Title: Time-Varying Parameters in the Demand for High Fructose Corn Syrup

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The United States (US), once the world's largest sugar importer with 20% of the global import market, today (1999) accounts for a 5.8% of such market (Evans; USDA, 1998; Hannah and Spence). This dramatic change has been considerably influenced by US sugar policy and dynamics within the US sweeteners market. Of major concern is the unintended consequence of the program that has contributed to the development and commercialization of an alternative sweetener, high fructose corn syrup (HFCS). HFCS is a liquid caloric sweetener made from ordinary cornstarch and can be substituted for sugar (sucrose) in most liquid uses. Given its relative low cost, HFCS has been adopted in a wide range of processed food products including beverages, baked goods, dairy products, jams, jellies etc. Potential for displacing liquid sugar in the US is evident where HFCS accounts for around 49% of total US sweetener consumption in 1998 (LMC International).

Several studies have addressed the phenomenal growth in corn sweeteners as a substitute for sugar, trying to predict the penetration of HFCS into the sugar market (Carman; Lopez and Sepulveda; Thomas Leu Schmitz and Knutson; Lin and Novick; Polopolus and Alvarez). While such studies have done a good job explaining the evolution of the product, most of the empirical models have not performed well. Most of these models fail to account for time-varying aspects of the estimated parameters. As pointed out by Ward and Tilley, in markets where significant adjustments are occurring, the parameters of a given configuration are likely to be time-varying. That is, the empirical linkages are evolving. They further noted that technological changes usually result in structural changes that must be factored into the parameter estimates and that failure to do so could cause serious errors in projections and policy positions.

Given the rapid growth in the development and the adoption of HFCS, the purpose of this paper is to measure the demand for HFCS in a time-varying framework. Using econometric models the shifts can be separated into structural in contrast to the impact attributed to the relative prices of sugar versus HFCS.

In the following discussion the domestic HFCS industry is highlighted and then an empirical model of the derived demand for HFCS is presented. A time-varying model, drawing on Kalman filter, is used to test for parameter stability. Then, simulations based on the estimates are used to provide insights in the dynamics of the industry.

HFCS Industry Trends

High fructose corn syrup is a liquid caloric sweetener made from ordinary cornstarch that can be substituted for sugar (sucrose) in most liquid uses. HFCS is measured in two strengths, with HFCS-42 containing 42% fructose and about 50% and 8% of dextrose and other saccharides while HFCS-55 contains 55% of fructose and about 40% and 5% of dextrose and other saccharides. HFCS-42 is approximately 90% as sweet as sugar and HFCS-55 is 110% as sweet. Commercial production of HFCS-42 began in 1972 while that of HFCS-55 began in 1977. In 1985, through further processing of HFCS-55 into a crystalline form of the product was prepared for commercial use. Certain technical and economical problems still hamper its manufacturing and limit its widespread use as a direct substitute for crystallized (tabletop) sugar. The crystalline form still has a relatively high cost of production compared with sugar, and its sweetness appears to vary depending upon the particular use (Polopolus and Alvarez; Thomas).

The price of HFCS since its commercial inception has been lower than that of sugar on a sweetness equivalency basis. Nevertheless, the adoption had been cautious taking a decade for the major soft drink industries to make the conversion from liquid sugar to HFCS. There have been considerable advances in technology resulting in noticeable development of the product and product usage. On the demand side, the adoption of the product has been aided by the producers of HFCS working in concert with users, providing technical assistance and adapting the product to the special requirements of the various clients. It is in this context that HFCS-55 was developed as a more effective substitute for liquid sugar than HFCS-42 in the soft drink industry. Likewise on the supply side, there has been a constant effort to improve the technology involved in the production of the commodity, with a view to producing an effective substitute sweetener at the lowest cost. An implication of this type of client-oriented technology development is that the industry has and continues to evolve and as such the structural parameters of the industry most likely have changed.

Judging from the structure of the industry and the consensus of industry experts, the HFCS industry operates within an oligopolistic framework (LMC, 1997; Polopolus and Alvarez, 1991). In 1994, the "Big Five" companies (ADM, Cargill, A.E Staley, Cerestar and CPC) accounted for 93% of total capacity. Although by 1997 their total shares had declined, the "Big Five" still accounted for approximately 85% of total capacity (LMC, 1997). These five companies along with four smaller companies comprise the membership of the Corn Refiners Association. Together they operate 25 processing plants scattered throughout the midwestern region of the US (Corn Refiners Association, 1998).

Growth of the industry in the US is attributed to several factors including: 1) a marketing environment with no restriction on supply; 2) advancements in technology; 3) relative cheap supply of the main ingredient, corn; and 3) the relative cheapness of the product in relation to sugar on a sweetness equivalency basis. The considerable success of HFCS as a substitute for sugar in the US is illustrated in Figure 1. Figure 1 shows a comparison in per capita consumption of HFCS, total corn sweeteners and sugar over the same time period. Between 1975 and 1997, per capita consumption of sugar fell from 89.2 pounds to 67.1 pounds after reaching a low of 60.8 lbs. in 1986, while the per capita consumption of HFCS increased from 5 to 61.4 lbs. over the same period. In 1975 sugar accounted for about 76% of the caloric market shares and HFCS only 4%. By 1997 the market share of sugar fell to 43% while HFCS increased to 40%.

The rapid and considerable increase in the production and consumption of HFCS in the US and the concomitant displacement of a portion of the US sugar demand has come largely at the expense of sugar imports and by implication, US sugar refiners (Hannah and Spence, 1997). The US continues to be both the world's largest producer and consumer of HFCS. Of the 10.41 million metric tons (mmt) of total world production and consumption of HFCS in 1997, US production and consumption were 7.7 (74.0%) and 7.6 (73.0%) mmt, respectively (LMC International, 1997).

Derived Demand for HFCS

While recognizing the potential dynamics in the growing use of HFCS, demand for this relatively new product should be related to its own price, the price of substitutes and complements, as well as the prices of products using HFCS as a sweetener. Total U.S. utilization of HFCS-42 and HFCS-55 (millions of short tons dry weight equivalent) reflects US domestic disappearance (i.e., total supply less exports and stock of HFCS). The HFCS-42 price (cents per pound dry weigh) is used as an indicator of HFCS. Using this series was necessary in light of the incompleteness in the HFCS-55 price series. This should not pose a serious problem since both prices tend to be highly correlated (USDA, 1998).

US wholesale beet sugar prices (cents per pound) represent the substitutes value. Wholesale refined sugar beet price readily compares with the price of HFCS on a sugar equivalency basis. While other corn sweeteners such as dextrose and glucose can be substituted for HFCS, in general owing to their much higher price per unit of sweeteners, there is limited substitution among these products. The non-caloric (artificial) sweeteners were excluded from the analysis owing to health concerns surrounding their use and the fact that they are more or less restricted to the diet market (Hannah and Spence, 1997). Consequently, only the price of sugar beets was included in the analysis to capture the effect of substitutes.

With respect to the final HFCS containing products, the price of soft drinks was used. Although there is a range of industries using HFCS, the soft drink industry utilizes the bulk of the HFCS produced. In addition, sufficient information on other uses was not available to compute a weighted index across the other products. While the soft drink index is not completely representative of the range of final products, it should serve as a reasonable proxy for those unrepresented final products.

Next to the soft drink industry, the baking industry utilizes a considerable amount of HFCS. Hence changes in the demand for baking products should impact the HFCS market. The price of flour, a major ingredient in this industry, is used a proxy for measuring change in the demand for baking goods. All prices in the final equation are expressed in real terms using the GDP deflator and then expressed with a double log specification, giving the derived demand set forth in equation (1).

$$LQH_t = \beta_0 + \beta_1 LRPH_t + \beta_2 LRPS_t + \beta_3 LRPF_t + \beta_4 LRPD_t + e_t \quad (1)$$

where LQH_t is the log of the annual quantity of HFCS used in period t; $LRPH_t$ is the log of the real price of HFCS; $LRPS_t$ is the log of the real price of refined sugar; $LRPD_t$ is the log of the real price of soft drinks; $LRPF_t$ is the log of the real price of flour; and e_t is the error term. Theoretically, β_1 should be negative while β_2, β_3 and β_4 are expected to be positive.

We are dealing basically with an oligopoly industry, and as such the producing companies should be price setters. Given the demand for HFCS expressed with equation (1) and the input costs for producing HFCS, the HFCS price should be expressed as some function of the demand factors (i.e., variables influencing marginal revenue) and those production costs. In equation (2) the corn sweetener price is expressed as a non-linear function of the costs and demand variables.

$$LRPH_t = \phi_0 + \phi_1 LRPC_t + \phi_2 LRPE_t + \phi_3 LRI_t + \phi_4 LRPS_t + \phi_5 LRPD_t + \phi_6 LRPF_t + v_t \qquad (2)$$

where, $LRPH_t$ is as defined earlier; $LRPC_t$ is the log of the real price of corn; $LRPE_t$ is the log of the real price of energy; LRI_t is the log of the real long term interest rates; v_t is the usual error term; and the remaining variables are as defined in the derived demand equation (1). The real price of corn ($LRPC_t$) was included since corn constitutes the main input used in the production of HFCS. The price series for the yellow dent corn was chosen since this represents the variety most commonly used in the wet-milling process. Consideration was given to using the net cost of cornstarch, (i.e., the price of the starch after the returns from the major byproducts have been netted out) rather than the gross price of the corn. However, econometric experiments with both variables showed that the price of corn was the better predictor of the price of HFCS. The cost of energy ($LRPE_t$) was included because of the highly capital intensive nature of the industry. Energy is the second highest variable cost used in the production of the product. Finally, long-term real interest rate (LRI_t) reflects the cost of borrowed capital. This was computed as the difference between the long-term nominal interest rate and the inflation rate.

Annual data from 1977 through 1998 were used in the estimation of equations (1) and (2). The choice of the period was limited by the fact that the HFCS industry began operations in the early 1970s with commercial production of HFCS-55 commencing in 1977. Data on the prices of sugar, HFCS, corn and cornstarch, and the quantities of HFCS were obtained from various issues of the United States Department of Agriculture (USDA), Economic Research Services (ERS), Commodity Economic Division, Sugar and Sweeteners Situation, and Outlook publications. The consumer price index for carbonated drinks, the price index for flour, the index for energy (electric power and natural gas utilities) and the GDP price deflator were all obtained from the US Bureau of Labor Statistics (BLS). Price indices for flour and energy were taken from the BLS producer price index revision-current series. The real long-term interest rate was calculated as the difference between the 30-year (Moody's) corporate bond and the rate of inflation. Information on the interest rates was obtained from the Economic Report of the President (1997).

Dynamics in the HFCS Derived Demand

The coefficients in equations (1) and (2) are assumed fixed as specified. Yet given the rapid changes in the market and technologies for HFCS, it is unrealistic to assume that the derived demand has remained fixed. One approach to measuring the coefficient stability is to use one or more forms of the Kalman filtering technique, and specifically the Cooley-Prescott method for measuring parameter change over time. Both techniques are well documented; hence details are not presented in this paper[1]. For convenience let equation (1) be rewritten in matrix form where $\hat{Y} = X\hat{b}$. If the $b's$ are fixed then b is of size (k x 1) and X is a (n x k) matrix. If on the other hand the $b's$ are dynamic, then each Y_t must be predicted based on the coefficients for that period where now $\hat{Y}_t = X_t \hat{b}_t$, where X_t is now a (1 x k) and $\hat{b}_t$ is still a (kx1) vector for period t. For any given set of periods, the block diagonal matrices Z and M can be defined where:

$$Z = \begin{bmatrix} X_1 & 0 & 0 & \dots \\ 0 & X_2 & 0 & \dots \\ 0 & 0 & X_3 & \dots \\ \dots & \dots & \dots & \dots \end{bmatrix} \quad \hat{\Phi} = \begin{bmatrix} b_1 & 0 & 0 & \dots \\ 0 & b_2 & 0 & \dots \\ 0 & 0 & b_3 & \dots \\ \dots & \dots & \dots & \dots \end{bmatrix} \text{ and } \qquad (3a)$$

[1] The reader is directed to Ward and Myers; and Harvey for good applications and theoretical discussions of the techniques.

$$\hat{Y} = Z\hat{\Phi}. \tag{3b}$$

In applying the Kalman filtering or Cooley-Prescott procedures, a requirement is the need for the researcher to provide a seed matrix of variation in the coefficients. The variance-covariance matrix from an OLS estimate of the model is typically used and often just the diagonal of this matrix is applied. Hence, for the estimates in the next section we follow this convention and adopt the $\mathrm{diag}(s^2(X'X)^{-1})$ for the OLS estimates of equation (1) and re-estimate the derived demand with the varying parameters technique (Ward)

With this technique, estimates at any point within the sample can be obtained and hence it gives a valuable way of examining how a trend or a given parameter estimate might have evolved over a specified period. The most useful aspect of the varying parameter method is what may or may not be revealed with the patterns of change in the HFCS demand. Is HFCS and sugar becoming more or less substitutes? Is the demand for HFCS increasing after accounting for other factors? How much of the change is structural versus simply changes in the variable values?

A second requirement in applying the Kalman filter technique is the need to ensure that all explanatory variables are exogenous. Consequently, equation (2), our hypothesized price formation equation, was first estimated by ordinary least squares (OLS) and the predicted price of HFCS was used as the price variable in equation (1). The re-specified equation to which the Kalman filter was applied is:

$$LQH_t = \beta_{0t} + \beta_{1t}LRPH_t^* + \beta_{2t}LRPS_t + \beta_{3t}LRPF_t + \beta_{4t}LRPD_t + e_t \tag{4}$$

where, $LRPH_t^*$ represents the predicted values of original HFCS price variable and the other variables are as defined for equation (1). As noted before the variance-covariance matrix of the estimated parameters where diagonalized and used as the seed matrix.

HFCS Derived Demand Estimates

First, equation (2) was estimated as a double log using OLS, giving an adjusted R^2, of 0.63. However, the Durbin-Watson value was relatively low (1.09) indicating serial correlation problems. The equation was re-estimated using a first-order serial correlation and the maximum likelihood technique, resulting with an adjusted R^2 of 0.79 and the Durbin-Watson value of 1.72. The prices of corn, sugar and the final goods were all shown to have significant impacts on the pricing of HFCS in a manner consistent with *a prior* expectation. The results of both equations are shown in Table 1 as equations (2a) and (2b), respectively.

With the information obtained from equation (2b), in particular the estimates of price of HFCS (LRP_{Ht}^*), the Kalman filter was used to estimate equation (3). The values of the most recent set of estimates together with their p-values are presented in Table 2. The results indicate that all of the chosen explanatory variables estimates, except for flour, were significant at the 1% level. The signs on the trend, HFCS price and the price of the final goods variables were consistent with expectations. In the case of the other two variables (other inputs) no *a prior* assigning of the signs was possible given the nature of the derived demand curve and the fact that the output and substitution effects do not necessarily act in unison. Since the double log formulation was used, the values of the coefficients also represent the elasticities. The estimate of the own-price elasticity of HFCS was -0.91 implying that the demand for the commodity was relatively inelastic. And the cross-price elasticity for sugar was also inelastic.

Figures 2-4 show the dynamic paths of adjustments of the estimated trend (β_0), own-price (β_1) and cross-price elasticities (β_2) over time. For each estimate two paths are illustrated, the " state" and "smoothed". The former represents the actual estimates of the coefficient for each of time period. Smoothed coefficients are calculated starting with the final Kalman filter estimate (state) and then working backwards. Such estimates are regarded as optimal since they are based on all the information up to and including the final observation (Harvey). In Figures 2-4, the adjustment paths indicate quite clearly that the estimated coefficients varied over time implying that the industry was still in a process of evolution over the 1977 to 1998 period. Of more interest to this study is the question of the extent to which the observed shift in the demand for sweetener can be attributed to the structural changes seen in the parameters versus changes in the relative prices. Once we know the state estimates, then simulation procedures can be used to separate the structural effects compared to the price impacts. For example, in the matrices in equation (3a), one can hold the β's fixed for the initial period and then use the actual X observations. Then do the same but let the β's take the actual state values and hold X fixed. Finally, both can be held fixed, giving a base for comparison.

HFCS Demand Sensitivity

In the previous section the dynamics in HFCS demand was captured with both changes in the demand drivers (i.e., prices and costs) and the underlying coefficients. Kalman filter estimates in Figures 2-4 clearly show the change that has occurred over the last two decades. Given these estimates, of particular importance is the sensitive of the quantity demanded to these changes and the relative importance of the demand drivers over time. Both issues will be addressed in this and the next section. Changes in the price spread and the direct and cross price elasticities are of immediate interest.

Denoting q^o as the demand for HFCS in a base period, say 1998, then the sensitivity of the demand to change is relatively easy to show as set forth in equation (5) using the estimated HFCS model from (4). Changes in HFCS in this equation are attributed only to the direct price elasticities and the price spread. Clearly, the conclusion is also dependent on the level of raw sugar prices in the base period. Values for β*'s* and price spread, Δ , can be simulated over the historical range as illustrated in Figure 5. The percentage changes in HFCS relative to the base q^o is q/q^o -1and these percents are simulated letting the bottom left axis represent the price spread between raw sugar and HFCS and the bottom right axis denotes the direct price elasticity. An arbitrary starting point for 1998 is used as the base with PS^o and Δ^o= (PS^o - PH^o) being the valves in that year.

$$\frac{q}{q^0} - 1 = \frac{(PS^0 - \Delta)^{b_1}}{(PS^0 - \Delta^0)^{B_1^0}} \text{ -1} \qquad (5)$$

As the price spread increases from of 5.54 cents (i.e., the 1998 value) up to 15.54 cents and using the 1998 elasticity of -1.10, HFCS demand is shown to increase by around 100 percent from the base. In

Figure 5 compare the increase on the bottom left axis moving from right to left. Next since changes in the price elasticity has been shown, what impact does that have on the potential HFCS demand? Taking the base price spread at 5.54 cents and ranging the elasticities from -1.10 to -0.90, the model points to a gain in HFCS demand of about 76 percent over the base value (i.e. $1.76q^o$). Finally, changing both the elasticity and spread provide some idea of the potential change that could be feasible. Moving out both axis and up to the peak point on the plane in Figure 5, a value of 3.23 is seen or an approximate 223 percent increase over the base.

Clearly the values in Figure 5 are not forecasts; rather they show the potential changes that could occur given adjustments in both the elasticity and spread. What is important is that the dynamics in the parameters and any decline in HFCS relative to sugar can make a substantial difference in the HFCS market. Also, the changes in Figure 6 say nothing about shifts in the model intercept or other variables and their corresponding values. The evidence from the Kalman estimates (see Figure 5) indicates that the move in elasticity from the -1.10 to nearer -.90 benefits the HFCS industry and that increased price competitiveness for corn sweetener can have a substantial impact on the derived demand.

In Figure 6 similar sensitivity analyses has been used by changing both the direct and cross price elasticities while holding the spread fixed, again at the base of 5.54 cents. While the cross effects were not pronounced the results point to a gain in the vicinity of 80 percent or more of the base. At the peak in the plane the potential gain points to a maximum of 1.86 or 186 percent of the base (i.e., $2.86q^o$).

Combined these two figures provides empirical insight into the range of changes in the demand for HFCS over the historical periods of the analysis. Probably the more likely situation now however is to use the most recent elasticities that have evolved as corn sweetener becomes an integral part of the food chain. Then in Figure 5 the right portion of the plane would be used to show the potential over reasonable price spreads. Note that the cross elasticity in Figure 5 is using the most current values shown in Figure 6 (i.e., .70). Specifically, for the lower price spread HFCS derived demand was $1.76\ q^o$ and for the highest price spread the value is $3.23\ q^o$ or the potential gain directly attributed to price competitiveness over the full range of price spreads is $(3.23 - 1.76)\ q^o$ or $1.47q^o$. That is, the price spreads could lead to around a 150 percent increase in HFCS demand using the most recent elasticities.

Sensitivity of the Intercept (β_0)

As shown in Figure 2, there were noticeable changes in the estimated intercept coefficients over time, reflecting a strong upward trend in the quantities of HFCS demanded. Among other things, this structural change has the potential to greatly influence the market price of HFCS through the shifting of the intercept. Hypothetically this impact can be demonstrated by holding the supply of HFCS constant at the 1998 level and computing the implicit price of HFCS (Ph*), that is, the hypothetical price of HFCS that would have prevailed in a given year had all factors, other than the intercept coefficient, remained the same at the 1998 level. This can be achieved by manipulating equation 4 and substituting in the estimated intercept coefficients into the following equation:

$$PH* = PH^{0} * (b_0^0 / b_0^t)^{1/a_1} \qquad 6$$

where PH^0 is the 1998 price of HFCS, b_0^t is the estimated intercept coefficient in time t, and α_1 is the 1998 direct price elasticity. Figure X and the table present the results of the analysis and shows quite clearly the potential price impact that can be attributed to the growth in the intercept. For example, in order to maintain the 1998 quantity of HFCS demanded on the basis of the 1982 intercept coefficient, all other factors remaining constant at their 1998 levels, the price of HFCS would have been 46 percent of the 1998 base, representing a 54 percent decline in the current price. Interpreted another way, the prices in Figure x represent the implicit value of the growth variable. Equivalent price increases are attributed to the underlying growth or shifts in demand.

Table 4

Year	Implicit Price of HFCS (PH*)	Percentage Change in Relation to 1998 price
1982	4.85	- 0.54
1983	5.12	- 0.52
1984	6.04	- 0.43
1985	6.95	- 0.34
1986	7.19	- 0.32
1987	7.47	- 0.29
1988	7.96	- 0.25
1989	7.81	- 0.26
1990	8.44	- 0.20
1991	8.09	- 0.24
1992	8.36	- 0.21
1993	9.16	- 0.13
1994	9.65	- 0.09

1995	9.71	- 0.08
1996	9.57	- 0.10
1997	9.98	- 0.06
1998	10.58	0.00

Simulating the Dynamics of HFCS Demand

Figure 8 represents an attempt to separate out the structural effects due to changes in the estimated parameters from the price effect. Accordingly, Figure 8 shows: 1) the simulated quantities of HFCS demanded (q4) when all variables are allowed to vary; 2) the quantities of HFCS demanded (q2) when both the own and cross price elasticities are held constant at their 1982 levels, and the price spread, intercept and other variables change; and 3) the quantities of HFCS demanded (q5) when both the own and cross price elasticities and the intercept are held constant at their 1982 levels, and the price spread and other variables change The difference between Q4 and Q2 in Figure 8 can be interpreted as changes in the quantities of HFCS demanded due to impact of structural changes in the direct and cross price elasticities i.e. those due to technological innovations in making the product (HFCS) more user friendlier and more of a substitute for liquid sugar in the various uses. Likewise the difference between Q4 and Q5 reflects the full extent of the structural effect on the quantity of HFCS demanded over time. In this latter case the impact includes the structural effect as reflected in the growth of the

YEAR	**Gross Rev Q4 ($mn)**	**Gross Rev Q2 ($mn)**	**Gross Rev Q5 ($mn)**	**% Difference Q2 & Q4**	**% Difference Q5 & Q4**
1982	1191.69	1191.69	1191.69	0.00	0.00
1983	1251.70	1262.54	1120.39	-0.87	10.49
1984	1516.93	1098.54	895.88	27.58	40.94
1985	1784.01	1138.70	753.79	36.17	57.75
1986	1717.03	1115.83	679.78	35.01	60.41
1987	1804.58	1139.87	656.24	36.83	63.63
1988	2000.99	982.04	620.84	50.92	68.97
1989	2080.54	1033.76	669.68	50.31	67.81
1990	2684.09	1056.87	701.20	60.62	73.88
1991	2372.62	902.55	673.88	61.96	71.60
1992	2486.35	924.52	685.36	62.82	72.44
1993	2738.38	884.22	638.57	67.71	76.68
1994	2767.07	838.09	569.37	69.71	79.42
1995	2783.89	917.85	625.45	67.03	77.53
1996	2658.20	925.20	642.47	65.19	75.83
1997	2116.82	805.35	451.56	61.95	78.67
1998	1950.67	730.74	367.65	62.54	81.15

intercept. These differences suggest that a substantial amount of the observed increase in the quantities of HFCS demanded is due to the changes in the demand parameters and to a lesser extent to changes in the price spread. The magnitude of the impact of the structural effects is further highlighted in Table 5, which shows the percentage differences in gross revenue overtime between Q4 and Q2, and Q4 and Q5. The Table reveals in the absence of the full impact of the structural shift gross revenues would be lowered by as 81.1%, other factors remaining constant.

V. CONCLUDING REMARKS & IMPLICATIONS

The paper focused on the dynamics of the US HFCS industry. The ongoing product development, which has occurred in the market for HFCS, suggests from a research standpoint that the coefficients of the derived demand for the product should be estimated within a framework that allows for the estimation of time-varying parameters. The particular framework chosen in this analysis was the state-space model and the Kalman filters, which permits observation of the dynamic path of adjustments taken by the varying parameter of the derived demand equation.

The results showed quite clearly that *structural drift* has been an important component of the derived demand for HFCS in the US over time. This finding is consistent with the views of some industry experts that in light of the considerable amount of HFCS product development over the years, *the product is establishing its own market and is being regarded in certain uses as a superior product to liquid sugar.* As shown in Figures 3, the dynamic path of adjustments of the direct price elasticity suggests that over time the product has become relatively less inelastic. This implies that HFCS is becoming more essential and less sensitive to a change in price. Likewise Figure 4 shows that over time the cross price elasticity has become relatively more elastic. This suggests that as HFCS continues to improve as substitute for liquid sugar a one percent rise in the price of sugar results in a greater quantity of HFCS demanded.

The findings also support the views of Marks that a simple lowering of the current sugar prices will not necessarily bring about a reversal of the current pattern of sweetener demand in the US. Finally, the results suggest that over time the US could find itself with a huge surplus of sugar as, the US seeks to honor: (1) its WTO commitments to import no less than 1.14 million short tons; (2) its sugar commitments to Mexico under the NAFTA to accelerate the rate of reduction in tariff and accommodate all that country sugar surplus by year 2008 (or by year 2000 according to the original Agreement) and; (3)

it commitments to its own domestic sugar producer to provide non-recourse loan when the level of sugar imports exceeds 1.36 million metric tons. On the other hand as the extent of the substitution is completed the HFCS producers will be forced to seek external markets for their product. This could have implication for the continuation of the current strong sweetener coalition.

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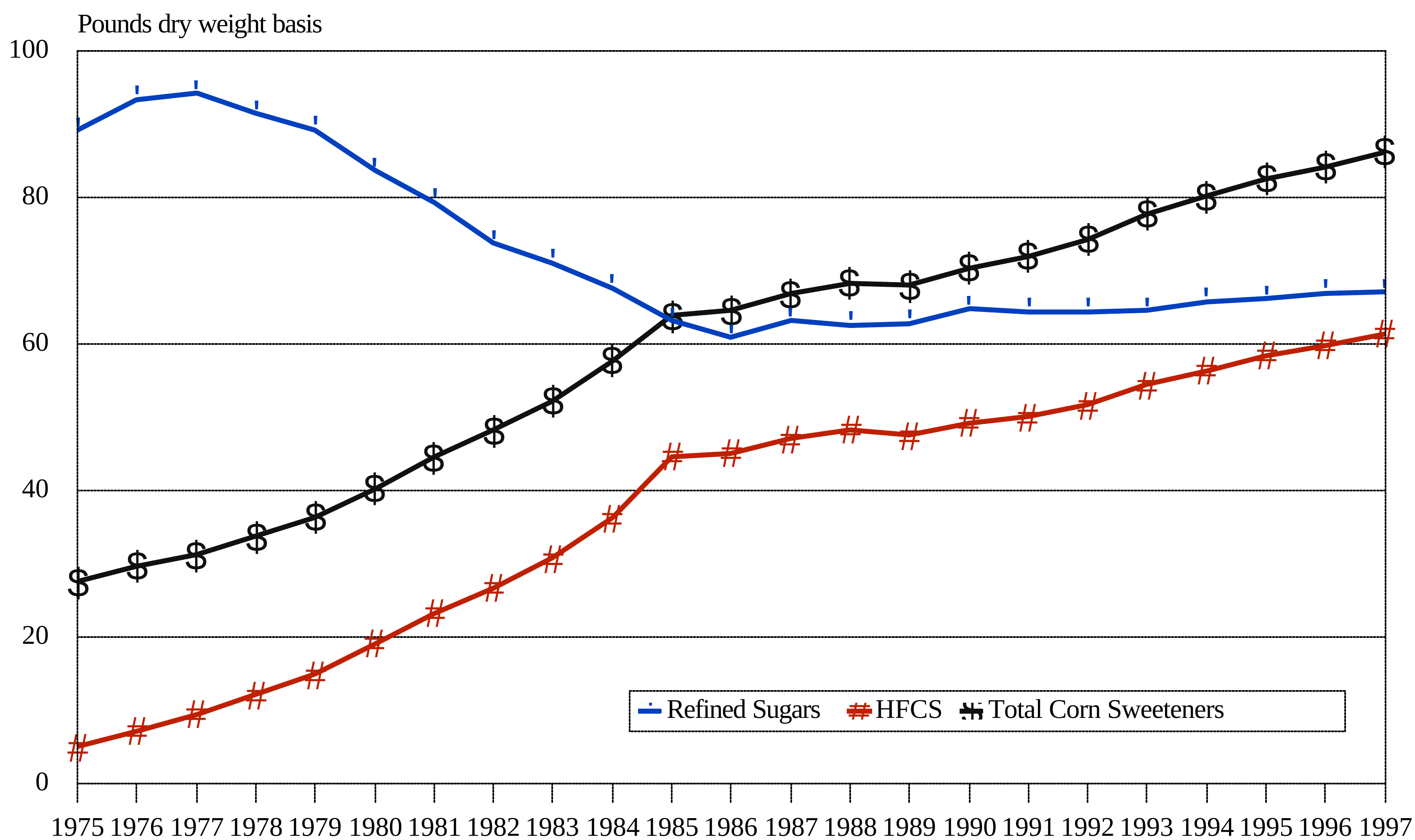
Table 1. Estimation of Price Equation

Description		Equation 3a--OLS Estimates			Equation 3b--Maximum Liklihood Estimates		
Parameters	Variables	Coef.	Std. Error	p-value	Coef.	Std. Error	p-value
ϕ_0	Intercept	0.7395	1.4951	0.628	0.2797	0.9267	0.763
ϕ_1	Price of Corn ($LRPC_t$)	0.2873	0.4150	0.499	0.6347	0.3310	0.055
ϕ_2	Price of Electricity($LRPH_t$	-2.0969	0.9381	0.041	-1.0939	0.8579	0.202
ϕ_3	Interest Rate (LRI_t)	-0.4680	0.5829	0.435	-0.2425	0.4541	0.593
ϕ_4	Price of Sugar ($LRPS_t$)	0.5301	0.4065	0.212	0.5772	0.2522	0.022
ϕ_5	Price of Soft Drink ($LRPD_t$)	-1.2976	1.0847	0.250	-1.1964	0.8114	0.140
ϕ_6	Price of Flour ($LRPF_t$)	6.1545	2.3772	0.021	3.5046	1.8791	0.062
Adjusted R^2		0.62			0.79		
Durbin-Watson Statistic		1.09			1.73		

Table 2. Final Estimates Using Kalman Filter

Parameter	Variable	Coefficient	Standard Error	p-value
β_{0t}	Intercept	2.754	0.512	0.000
β_{1t}	Price of HFCS ($LRPH_t^*$)	-0.908	0.252	0.000
β_{2t}	Price of Sugar ($LRPS_t$)	0.702	0.177	0.000
β_{3t}	Price of Flour ($LRPF_t$)	0.305	0.390	0.434
β_{4t}	Price of Soft Drink ($LRPD_t$)	4.045	0.664	0.000

Figure 1. Changes in US per capita consumption of selected sweeteners, 1975-95



Source: USDA, ERS, Commodity Economic Division, Sugar and Sweetener: Situation and Outlook Report, various

Figure 2. Dynamic path of HFCS intercept over time, 1982-98

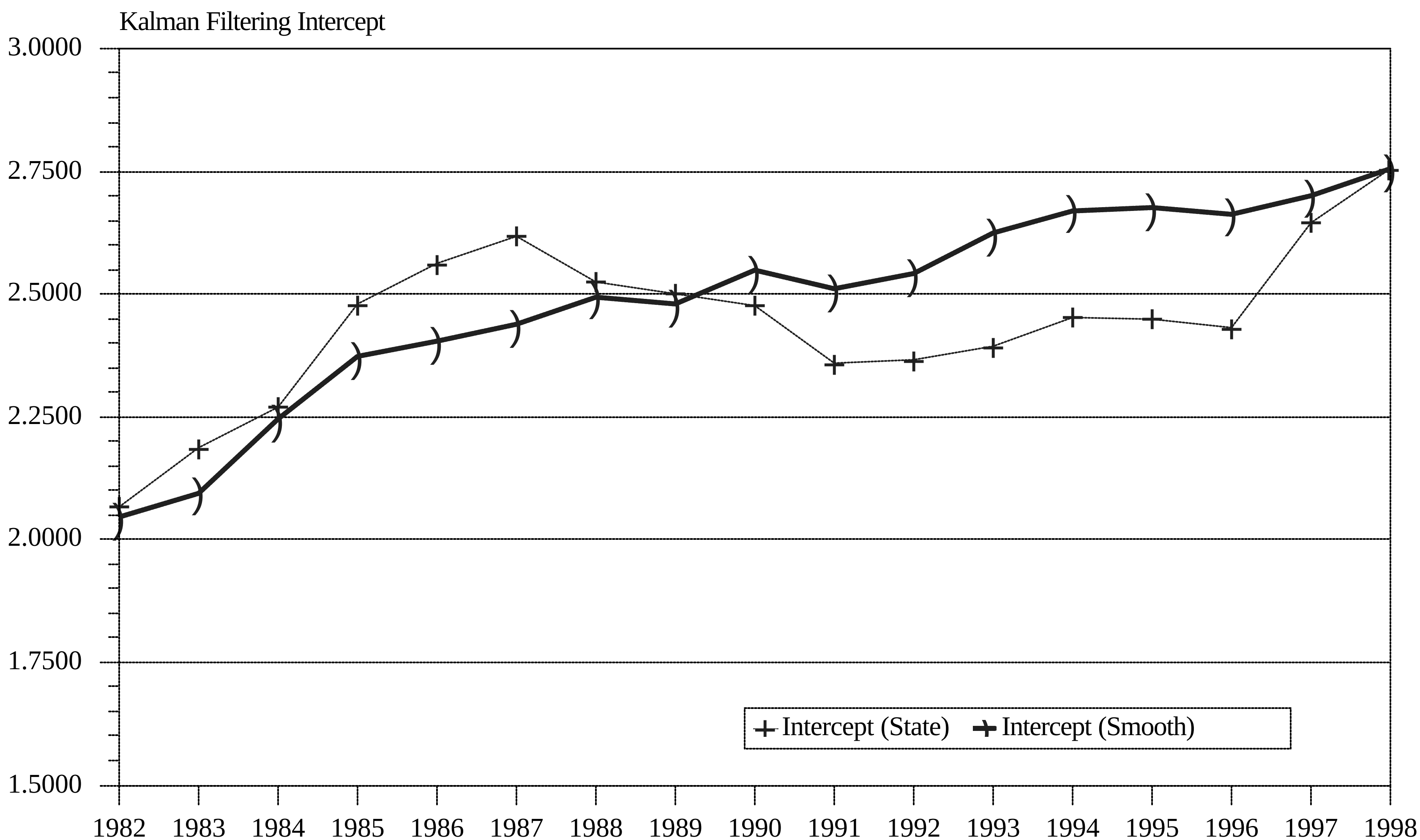


Figure 3. Dynamic path of Adjustment in HFCS direct price elasticity, 1982-98

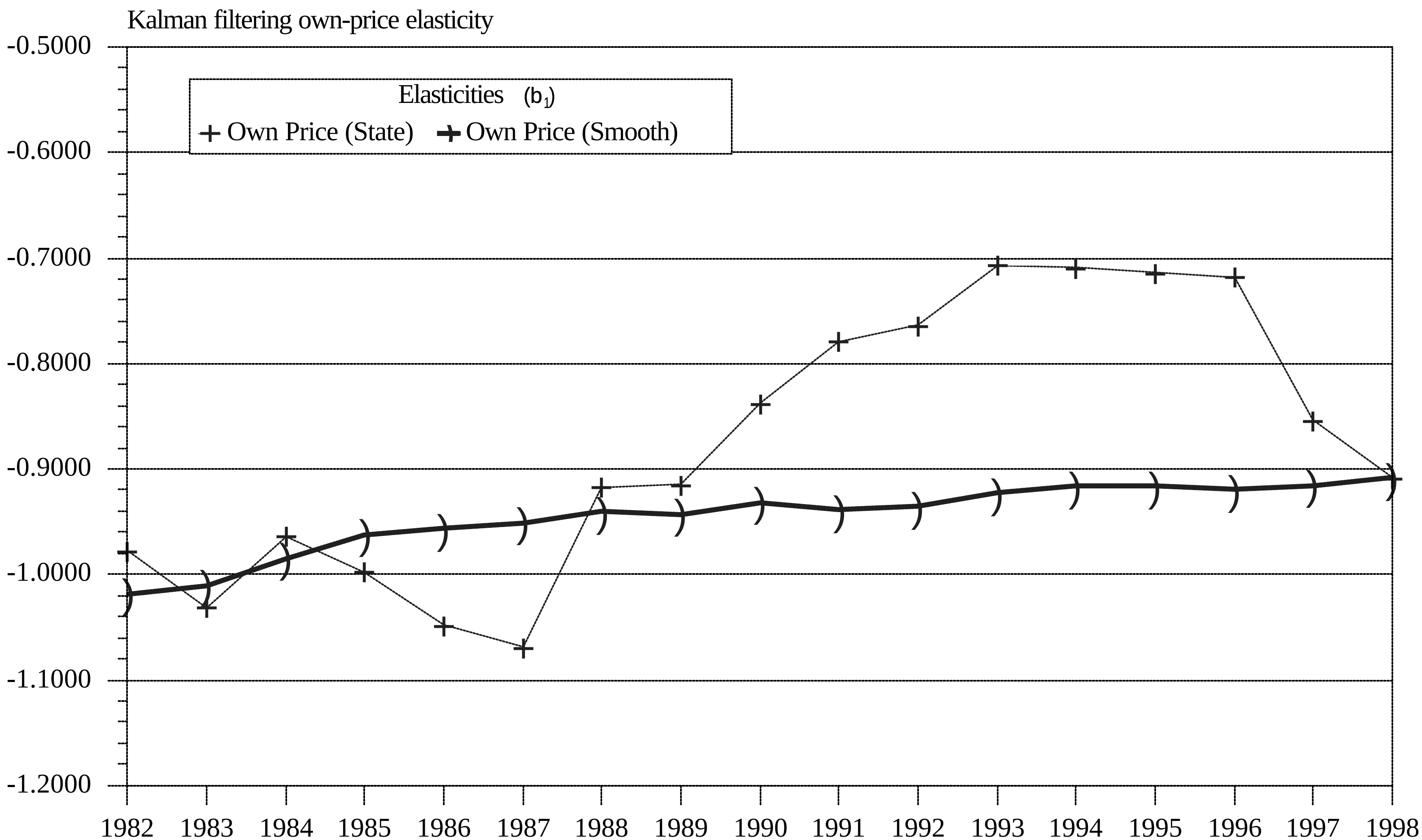


Figure 4. Dynamic path of Adjustment in HFCS cross price elasticity, 1982-98

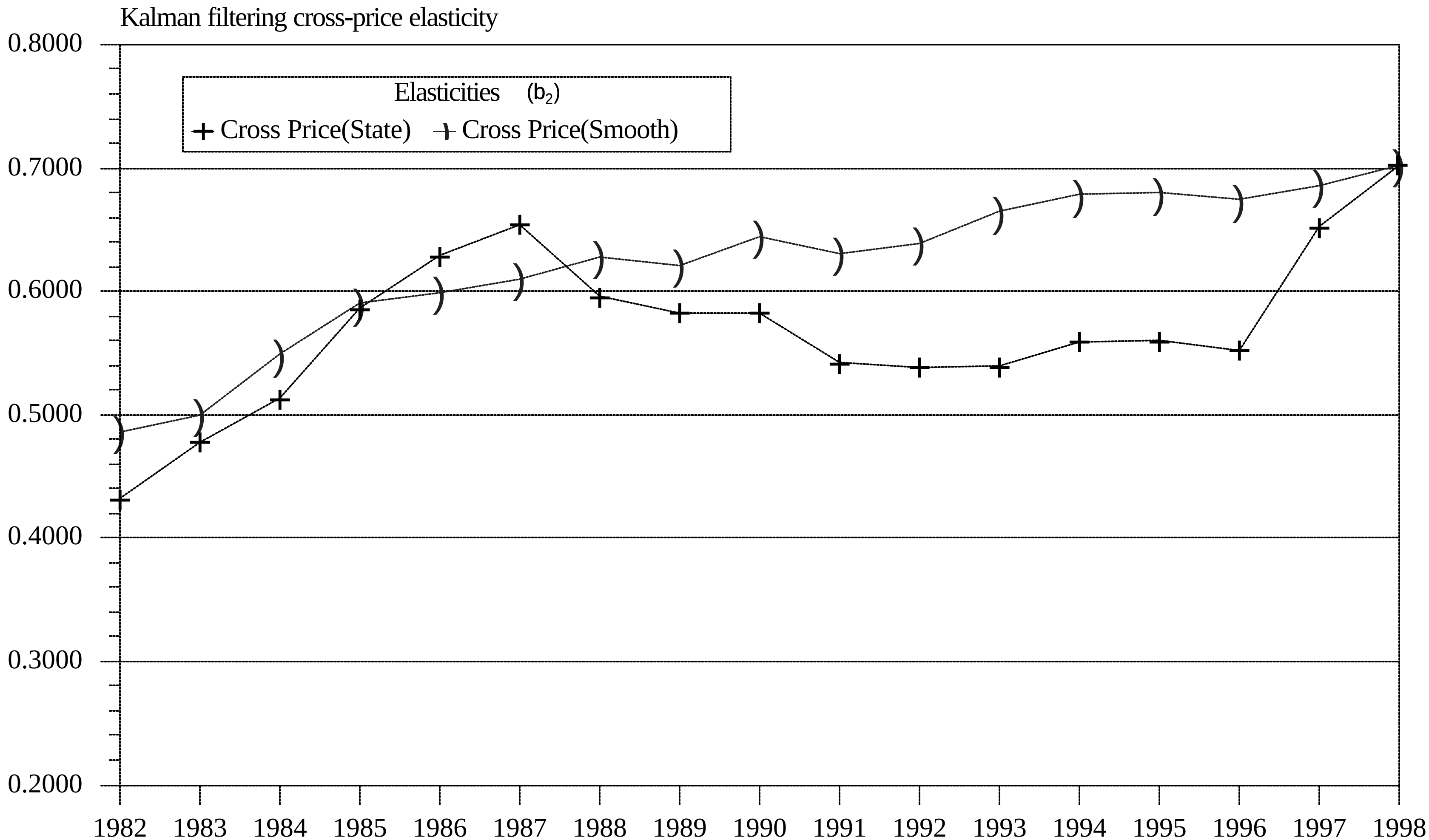


Figure 5. Simulated effects of changes in price spread and own-price elasticity on the quantities of HFCS demanded

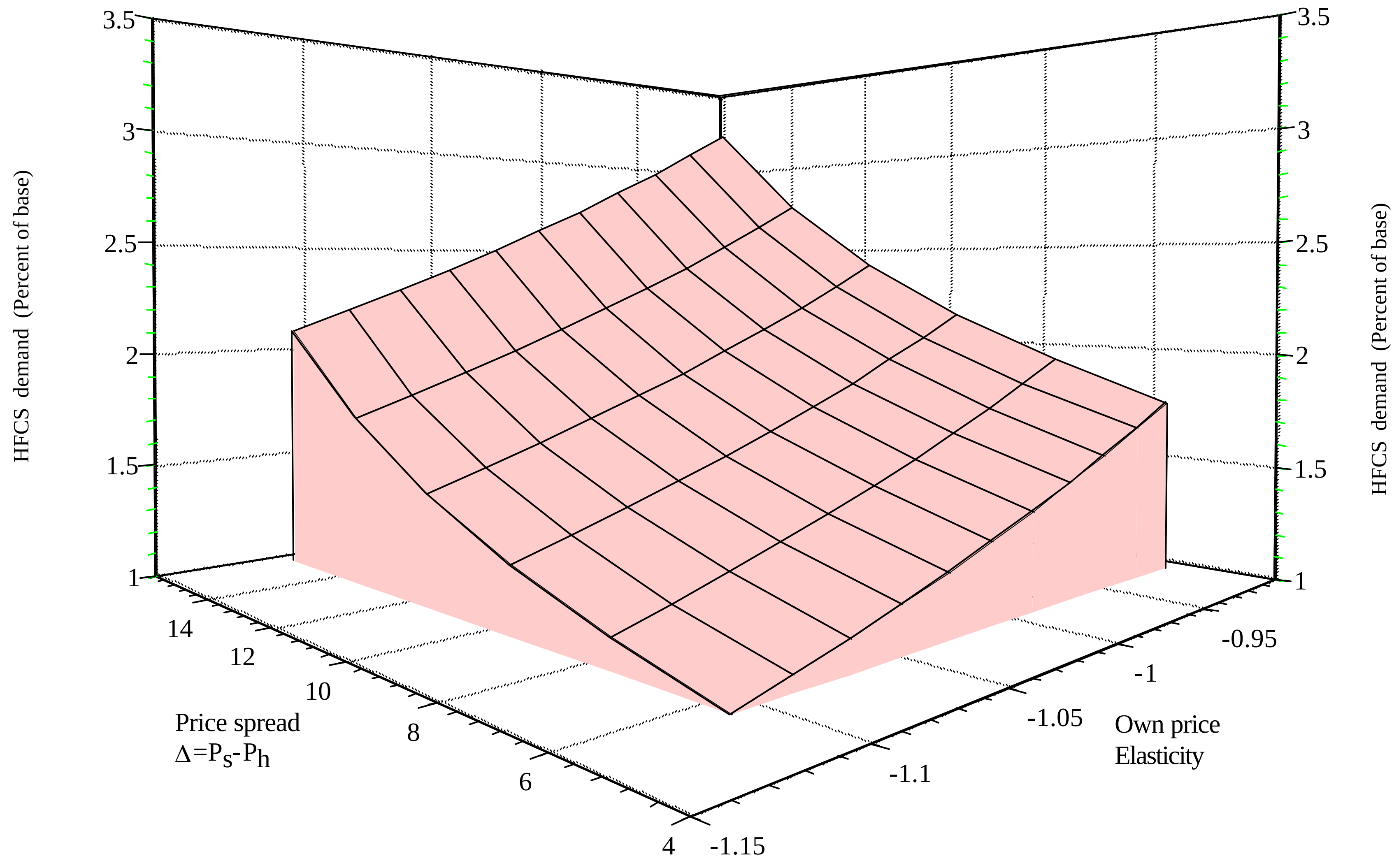


Figure 6. Simulated effects of changes in direct and cross price elasticities on the quantities of HFCS demanded

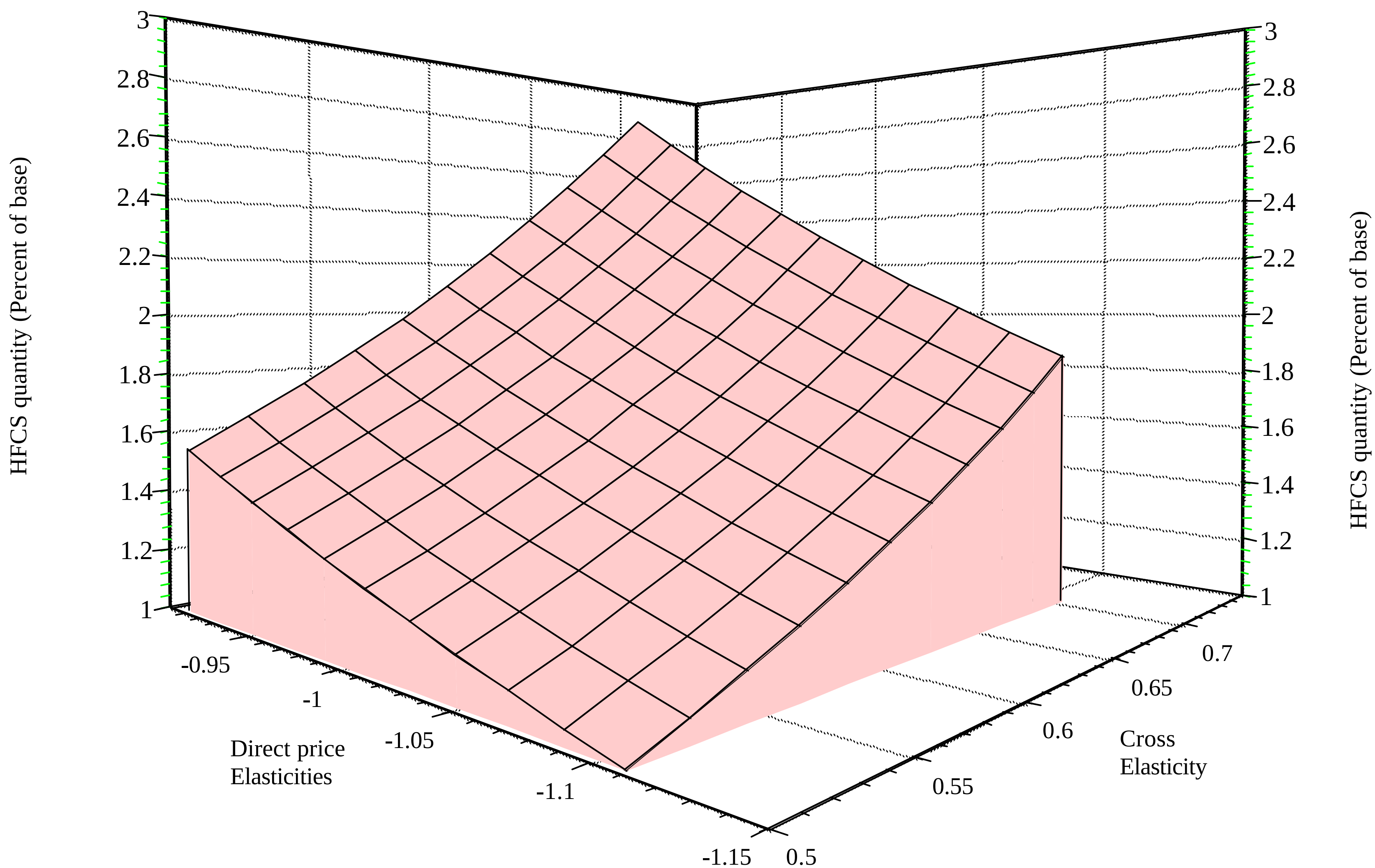
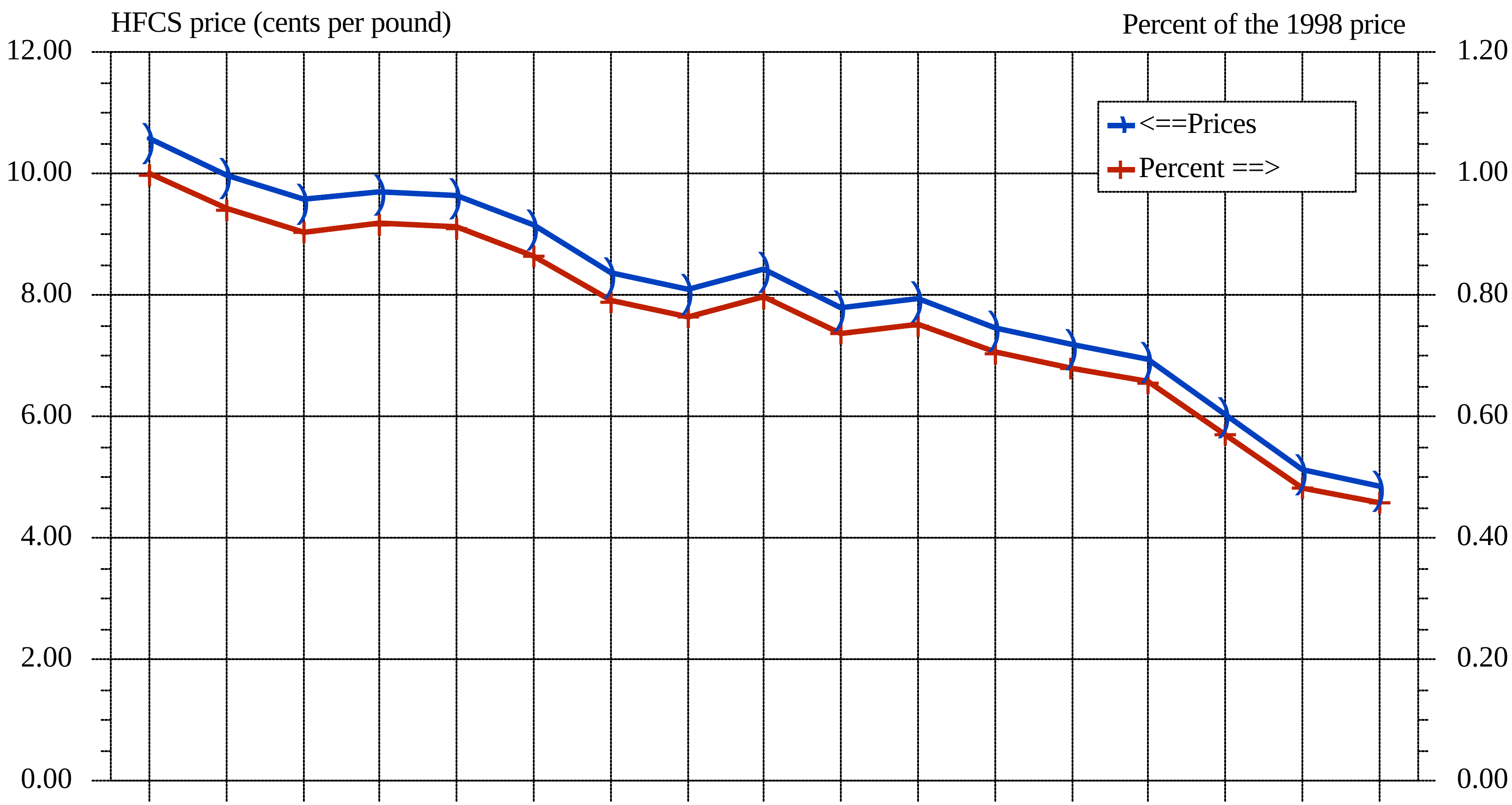


Figure 7. Implicit HFCS prices resulting from shifts in the HFCS intercept, 1982-98



	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982
<==Prices	10.58	9.98	9.57	9.71	9.65	9.16	8.36	8.09	8.44	7.81	7.96	7.47	7.19	6.95	6.04	5.12	4.85
Percent ==>	1.00	0.94	0.90	0.92	0.91	0.87	0.79	0.76	0.80	0.74	0.75	0.71	0.68	0.66	0.57	0.48	0.46

Figure 8. Simulated impact of time-varying parameters on the quantities of HFCS demanded, 1982-1998

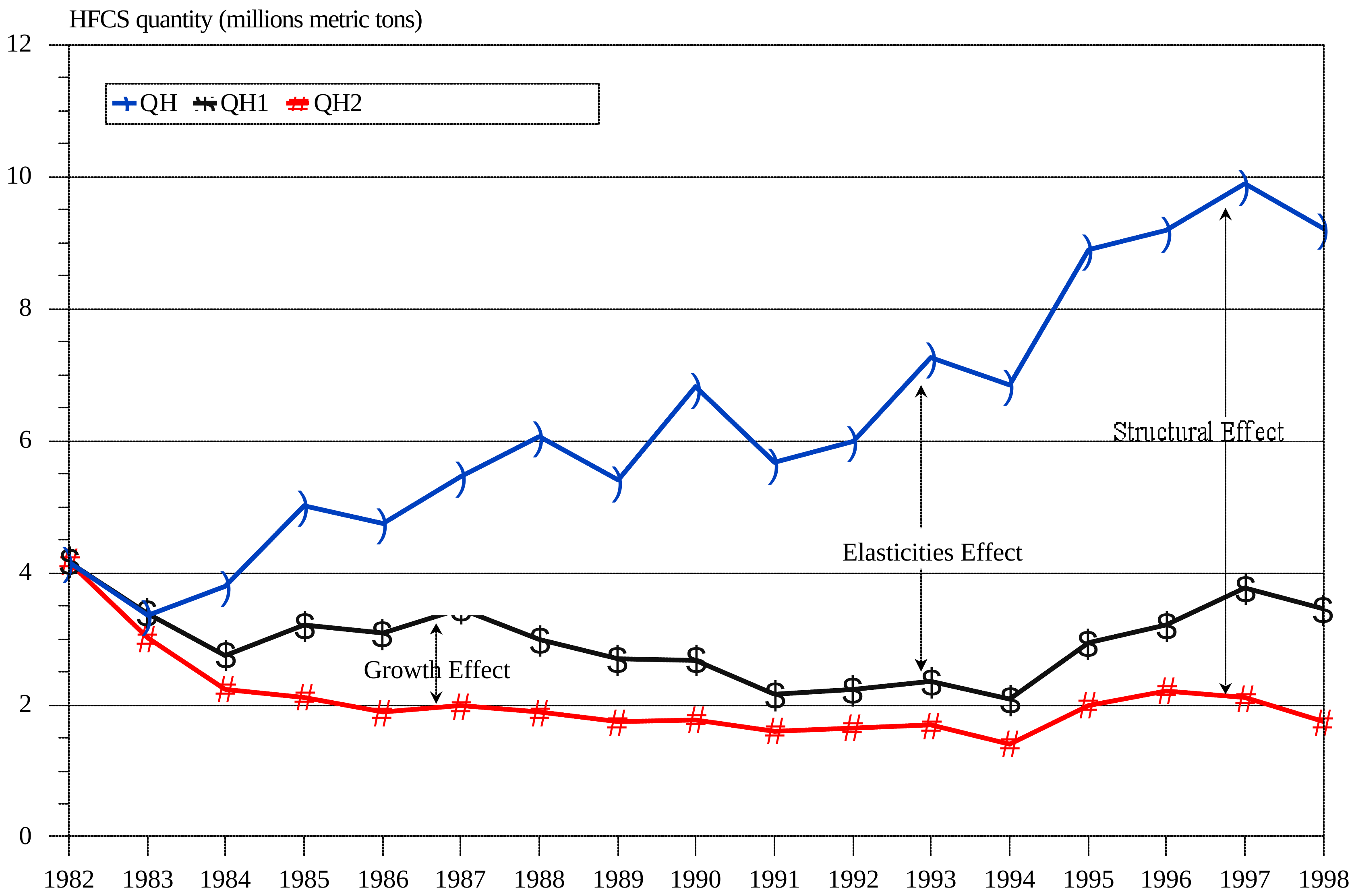


Figure 9. Revenue implications oftime-varying parameters over the period 1982-98