test show that the impact of some variables on the quantity of beverage sugar and nonbeverage sugar changed

[16]There was no indication that higher orders of serial correlation were present based on an analysis of the residuals.

[16]Seemingly unrelated regression estimates (see Judge and others, 1985) were also obtained but there was no identifiable gain in estimate efficiency.

[17]The substitution of HFCS for sugar in soft drinks was a major factor in the development of the HFCS industry. HFCS-42 began to be substituted for sugar in 1974 by Coca Cola in response to the increase in sugar prices. Other soft drink manufacturers soon followed suit. In 1978 Coca-Cola as well as the rest of the soft drink industry began shifting to HFCS-55. By November 1984, full replacement of refined sugar by HFCS-55 was approved by both Coca-Cola and Pepsi-Cola in their flagship brands (Butler, 1981, Vuilleumier, 1981, 1989).
The overall trend has seen sugar fall from accounting for slightly more than 67 percent of all caloric sweeteners consumed per capita in 1980 to around 46 percent in 1992 while HFCS has increased from accounting for less than 15 percent of total per capita caloric sweeteners consumption in 1980 to more than 35 percent in 1992 (Economic Research Service, March 1993). Moreover, in excess of 75 percent of HFCS sales in 1992 were associated with soft drinks while they were responsible for just 47 percent in 1980.

[18]Using the domestic price of sugar as the base, HFCS is priced at a discount to this price (Morris, 1980, Nordlund, 1977, and Vuilleumier, 1989).

[19]Stability is defined here in the statistical sense of the estimated coefficients on the explanatory variables remaining constant over time.

Table 1—Beverage sugar and nonbeverage sugar demand equation estimates (standard errors of the estimates in parentheses)

1 Beverage sugar demand

$$Q_{bt} = \underset{(0\ 6691)}{2\ 7968} + \underset{(0\ 0617)}{0\ 7987}\ Q_{b9t\ 1)} - \underset{(0\ 0152)}{0\ 0521}\ P_{ab(t)}$$

$$+ \underset{(0\ 0167)}{0\ 0347}\ P_{ot} + \underset{(0\ 9544)}{6\ 3588}\ ECON_t + \underset{(3\ 4365)}{22\ 0201}\ D78_t$$

$$- \underset{(3\ 5903)}{33\ 3881}\ D85_t - \underset{(0\ 8079)}{5\ 3371}\ ECON_{(78)T} + \underset{(0\ 7114)}{6\ 8224}\ ECON_{(85)t}$$

R^2	=	0 9976
Durbin h	=	0 9786
S E	=	0 3594

2 Nonbeverage sugar demand

$$Q_{nt} = \underset{(2\ 5576)}{7\ 8257} + \underset{(0\ 0864)}{0\ 8555}\ Q_{n(t-1)} - \underset{(0\ 0283)}{0\ 0882}\ P_{an(t)}$$

$$+ \underset{(0\ 0077)}{0\ 0514}\ P_{ot} + \underset{(0\ 0004)}{0\ 0145}\ ECON_t - \underset{(0\ 8182)}{3\ 1757}\ D78_t$$

$$+ \underset{(0\ 0010)}{0\ 0025}\ Q_{n78(t-1)}$$

R^2	=	0 9894
Durbin h	=	1 0311
S E	=	0 8402

Where Q_{bt} is the per capita quantity of beverage sugar demanded in period t, Q_{nt} is the per capita quantity of nonbeverage sugar demanded in period t $P_{ab(t)}$ is the average price of beverage sugar in period t, $P_{an(t)}$ is the average price of nonbeverage sugar in period t P_{ot} is the price of the sweetener substitute for sugar, $ECON_t$ in the beverage sugar demand equation is soft drink sales in period t and in the nonbeverage sugar demand equation it is disposable personal income, $D78_t$ is a qualitative variable equal to zero prior to 1978 and equal to 1 for 1978 and after, $D85_t$ is a qualitative variable equal to zero prior to 1985 and equal to 1 for 1985 and after, $ECON_{(78)t}$ is equal to zero prior to 1978 and is equal to soft drink sales in period t for 1978 and later, $ECON_{(85)t}$ is equal to zero prior to 1985 and is equal to soft drink sales in period t for 1985 and after, and $Q_{n78(t-1)}$ is equal to zero prior to 1978 and equal the quantity of nonbeverage sugar demanded in the previous period for 1978 through 1991 R^2 is the coefficient of determination Durbin h is the Durbin h statistic used in testing for the presence of first order serial correlation, and S E is the standard error of the regression

over the period 1960 through 1992 The effects of other variables, however, remained constant throughout the period This does not mean that they had no affect on the quantity demanded, but that the magnitude of the effect did not vary over the sample period

Finally, the structural instability in the demand for beverage sugar and the demand for nonbeverage sugar did not lead to erroneous results as far as the tests of the functional specification are concerned The Davidson-MacKinnon statistical tests addressing both the selection of the adjustment specification and the linear specification were performed using the revised models taking into account the structural instability in both the beverage sugar demand and the nonbeverage sugar demand equations In both instances, the previous test results were not changed

The actual estimates of the beverage sugar and nonbeverage sugar demand equations that give rise to the structurally stable relationships are reported in table 1 The values in parentheses below the coefficient estimates are the standard errors of the estimates The signs on the estimated coefficients are consistent with *a priori* expectations Thus, for example, the demand for beverage sugar is inversely related to the price of sugar and directly related to the quantity of sugar demanded in the previous period, the price of sugar substitutes, and soft drink sales The demand for nonbeverage sugar, on the other hand, is inversely related to the price of sugar and directly related to the price of sugar substitutes and disposable personal income

With regard to the stability issue, the demand for beverage sugar destabilized in two ways First, in both 1978 and 1985, the demand curve shifted as indicated by statistically significant (at the 5 percent level) coefficient estimates on the terms D78 and D85 Second, after 1978, the demand for beverage sugar became much less responsive to soft drink sales In fact, the demand for beverage sugar is unresponsive to changes in soft drink sales[20] This responsiveness, however, increased to approximately its original level subsequent to 1985 Nonbeverage sugar demand also destabilized in two ways First, in 1978, the demand curve shifted as indicated by the statistically significant (at the 5 percent level) coefficient estimate on the term D78 Second, the habit formation process changed such that consumers subsequently adjusted their consumption of sugar relatively more rapidly to changes in the price of sugar, the price of sugar substitutes and disposable personal income than they did prior to 1978, although this change was fairly modest

Beyond these descriptive results, is there anything more definitive that can be concluded? Knowledge of the quantitative magnitudes of the responsiveness of consumers to changes in the various explanatory factors will help in answering this question These magnitudes will be presented here as long-run elasticities and will be based on the estimated coefficients and the average values of both the dependent variable and the explanatory variables Assuming the adjustment process given in relationship 2, the long run elasticity of a specific variable will equal (1/(1-a)) times the short run elasticity The short run elasticity can be computed as the estimated coefficient on the variable under consideration times the average value of that variable divided by the average (computed based on a time period coincident with that of the variable of interest) of the quantity of beverage sugar (nonbeverage sugar) demanded

Table 2 presents selected long-run elasticities for beverage sugar and nonbeverage sugar Standard errors of these elasticity estimates are given in parentheses They are computed following the suggestion of Horowitz (1981) The results are interesting from several points of view First, the introduction of HFCS resulted in the demand for both beverage sugar and nonbeverage sugar becoming more price responsive (that is, the absolute value of the own price elasticity increased)[21] In both instances, the price responsiveness more than doubled between the first period (1960 through 1977) and the third period (1985 through 1992) In the case of beverage sugar, the cross price elasticity increased nearly fourfold between the first and third periods For nonbeverage sugar, on the other hand, the cross price elasticity remains relatively small, though statistically significant at the 5 percent level This is consistent with the argument that other sweeteners, for a variety of reasons, are not good substitutes for sucrose The responsiveness of beverage sugar demand to soft drink sales is relatively large as would be expected with the relevant elasticity approaching one for both the first and third periods During the second period (1978 through 1984), the soft drink sales elasticity decreases to zero partially in response to the introduction of HFCS-55[22] By 1985, the adjustments to this new sugar substitute seem to have run their course with the soft drink sales elasticity returning approximately to the level it was at during the 1960-1977 period The income elasticity for nonbeverage sugar is relatively small and a test of the null hypothesis that the income elasticity is constant across all three periods is accepted Thus, there is a small but positive effect of changes in disposable income on nonbeverage sugar demand and this effect has remained roughly constant for the past three decades

Table 2—Long run elasticities (standard errors of the estimates in parentheses)

Period[(1)]	Own price elasticity	Cross price elasticity	Other[(2)] elasticity
I Beverage sugar			
(a) Period 1	-0 47	0 21	0 86
	(0 20)	(0 09)	(0 32)
(b) Period 2	-0 86	0 27	0 21
	(0 35)	(0 11)	(0 07)
(c) Period 3	-1 02	0 96	0 97
	(0 41)	(0 34)	(0 39)
II Nonbeverage sugar			
(a) Period 1	-0 19	0 07	0 17
	(0 07)	(0 03)	(0 07)
(b) Period 2	-0 49	0 10	0 21
	(0 19)	(0 04)	(0 09)
(c) Period 3	-0 50	0 12	0 23
	(0 19)	(0 05)	(0 11)

(1) Period 1 corresponds to 1960 through 1977, Period 2 corresponds to 1978 through 1984, and Period 3 corresponds to 1984 through 1991

(2) For beverage sugar, the other elasticity is for soft drink sales while for nonbeverage sugar, the other elasticity is for disposable personal income

[20]That is, when the coefficient estimates on the two soft drink sales variables $ECON_t$ and $ECON_{(78)t}$ are considered in conjunction with their standard errors it is not possible to reject the null hypothesis that their sum is zero There is *a priori* no reason to expect this

[21]Note that some of the variability in these elasticities is an artifact of the way in which they were computed They are based on arithmetic averages of the respective variables over different time periods However, the average values together with the reported standard errors and knowledge of the sample sizes will permit the reader to check that in fact the elasticities did (or did not) change in the manner suggested

[22]It is not clear how reliable this elasticity estimate is since there was a relatively modest change in soft drink sales over this period but a substantial market penetration by HFCS-55 This would tend to obfuscate the impact of changes in soft drink sales on the demand for beverage sugar

Next, it is useful to compare the results reported here with the estimates of others for the United States First, note that few other studies have endeavored to disaggregate sugar demand into its beverage and nonbeverage components Given the decline in beverage sugar consumption, especially in response to the introduction of HFCS, it is important to disaggregate Secondly, no previous studies have focused on the structural stability issue As can been seen from the foregoing analysis, this is an oversight that has significant ramifications with regard to estimating the response of both beverage and nonbeverage sugar demand to changes in the price of sugar, the price of sugar substitutes, soft drink sales, and disposable personal income

One of the earliest studies of the demand for sugar was by Hayenga (1967) Using time series data covering 1949 through 1963 together with a linear specification, he finds an average price elasticity of demand for beverage sugar of –0 14 and an average elasticity for baking, canning, confection, and dairy products of –0 32 No soft drink sales or disposable personal income variables were included in his specifications It is interesting to note that his estimates suggest that beverage sugar demand is less than one half as responsive to price changes as is nonbeverage sugar demand while the results obtained in this study suggest just the opposite

Lamm (1982) estimates the demand for sugar as part of a system of dynamic demand functions Only a short-run price elasticity is reported for total sugar consumption This value is estimated to be –0 06 based on annual data covering 1946 to 1978 This is substantially smaller than the value of the short run elasticities obtained in this study Given the nature of Lamm's study, it is difficult to determine why the difference is so great

Other studies addressing the demand for sugar typically deal with the issue in a secondary role That is, estimation of price and income elasticities were not the factor motivating the respective studies but rather are done in support of some other activity As a consequence of this, there is typically scant discussion of the elements leading to an adopted demand specification Nevertheless, it is useful to report some of these estimates for comparison purposes Lopez (1989) estimates a long-run price elasticity of –0 59 for all sugar and an income elasticity of 0 49 based on data covering 1955-1985 Lopez and Sepulveda (1985) estimate an own price elasticity of –0 15 while King and George (1971) estimate an own price elasticity of –0 24 Finally, Leu and others (1987), using annual data covering 1961 through 1983, estimate a long-run elasticity of –0 32 This specification is unique among sugar demand studies in that it includes as explanatory variables in a linear specification not only the price of sugar in the current period but also the price in the previous period A test of the specification used in the current study, as noted previously, does not support such a distributed lag[23]

Measurement Error

Overview

There is one lingering problem that was alluded to previously The coefficient estimates reported here are based on the assumptions that the model used has been properly specified, that an appropriate estimation technique has been employed, and that the data used are accurate Is there reason to believe that one or more of these assumptions is invalid? With regard to the specification issue, considerable effort through a variety of statistical tests was expended to minimize the likelihood that the model was misspecified Concerning the estimation technique, both ordinary least squares and the seemingly unrelated regression technique were used in preliminary analyses and the estimates obtained are consistent with one another The accuracy of the data is another issue In particular, measurement of the price of substitute sweeteners for sugar is problematic Recall how this variable was measured The composite price of substitute sweeteners for sugar was computed as a weighted average of the prices of glucose corn syrup, dextrose, and high fructose corn syrup (both 42 percent and 55 percent) There are several problems with this measure First, some components of this price series are discontinuous Namely, HFCS did not exist prior to 1969 whereas

[23]One final empirical test was performed This involved testing for data outliers using the regression diagnostic techniques of Belsley, Kuh, and Welsch These diagnostic techniques look at whether the coefficient estimates are inordinately influenced by a subset of the data This is relevant since there are a few time periods where substantial changes occur in the data For example, a look at Figure 1 shows that the quantity of both beverage sugar and nonbeverage sugar demanded fell precipitously in 1975 This fall was the result of a jump in the price of granulated sugar from 15 cents per pound at the beginning of 1974 to 72 cents per pound at the beginning of 1975 This price increase generated by a number of factors including the increased cost of producing refined sugar, difficulties in processing and transporting sugar associated with the 1973-1974 energy crisis, world wide inflation currency devaluation, and uncertainties about United States sugar policy A fairly complete discussion of this is contained in *Confectionery Production* (May 1975) and Bohall and others (1977) In the context of the current discussion then did the year 1975 have a disproportionate impact on the reported (price) coefficient estimates? There are no observations for either of the equations that are judged to be beyond the cutoff points

the data series extends back to 1960 This means that for the series on the composite price of the substitute sweeteners for sugar, its underlying structure changes in 1970 because four price series rather than two contribute to its makeup Second, inclusion of the price of glucose corn syrup and dextrose as components of the series might be questioned because they are not good substitutes for sugar in many uses and the relative importance of the uses in these instances changed over time Finally, for the reasons previously indicated, no provision is made in the composite price of the substitute sweeteners measure for noncaloric sweeteners and they are a substitute for sugar in some uses (Moore and Buzzanell, 1991)

Based on these considerations, while the price variable used to reflect any substitution effects of other sweeteners for sugar is the best that could be constructed, it is still a relatively poor measure to rely upon because of the measurement error it contains Assuming this measurement error is random,[24] it will impact the estimated value of the coefficient on the substitute sweeteners price variable as well affect the coefficient estimates on all of the other explanatory variables To understand this, a brief digression is in order Theoretical Considerations

The classical regression model is defined as

$$y_t = \Sigma_i \beta_i x_{it} + \gamma z_t + e_t \tag{6}$$

for $i = 1, 2, \ldots, k$, $t = 1, 2, \ldots, n$ and where y_t is the dependent variable with zero mean and constant variance containing no measurement error, the x_{it} are independent variables with zero means and constant variances and they are observed with no measurement error, and z_t is a true variable that should properly be included in an empirical relationship but for which accurate observations are not available It is further assumed that e_t, the random error term, has a zero mean and a constant variance and is uncorrelated with y_t and x_{it} Finally, it is assumed that e_t has a constant variance, σ_{ee}

Random measurement error for an independent variable exists when observations are not available for z_t but they are available for Z_t where the relationship between z_t and Z_t is given by

$$Z_t = z_t + u_t \tag{7}$$

where u_t has a zero mean and it is uncorrelated with e_t, y_t and x_{it} Moreover, it is assumed that u_t has a constant variance, σ_{uu}

There are two diagnostics that are useful in evaluating the effects of random measurement error on the estimates These are the regression coefficient bounds and the bias correction factor Regression coefficient bounds prove to be useful because they indicate the impact on the estimated regression coefficients of not only the random component in y_t but the random component of the explanatory variable that contains the measurement error as well The bias correction factor is useful because it will indicate the extent of the difference between the true population parameter and the estimated value of the parameter

Regression coefficient bounds are computed in a fairly straightforward fashion and this computation process is well known (Fuller, 1987, Herbert, 1988, and 1989, and Maddala, 1988) What one finds is that when random measurement error is present, the estimated regression coefficient on the variable possessing the measurement error is the lower bound estimate of the true population parameter (if the true population parameter is positive)[25] The upper bound estimate (or lower bound estimate if the true population parameter is negative) is given by one divided by the coefficient estimate on the reverse regression The reverse regression results when the variable containing the measurement error is regressed on the dependent variable and the set of other explanatory variables (that is, those not possessing measurement error) The degree of the underestimation of the true population parameter depends on σ_{uu}/σ_{zz} Also, the better the data fit the estimated relationship, the closer are the bounds

Following Herbert and Dinh (1989), the expression for bias, BIAS, is given as

$$\text{BIAS} = \frac{\gamma\ (\Sigma_{xx})^{-1}\ \sigma_{Zx}}{1 + \Omega} \tag{8}$$

where $x = (x_1, x_2, \ldots, x_k)$, $\Omega = (\sigma_{zz}\ (1 - (p_{Zx})^2))/(\sigma_{uu})$ and p_{Zx} is the multiple correlation coefficient between the true Z and the other correctly measured (that is, possessing no measurement error) explanatory variables

The variance-covariance matrix of the x_t and Z_t is written as

[24]There is no reason to assume otherwise That is, there is no basis for assuming that there is some systematic error in the variable as it is measured

[25]It represents the upper bound if the true population parameter is negative

$$\Sigma_{xZ} = \begin{bmatrix} \Sigma_{xx} & \sigma_{Zx} \\ (\sigma_{Zx})' & \sigma_{ZZ} \end{bmatrix} \qquad (9)$$

It is assumed that σ_{Zx} is not equal to zero

Given these diagnostics, in what follows both the regression coefficient bounds and the bias correction factor will be computed for the previously estimated demand relationships for beverage sugar and nonbeverage sugar

Regression Coefficient Bounds

Consider first the regression coefficient bounds question Since the population parameter is (theoretically) positive, the values reported in table 1 for beverage and nonbeverage sugar represent the lower bound estimates of the impact of a change in the price of the substitute sweeteners for sugar The upper bounds are computed from the reverse regression The reverse regression estimation results are presented in table 3 (with the standard errors of the estimates in parentheses and all of the variables as previously defined) Note that the results of the stability test performed on the reverse regressions did not indicate that there was any structural shift in the relationships estimated Consequently, unlike the situation when the quantity of beverage sugar and nonbeverage sugar were the dependent variable, no additional variables had to be introduced to account for variation in the coefficients on the explanatory variables at different time periods

From these results, for beverage sugar the lower bound estimate is computed as 1 18 while for nonbeverage sugar it is computed as 1 12 Hence, the coefficient bounds for the population parameter C_1, for beverage sugar are given as $0\ 03 < C_1 < 1\ 18$ while for nonbeverage sugar they are given as $0\ 05 < C_1 < 1\ 12$

One procedure recommended for obtaining a single estimate to use in assessing the impact of the variable possessing measurement error on the dependent variable is to compute the geometric average For the current problem, the geometric average for beverage sugar is 0 19 and for nonbeverage sugar, it is 0 24 (Frisch, 1934, Samuelson, 1942)

These results suggest that, due to the presence of random measurement error, there is considerable uncertainty associated with consumers' response to changes in the price of substitute sweeteners for sugar in the short run Thus, using the mean values of the prices and quantities over the period 1985 to 1992, a 1 percent increase (decrease) in the

Table 3—Beverage sugar and nonbeverage sugar demand reverse regression equation estimates (standard errors of the estimates in parentheses)

1 Beverage sugar demand

$$P_{ot} = \underset{(3\ 5318)}{29\ 523} + \underset{(0\ 1903)}{0\ 2081}\ Q_{b(t-1)} + \underset{(0\ 1109)}{0\ 2630}\ P_{ab(t)} + \underset{(0\ 2451)}{0\ 5623}\ Q_{bt} + \underset{(0\ 0013)}{0\ 0045}\ ECON_t$$

R^2	=	0 9010
Durbin h	=	0 9623
S E	=	0 7317

2 Nonbeverage sugar demand

$$P_{ot} = \underset{(12\ 330)}{28\ 603} + \underset{(0\ 1982)}{0\ 2310}\ Q_{n(t-1)} + \underset{(0\ 1275)}{0\ 2618}\ P_{an(t)} + \underset{(0\ 3102)}{0\ 5311}\ Q_{nt} + \underset{(0\ 0059)}{0\ 0054}\ ECON_t$$

R^2	=	0 9343
Durbin h	=	1 0520
S E	=	0 0899

Where Q_{bt} is the per capita quantity of beverage sugar demand in period t, Q_{nt} is the per capita quantity of nonbeverage sugar demanded in period t, $P_{ab(t)}$ is the average price of beverage sugar in period t, $P_{an(t)}$ is the average price of nonbeverage sugar in period t, P_{ot} is the price of the sweetener substitute for sugar, $ECON_t$ in the beverage sugar demand equation is soft drink sales in period t and in the nonbeverage sugar demand equation it is disposable personal income, $D78_t$ is a qualitative variable equal to zero prior to 1978 and equal to 1 for 1978 and after, $D85_t$ is a qualitative variable equal to zero prior to 1985 and equal to 1 for 1985 and after, $ECON_{(78)t}$ is equal to zero prior to 1978 and is equal to soft drink sales in period t for 1978 and later, $ECON_{85(t)}$ is equal to zero prior to 1985 and is equal to soft drink sales in period t for 1985 and after and $Q_{n78(t-1)}$ is equal to zero prior to 1978 and equal the quantity of nonbeverage sugar demanded in the previous period for 1978 through 1992 R^2 is the coefficient of determination, Durbin h is the Durbin h statistic used in testing for the presence of first order serial correlation, and S E is the standard error of the regression

aggregate price of substitute sweeteners for sugar will result in between a 0 19 and 0 92 percent increase (decrease) in the quantity of beverage sugar demanded with a geometric average of 0 41 and between a 0 02 and 0 77 percent increase (decrease) in the quantity of nonbeverage sugar demanded with a geometric average of 0 12 These are wide ranges and make inferences about consumers' behavior in the face of changes in the price of the substitute sweeteners for sugar very tenuous The regression coefficient bounds for the long run price elasticities are comparably large For beverage sugar based on data covering 1985-1992, a 1 percent increase (decrease) in the price of substitute sweeteners for sugar will result in between a 0 93 and 4 49 percent increase (decrease) in the quantity of beverage sugar demanded with a geometric average of 2 04 and between a 0 13 and 5 02 percent increase (decrease) in the quantity of nonbeverage sugar demanded with a geometric average of 0 81

Bias Correction Factor

What does the bias correction factor indicate? To expedite the discussion, details for just one of the explanatory variables, the price of sugar, P_{at}, will be provided while results for soft drink sales (for beverage sugar) and disposable personal income (for nonbeverage sugar) will simply be indicated Consider the bias associated with the coefficient estimate on the price of sugar From the data used in the estimation of relationship 5 and from the estimation results, the following calculated values for the period 1985 through 1992 were obtained

Beverage Sugar Demand

$(\Sigma_{xx})^{-1}\ \sigma_{Zx} = 0\ 5135$, $\sigma_{ZZ} = 28\ 6761$, $\sigma_{Zx} = 38\ 8260$, $(p_{Zx})^2 = 0\ 5409$

Nonbeverage Sugar Demand

$(\Sigma_{xx})^{-1}\ \sigma_{Zx} = 0\ 6021$, $\sigma_{ZZ} = 28\ 6761$, $\sigma_{Zx} = 19\ 8560$, $(p_{Zx})^2 = 0\ 5409$

The sole remaining value to be determined is σ_{uu} Fuller (1987), for the situation when random measurement error is present, gives the expression for σ_{uu} as,

$$\sigma_{uu} = \sigma_{ZZ} - (\sigma_{Zy})^2\ (\sigma_{yy} - \sigma_{ee})^{-1} \qquad (10)$$

where σ_{yy} is the variance of the dependent variable and the other terms are as previously defined

A maximum value for σ_{uu} is obtained by setting $\sigma_{ee} = 0$ This assumption will be employed here With this expression (that is, equation 10), the final pieces of information needed to compute the bias are σ_{yy} and σ_{Zy} In the current examples, for beverage sugar, $\sigma_{yy} = 15\ 2827$ and $\sigma_{Zy} = 11\ 2862$ and for nonbeverage sugar, $\sigma_{yy} = 19\ 6272$ and $\sigma_{Zy} = 14\ 2714$ Using relationship 10 and the computed values of the variances and covariances, the computed value for beverage sugar of σ_{uu} = 20 3413 and for nonbeverage sugar, it equals 18 2990

Given these values, the bias associated with the coefficient estimate on the price of sugar is 0 0107 for beverage sugar and 0 0103 for nonbeverage sugar For beverage sugar, this is equal to about 20 9 percent of the estimated coefficient for the price of sugar variable and indicates the extent of the over-estimation of the response of the quantity of beverage sugar demanded to a change in the price of sugar [26] For nonbeverage sugar, the over-estimation is approximately 11 6 percent Thus, the measurement error associated with the sugar sweetener substitutes price variable yields an estimate of the response of variation in the quantity demanded of beverage and nonbeverage sugar demanded to changes in the price of sugar that is too large

Analogous computations can be performed for the soft drink sales variable (for beverage sugar) and disposable personal income variable (for nonbeverage sugar) Omitting the computation details, the bias in the coefficient on the soft drink sales variable is 1 6708 or 21 3 percent of the estimate while the bias in the coefficient estimate on the disposable personal income variable is 0024 or 16 8 percent Thus, in both instances measurement error in the substitute sweeteners price variable results in an over-estimation of the response of the quantity of sugar demanded to changes in soft drink sales and disposable personal income

Conclusion

This paper began by discussing some of the problems frequently encountered in obtaining estimates of the elasticity of demand To these problems was added that associated with inaccuracy in the measurement of one of the independent variables that impact the quantity demanded Two diagnostics—the regression coefficient bounds and the bias correction factor—were introduced to assess the affect that such measurement error has on the estimated coefficients of demand relationships

In considering the demand for beverage sugar and nonbeverage sugar in the United States, the price data for the substitute sweeteners for sugar contains measurement error The regression coefficient bounds diagnostic was used to indicate a range in which the true price responsiveness of consumers to changes in the price of sugar substitutes lies The results suggest that each 1 percent increase (decrease) in the price of sugar substitutes will result in between a 0 19 and 0 92 percent increase (decrease) in the quantity of beverage sugar demanded and between a 0 02 and 0 77 percent increase (decrease) in the quantity of nonbeverage sugar demanded in the short run In the long run, each 1 percent increase (decrease) in the price of sugar substitutes will result in between a 0 93 and 4 49 percent increase (decrease) in the quantity of beverage sugar demanded and between a 0 13 and 5 02 percent increase (decrease) in the quantity of nonbeverage sugar demanded The bias correction factor was computed to evaluate the magnitude of the over-estimation of the responsiveness of the quantity of

[26] Given the way the elasticity is computed in table 2, this is the magnitude of the overestimation of the beverage sugar price elasticity estimate as well This also holds for nonbeverage sugar

beverage sugar and nonbeverage sugar demanded to a change in the price of sugar. For beverage sugar, the over-estimation associated with the price of sugar variable was 20.9 percent while for nonbeverage sugar it was 11.6 percent. With regard to soft drink sales, the bias in the coefficient was 21.3 percent of the estimate while the bias in the coefficient estimate on the disposable personal income variable was 16.8 percent.

These results suggest that, in the presence of measurement error in the data for the price of the sweetener substitute, any conclusions or policy recommendations based on the estimated sugar demand relationships must be qualified. Consider the following. Policy analyses using estimates of the demand for sugar must be cognizant of the fact that the period being studied must use the appropriate elasticity estimate. Thus, for example, the U.S. General Accounting Office (GAO) estimates that the sugar program administered by the USDA costs U.S. consumers approximately $1.4 billion annually. A critical assumption in this analysis is a sugar price elasticity of –0.05 and is based on the historical period covering 1970-1987. This value is used in conjunction with a variety of supply elasticities ranging between 0.1 and 2.0 to get the reported result. From the results of the analysis in this paper, the appropriate price elasticity would be based on the period 1984-1992 which indicates a larger price responsiveness on the part of sugar consumers. The estimated annual impact of the sugar program would be less. Additionally, the uncertainty in the estimated price responsiveness of consumers associated with the measurement error in the price data for the substitute sweeteners for sugar must be reflected in the analysis.

An alternative use of demand elasticities is for forecasting purposes. For example, under the sugar program as configured in the Food, Agriculture, Conservation, and Trade Act of 1990 (P.L. 101-624), provision is made for standby domestic marketing allotments. USDA annually estimates the domestic production and quantity demanded for sugar and the supply quantity needed to keep domestic prices at a level that prevents producers from forfeiting sugar. USDA, in consultation with the Sugar Working Group, then determines the quantity of sugar to import. The Sugar Working Group is composed of representatives of various government agencies possessing an interest in the sugar program. The 1990 law requires that the quota be at least 1.25 billion short tons to ensure that sugar cane refiners continue to have access to foreign raw sugar. The quota also enables the federal government to meet foreign policy objectives. The U.S. Trade Representative allocates the quota to individual countries who can then export their quota to the United States.

If the import quota is met and if the price of sugar falls below the forfeiture level, domestic marketing allotments are to be used to support prices. These allotments restrict the quantity of domestically produced sugar and crystallized high fructose corn syrup that each manufacturer can sell. To administer marketing allotments, marketing rights based on historical production, ability to market sugar, and production capacity of sugar cane millers and sugar beet processors would be used. Of critical importance in predicting the impact of marketing allotments is knowledge of the sugar price elasticity and the cross price elasticity of substitute sweeteners. Recognition of what these elasticities are, the uncertainty of their measurement, and how they have changed over the historical period must be factored into the assessment of the effect of marketing allotments. For example, an assumed elasticity that is too small will yield marketing allotments that are too large, thereby reducing the net farm income of domestic sugar producers.

References

Angelo, L., R. Barry, P. Buzzanell, F. Gray, D. Harvey, R. Lord, and W. Moore. 1991. *U.S. Sugar Statistical Compendium*. SB 830, U.S. Dept. Agri., Econ. Res. Serv.

Blamberg, M. 1992. *Outlook for World and U.S. Raw Sugar Markets: 1992 and Beyond*. New York: Domino Sugar Corp. May 13.

Beach, C., and J. MacKinnon. 1978. "A Maximum Likelihood Procedure for Regression with Autocorrelated Errors," *Econometrica*. Vol. 46, pp. 51-58.

Belsley, D., E. Kuh, and R.E. Welsch. 1980. *Regression Diagnostics*. New York: John Wiley.

Bohall, R., L. Angelo, F. Gray, F. Hulse, L. Larkin, and C. Powe. 1977. *The Sugar Industry's Structure, Pricing and Performance*. U.S. Dept. Agri., Econ. Res. Serv.

Bowden, R.J., and D. Turkington. 1984. *Instrumental Variables*. Cambridge, England: Cambridge University Press.

Butler, M. 1981. "The 55% Boom," *Beverage World*. August, pp. 3-4.

Cook, B. 1986. *The Corn Sweetener Industry*. New York: Solomon Brothers.

Council of Economic Advisers 1993 *Economic Report of the President* Washington, DC U S Government Printing Office, February

Davidson, R , and J MacKinnon 1981 "Several Tests for Model Specification in the Presence of Alternative Hypotheses," *Econometrica* Vol 49, pp 781-93

Deaton, A , and J Muellbauer 1980 *Economics and Consumer Behavior* Cambridge, England Cambridge University Press

Economic Research Service *Sugar and Sweetener Situation and Outlook Report,* various issues, U S Dept Agri

Frisch, R 1934 *Statistical Confluence Analysis by Means of Complete Regression Systems* Pub No 5, University of Oslo Economic Institute, Oslo, Norway

Fuller, W 1987 *Measurement Error Models* New York John Wiley & Sons

General Accounting Office 1993 *Sugar Program Changing Domestic and International Conditions Require Program Changes* Washington, DC, April 16

George, P , and G King 1971 *Consumer Demand for Commodities in the United States with Projections for 1980* Giannini Foundation Monograph No 26, University of California, Berkeley

Griliches, Z 1986 "Economic Data Issues," in *Handbook of Econometrics,* Z Griliches and M Intriligator (eds) Amsterdam North-Holland Pub Co

Hayenga, M 1967 *Sweetener Substitution in Food Processing Industries,* Unpublished Ph D dissertation, University of California, Berkeley

Herbert, J 1989 "Comment on Measurement Error and the Estimation of Natural Gas Demand Elasticities," *International Journal of Energy Systems* Vol 9, pp 120-121

Herbert, J 1988 "A Data Analysis and Bayesian Framework for Errors in Variables," *Interfaces '88 Symposium on the Interface Computer Science and Statistics,* pp 490-99

Herbert, J , and K Dinh 1989 "A Note on Bias from Proxy Variables with Systematic Errors," *Economic Letters* Vol 30, pp 207-9

Horowitz, I 1981 "Market Definition in Antitrust Analysis A Regression Based Approach," *Southern Economic Journal* Vol 64, pp 1-16

Houthakker, H S , and L D Taylor 1970 *Consumer Demand in the United States* Cambridge, MA Harvard University Press

Intriligator, M 1978 *Econometric Models, Techniques, and Applications* Englewood Cliffs, NJ Prentice-Hall

Judge, G G , W Griffiths, R C Hill, H Lutkepohl, and T C Lee 1985 *The Theory and Practice of Econometrics,* second edition New York John Wiley & Sons

Lamm, R M 1982 "A System of Dynamic Demand Functions for Food," *Applied Economics* Vol 14, pp 375-89

Leu, G , A Schmitz, and R Knutson 1987 "Gains and Losses of Sugar Program Policy Options," *American Journal of Agriculture Economics* Vol 69, pp 591-602

Lichts, F O 1991-A "The Advance of Sugar's Competitors in Perspective," *International Sugar and Sweetener Report* Vol 123, pp 355-58

Lichts, F O 1991-B "US Sugar Consumption in the Past Two Decades," *International Sugar and Sweetener Report* Vol 123, pp 435-39

Lopez, R A 1989 "Political Economy of the United States Sugar Policies," *American Journal of Agricultural Economics* Vol 71, pp 20-32

Lopez, R A , and J Sepulveda 1985 "Changes in the Demand for Sugar and Implications for Import Policies," *Northeast Journal of Agriculture and Resource Economics* Vol 14, pp 177–82

Maddala, G S 1988 *Introduction to Econometrics* New York Macmillan Co

Mixon, J W , and N D Uri 1985 *Managerial Economics* New York Macmillan Co

Moore, W , and P Buzzanell 1991 "Trends in U S Soft Drink Consumption-Demand Implications for Low Calorie and Other Sweeteners," *Sugar and Sweetener Situation and Outlook Report,* Econ Res Ser U S Dept Agri , Washington, September, pp 33-39

Morris, C 1980 "New Directions for Basic Commodities," *Food Engineering* Vol 32, pp 95-111

Nordlund, D 1977 "High Fructose Corn Syrup-Review, Update, and Outlook," *Lamborn Sweetener News* New York Lamborn and Co , March 29

Page, L , and B Friend 1974 "Levels of Use of Sugars in the United States," *Sugars in Nutrition* Vol 12, pp 93-107

Phlips, L 1974 *Applied Consumption Analysis* Amsterdam North Holland Publishing Co

Samuelson, P A 1942 "A Note on Alternative Regressions," *Econometrica* Vol 10, pp 80-83

Stigler, G 1966 *The Theory of Price* New York Macmillan Co

Uri, N D 1993 "A Re-examination of the Demand for Sugar in the United States," processed

Uri, N D , and R Boyd 1990 "Considerations on Modeling the Market for Softwood Lumber in the United States," *Forest Science* Vol 36, pp 680-92

Vuilleumier, S 1981 "Corn Sweetener Outlook," 1981 Agricultural Outlook Conference Washington, DC, November 18

Vuilleumier, S 1989 "High Fructose Corn Syrup Examining Worldwide Trends," *Sugar Y Azucar* Vol 84, pp 14-36