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Policy induced substitution of high fructose corn syrup for sugar in the United States

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US sugar policies have depressed the world sugar price markedly, and the substitution of high fructose corn syrup for sugar brought about by US sugar policies has contributed a major part of this price depressing effect. Current US sugar policies impose substantial costs on US consumers, the US economy and sugar exporters, most of which are developing countries. This paper measures the impact that the increased consumption of high fructose corn has had on both the US and world sugar economies. Three scenarios are analysed by running SUGABARE, an econometric model of the world sugar market. The first scenario models the actual policies in place from 1982 to 1993. The second excludes the expansion in high fructose corn syrup production brought about by US sugar policies, while the third provides for the full liberalisation of US sugar policies.

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Introduction

Over the past 30 years high domestic sugar prices established under the implementation of US sugar policies have induced a substitution of high fructose corn syrup (HFCS) for sugar and encouraged the development of the HFCS industry. This indirect effect of US sugar policy exacerbated the adverse effect of US sugar policies on world sugar exporters. US sugar policies provide significant assistance to US sugar beet and cane producers but at the same time have imposed large costs on raw sugar exporting countries and US consumers.

In this paper, the benefits to US sugar producers and the costs to US consumers and taxpayers and to world sugar exporters of US sugar policies over the period of 1982 to 1993 are examined. The contribution of the policy induced substitution of HFCS for sugar to these benefits and costs is also identified.

The US sugar and alternative sweetener situation

Consumption of caloric sweeteners (sugar and HFCS) in the United States has been gradually rising over time in both absolute and per person terms (table 1). The rising sugar and HFCS consumption reached a high level of 58.5 kg per person in 1993-94. Although total consumption has been rising, there have been rapid changes in the share of alternative caloric sweeteners. A sharp decline in sugar consumption in the late 1970s and early 1980s was largely the result of increased consumption of HFCS (table 1). Consumption of HFCS has grown because it is competitively priced against sugar and can be substituted for sugar in many liquid sweetener uses. The trend toward higher consumption of HFCS has continued and sugar's share of total sugar and HFCS consumption has fallen from an average of 72 per cent for the three years to 1982-83 to 51 per cent for the three years to 1993-94. In absolute and per person terms sugar consumption has also declined between the two periods, although consumption bottomed in 1985-86 and has gradually risen since that time. Although sugar consumption increased during the late 1980s, the increase was not as rapidly as that of HFCS resulting in the continued decline in the market share of sugar.

US sugar production has followed a similar pattern to consumption, with declines occurring to the mid 1980s, before there being growth over the last 10 years. However, the strong growth over the latter period has meant that production has increased by 28 per cent from an average of 5.3 million tonnes a year for the three years 1981-82 to 1983-84 to 6.8 million tonnes a year for the three years 1991-92 to 1993-94 (table 2).

Table 1: **Consumption of caloric sweeteners in the United States**
raw sugar equivalents

Year	Aggregate				Per person		
	Sugar	HFCS	Sugar and HFCS Total	HFCS share of sugar	Sugar	HFCS	Sugar and HFCS
	Mt	Mt	Mt	%	kg	kg	kg
1980-81	8.9	2.9	11.8	75	38.8	11.2	50.0
1981-82	8.4	3.2	11.6	72	36.1	12.3	48.3
1982-83	8.1	3.9	11.9	68	34.4	14.6	49.0
1983-84	7.8	4.6	12.4	63	32.9	17.3	50.2
1984-85	7.3	5.8	13.1	56	30.7	21.3	52.0
1985-86	7.0	6.1	13.1	54	29.3	22.2	51.5
1986-87	7.2	6.3	13.6	53	29.9	23.0	52.9
1987-88	7.4	6.6	14.0	53	30.2	23.8	54.0
1988-89	7.5	6.6	14.0	53	29.9	23.2	53.1
1989-90	7.7	6.8	14.5	53	30.9	24.0	54.9
1990-91	7.9	6.9	14.8	53	31.3	24.3	55.6
1991-92	8.0	7.4	15.3	52	31.3	25.4	56.7
1992-93	8.1	7.7	15.8	51	31.3	26.4	57.7
1993-94	8.2	8.0	16.2	51	31.4	27.1	58.5

Source: US Department of Agriculture 1994.

Raw sugar imports into the United States have gradually been falling (see table 2), largely because of increased US sugar production, the use of HFCS and the use of import quotas to control the level of imports.

The US sugar program

The US sugar program has operated largely unchanged since 1981. A history of the program is given in Sturgiss, Field and Young (1990). The principal features of the program have been a loan rate scheme and the previously mentioned import quotas. Under the 1990 legislation, import quotas are not able to fall below 1.134 million tonnes a year. The loan rate is intended to guarantee millers and processors a minimum domestic market price for their sugar. They in turn are required to pay producers a fixed minimum price for cane and beet. Raw cane sugar and refined beet sugar are used as collateral by millers and processors for loans provided by the Government. These loans have a repayment period of

Table 2: **Production of sugar in the United States - raw sugar equivalents**

Year	Production			Imports[a]
	Beet Mt	Cane Mt	Total Mt	Mt
1980-81	2.93	2.57	5.50	3.36[b]
1981-82	3.01	2.44	5.45	3.01[c]
1982-83	2.44	2.91	5.36	2.71
1983-84	2.57	2.70	5.27	2.73
1984-85	2.64	2.65	5.29	1.99
1985-86	2.71	2.76	5.47	1.67
1986-87	3.31	2.93	6.25	1.11
1987-88	3.47	3.02	6.48	0.79
1988-89	3.08	3.01	6.09	1.25
1989-90	3.14	2.86	6.01	1.77
1990-91	3.50	2.77	6.26	2.08
1991-92	3.49	3.08	6.57	1.35
1992-93	3.98	3.07	7.05	1.21
1993-94	3.67	3.14	6.81	1.02

a Quota sugar imports. An import quota was applied under US sugar policy during most of the 1970s and 1980s. The import quotas were temporarily removed from the 1979-80 crop year until 4 May 1982. b Net imports and no import quotas applied. c Net imports and includes 0.33 Mt quota imports made after the reimposition of quotas on 5 May 1982

Source US Department of Agriculture 1994

up to nine months, and are obtained from the Commodity Credit Corporation (CCC). The CCC is the organisation within the US Department of Agriculture which is responsible for implementing most of the government farm policies. When the sugar is sold, the miller or processor repays the loan to the CCC. Alternatively, processors may forfeit stocks to the CCC. For the 1993-94 crop, the loan rate for raw sugar was US18c/lb and US23.62c/lb for refined beet sugar. In comparison, during calendar year 1994 when most of the sugar would have been sold, world raw sugar prices averaged US12.1c/lb and world white sugar prices averaged US15.7c/lb.

While the loan rate scheme clearly provides for a commitment of taxpayer funds in the event of loan forfeitures, the scheme as a whole is managed to run on a 'no-net-cost-to-government' basis. This condition was stipulated in the 1985 farm legislation and has remained until the present time. Unlike other US commodity programs, with the exception of that for milk, the costs of the sugar program are borne largely by consumers (Brooks and Carter 1994). In order to prevent domestic sugar prices from falling below the loan rate,

import quotas are used to limit the supply of sugar onto the domestic market. Each year the US Department of Agriculture estimates the domestic production and demand for sugar and the level of supply and minimum stock levels that would keep domestic prices at a level above the loan rate. This level discourages producers from forfeiting sugar to the CCC.

Effects of US sugar policies

Without HFCS substitution

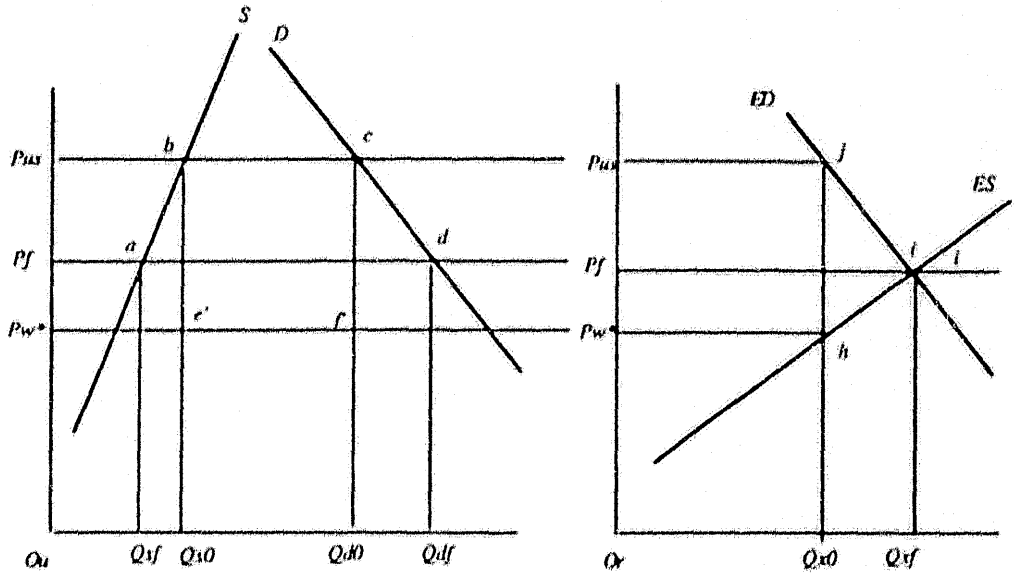
The effects of US sugar policies on the United States and world sugar markets are illustrated in figure A using a simple two market (United States and rest of the world) model with the rest of the world assumed to be an exporting market and the US an importing market. Under free trade between two markets, the US sugar market (panel A1) is represented with a supply curve *(S)* and a demand curve *(D)* for sugar while the rest of the world sugar market (panel A2) is represented with its excess supply curve *(ES)* and the US excess sugar demand (import demand) curve *(ED)*.

In a free trade situation both producers and consumers in the United States would face the world price P_f which is determined at *i*, the intersection of the rest of the world excess supply curve *ES* and US excess demand curve *ED*. Initially assuming no substitution of HFCS for sugar in the United States, a higher internal price (P_{us}) supported with import quotas will reduce consumption from Q_{df} to Q_{d0} and increase production from Q_{sf} to Q_{s0}. As a result, sugar imports (and exports from the rest of the world) to the United States decrease from Q_{df}–Q_{sf} (Q_{xf} in panel A2) to Q_{d0}–Q_{s0} (Q_{xo} in panel A2), leading to a fall in the world sugar price to P_w^*.

The US producer gains from the higher price and production than that would be achieved under a free trade situation are measured by the area P_fabP_{us}. Consumer losses due to a higher price and a lower consumption from the free trade levels (P_fdcP_{us}) are much larger than producer gains resulting in a net loss to the US economy for sweeteners as a whole as measured by area *abcd*. Import quotas are allocated between a number of countries which are able to capture a price premium (P_{us}-P_w^*) on the quantity they export to the United States.

The benefits which the rest of the world exporters receive for sugar sold on the US market under quota are not without cost because US sugar policy depresses the world sugar price for export sales to the rest of the world domestic market in this example. If more import markets are considered and assuming open trade, there would also be a lowering of prices

A Effects of US sugar policies without HFCS substitution



A1 United States **A2 Rest of theWorld**

in these markets. The net cost to rest of the world if there were no HFCS substitution is given by the losses due to a lower world price and lower exports (area $P_fihP_w^*$ in panel A2) minus the benefits from increased prices from US sales (area $bcfe'$ in panel A1 or $P_{us}jhP_w^*$ in panel A2).

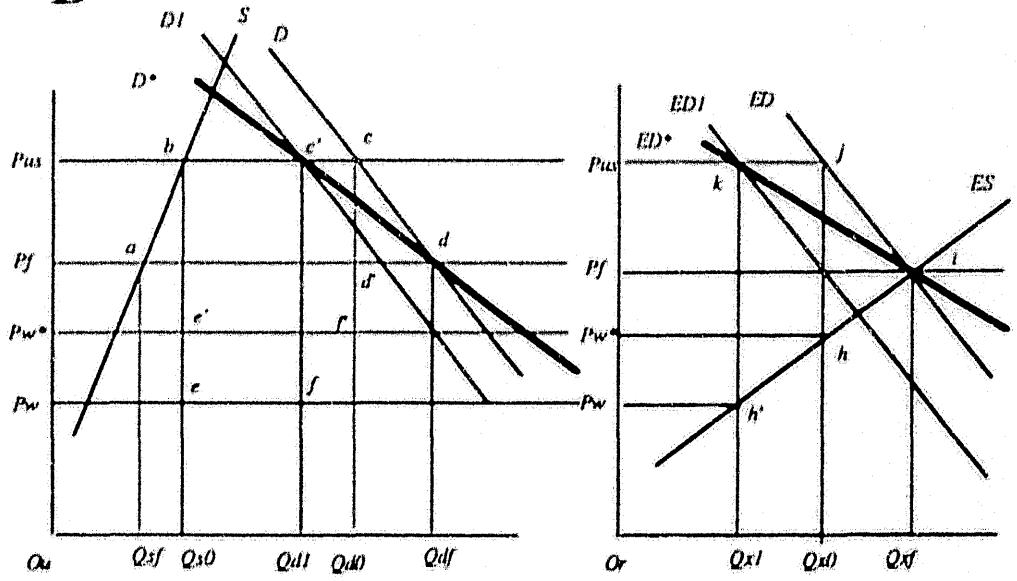
With HFCS substitution

A consequence of the US sugar program with the higher internal sugar price has been that HFCS has been substituted for sugar and that HFCS production in the United States has been much higher than it would have been otherwise. Therefore, by indirectly supporting an alternative sweeteners sector, the US sugar policy has had a much larger effect on world sugar market than would have initially been envisaged.

As illustrated in figure B, with the substitution of HFCS for sugar, the US sugar demand curve D in year t shifts to D_1 over n years (panel B1) resulting in a shift in its excess demand curve from ED to ED_1 over that period (panel B2). The shifts in the demand curve over n years trace out the general equilibrium demand curve D^* for sugar for year $t + n$ with $n + 1$ year-length of run. This general equilibrium demand curve for sugar takes into

account simultaneous adjustments in the HFCS market. Similar general equilibrium demand curves for sugar can be derived for each year in the n year period. The two-market equilibrium demand curve for sugar in year t ($n = 0$) with 1 year-length of run, D' overlaps D. The intermediate length of run general equilibrium demand curves between D' and D^* such as the demand curve in year $t + 1$ with 2 year-length of run and the demand curve in year $t + 2$ with 3 year-length and, so on are not illustrated in figure B.

B Effects of US sugar policies with HFCS substitution



B1 United States **B2 Rest of the World**

The new equilibrium with HFCS substitution is achieved in the United States at c' in panel B1 where the P_{us} line intersects D^* and in rest of the world at k in panel B2 where P_{us} line intersects US excess demand curve, ED^*. US sugar consumption and thus imports (exports from the rest of the world) decreases by $Q_{d0} - Q_{d1}$ in panel B1 ($Q_{x0} - Q_{x1}$ in panel B2) forcing the world sugar price further down to P_W.

As the general equilibrium demand curve takes account of simultaneous equilibrium adjustments in the HFCS market, consumer losses measured against it represent a joint net loss over all sweetener consumers and HFCS producers (Just, Hueth and Schmitz 1982, pp. 64–7). A similar approach was used by Leu, Schmitz and Knutson (1987) in their study of US sugar policy.

The joint net consumer losses over all sweetener consumers and HFCS producers as measured against the general equilibrium demand curve D^*, is given by area $P_{us}c'dP_f$ Therefore, HFCS substitution has reduced the consumer losses by area $c'cd$ from the levels without HFCS substitution (area P_fdcP_{us} in figure A1). The total loss to the economy for sweeteners as a whole is the area $abc'd$. The reduction in the loss to the economy as a whole with HFCs substitution is the difference between the loss without the substitution (the area $abcd$) and the loss with the substitution (area $abc'd$) which is equal to the area $c'cd$. US producer gains remain unchanged at P_fabP_{us}

When there is substitution of sugar by HFCS, the world price is lower and exports decline further, the loss to exporters becomes larger (area $P_fih'P_w$ in panel B2) while benefits from increased prices from US sales decrease from $bcf'e'$ to $bc'fe$ in panel B1 or from $p_{us}jhp_w^*$ to $p_{us}kh'p_w$ in panel B2.

The key feature of the US sugar policies is that they support internal US prices for sugar at levels well above world prices. From 1982 to 1993, the US domestic price averaged 178 per cent of estimated import parity. The domestic price was above world prices at all times during that period.

Modelling effects of US sugar policies on the US and world sugar markets

A updated version of the SUGABARE econometric model of the world sugar market was used to estimate the effect of US sugar policies on the world sugar market (Hafi, Connell and Sturgiss 1993). The current version of SUGABARE has 23 countries or regions. For each region in the model, behavioural equations have been specified for production, consumption, stocks, some policy variables, the share of white sugar in both total imports and exports, and export equations where a region both exports and imports. Exports from the pure exporters and imports are given as the residual of each individual sector. The world prices for raw sugar and for white sugar are not estimated directly, but are solved through simulation of the entire model and flow from the closing identities which equate the traded quantities demanded and supplied for raw sugar and white sugar.

In the model, the US sweetener sector is represented by two separate demand equations, one for sugar and the other for HFCS. The responsiveness of the demand for sugar and HFCS to changes in their respective prices is captured by using relative prices in the demand equations.

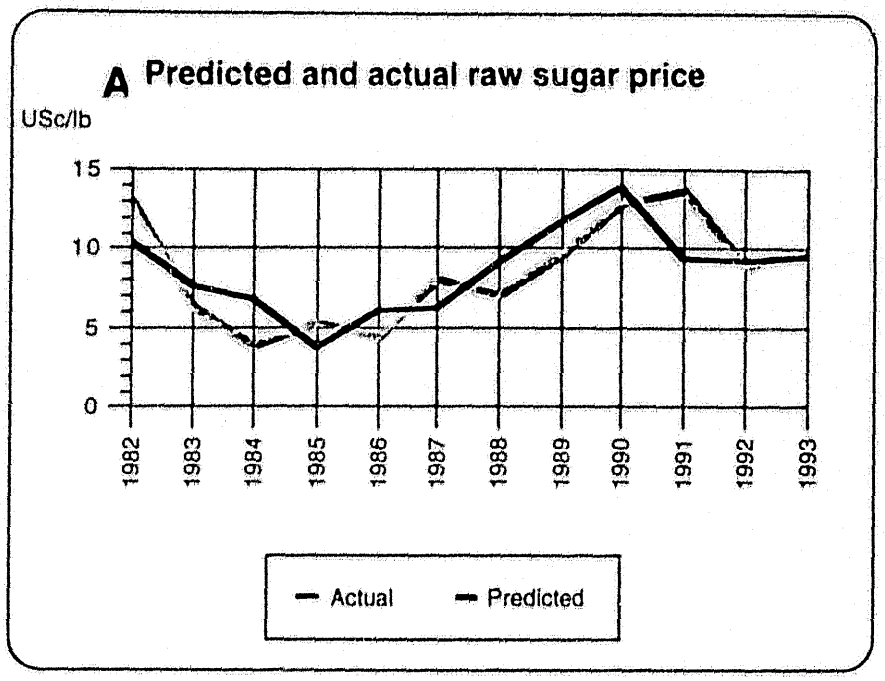
The growth in demand for HFCS which started in 1970s, continued into the early 1980s mainly resulting from some increase in the substitution of HFCS for sugar. Higher world sugar prices in the early 1980s and the reintroduction of a loan rate scheme for sugar in 1982 significantly increased the rate of substitution of HFCS for some uses of sugar. The higher demand for HFCS encouraged increased investment in HFCS production technology. As a result of economies of scale in production and lower prices of corn relative to the prices of alternative inputs which can be used to produce fructose syrup, the price of HFCS has remained competitive against US domestic sugar prices under the sugar policies in place since 1981.

The model was simulated under three different scenarios to estimate the effects of US sugar policies over the period 1982 to 1993.

The first simulation provides a baseline scenario using actual policies in place from 1982 to 1993, a period which led to a significant substitution of HFCS for sugar. The model was run to estimate representative world raw and white sugar prices and world and US production and trade effects over the simulation period. The estimated price series was found to follow the actual price series fairly closely (figure A). The Theil's inequality coefficient calculated using simulated and historical values for world raw sugar price over the simulation period was 0.11. (A close to zero value of the calculated Theil's inequality coefficient indicates the model's sound capability in tracking recent price movements.)

The second scenario excludes the expansion in HFCS production brought about by US sugar policies and thus removes any policy induced substitution of sugar by HFCS. In this simulation, the demand curve for sugar used in the first simulation, for each year was shifted outward by removing the cumulative policy induced substitution of sugar by HFCS from 1982 to that year. The method used to approximate the sugar demand curve if there was no policy induced substitution of HFCS for sugar is explained in Appendix A.

Effectively, this scenario provides a base for separating out the effects of US sugar policies on changes in US HFCS production on the world sugar market and on US sugar consumption. If there was no HFCS substitution, US sugar consumption and imports would have been higher and the world price depressing effects of US policies smaller.



The third scenario provides for the full liberalisation of US sugar policies. That is, all support through the loan rate and other domestic measures is eliminated and all quotas and other barriers to imports are removed. Policies in other countries remain unchanged. Given this scenario, estimates are made of how US policies have affected world market behaviour.

In the absence of US sugar support policies, that is with full liberalisation of US policies, US sugar prices would have been much lower than actually applied and it is uncertain whether the research and development and high set up costs for the HFCS industry would have been feasible. Consequently, the HFCS industry might not even have been developed. Even if the industry had developed, the expansion would have occurred at a lower rate than with the US sugar policies in place. Similarly US consumption of HFCS would also have continued to rise, but at a lower rate than with US sugar support policies in place.

Estimated effects of current policies

When compared with the situation which would have applied if all US support and import barriers had been removed (full liberalisation - scenario 3), US sugar policies have depressed world raw sugar prices, on average, by an estimated 40 per cent over the twelve years to 1993 (table 3). The depressing effect on world sugar prices would have been less if

the US sugar policies had not induced such a large rate of substitution of HFCS for sugar in the United States. If there was no increase in the rate of substitution of HFCS for sugar brought about by US sugar policies, world prices would have declined by only around 12 per cent over the twelve years to 1993 as a result of US support policies and import restrictions.

Table 3: **Estimated effect of US sugar policies on world raw sugar price**

Year		*Scenario 1*	World price with full US liberalisation			
			Scenario 2 Without HFCS substitution		*Scenario 3* With HFCS substitution	
	World market price	Baseline world price	Price	Change from baseline	Price	Change from baseline
	USc/lb	USc/lb	USc/lb	USc/lb	USc/lb	USc/lb
1982	10.4	12.9	13.5	0.6	13.8	0.9
1983	7.6	6.3	7.3	1.0	8.4	2.1
1984	6.7	3.8	5.1	1.3	7.3	3.5
1985	3.7	5.3	8.5	3.1	13.9	8.6
1986	6.0	4.4	8.4	3.9	12.4	7.9
1987	6.2	8.1	16.8	8.7	19.6	11.5
1988	9.0	7.0	11.9	4.8	12.0	5.0
1989	11.6	9.7	15.3	5.6	16.3	6.7
1990	13.9	12.9	18.1	5.3	19.5	6.6
1991	9.3	13.6	19.3	5.6	20.1	6.5
1992	9.2	8.9	12.0	3.1	12.4	3.5
1993	9.6	10.1	16.1	6.0	17.2	7.1
Average	8.6	8.6	12.7	4.1	14.4	5.8

US sugar policies have resulted in lower sugar consumption (table 4), increased domestic production, and thereby have reduced US sugar imports by an average of 3.9 million tonnes a year from 1982 to 1993. The increased rate of substitution of HFCS for sugar brought about by US sugar policies accounted for approximately two thirds of the estimated reduction in US imports of sugar over that period.

Table 4: **Estimated effect of US sugar policies on US sugar market variables - change from the levels which would have applied with full US liberalisation**

	Consumption			Production		Imports		
		Policy induced reduction in consumption			Policy induced increase in production		Policy induced reduction in imports	
	Actual	Without HFCS substitution	With HFCS substitution	Actual		Actual[a]	Without HFCS substitution	With HFCS substitution
	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt
1982	8.4	-0.09	-0.87	5.45	0.00	3.01[b]	-0.25	-0.87
1983	8.1	-0.24	-1.56	5.36	0.46	2.71	-0.95	-2.33
1984	7.8	-0.28	-1.94	5.27	1.66	2.73	-2.10	-3.87
1985	7.3	-0.10	-2.74	5.29	2.42	1.99	-2.41	-4.97
1986	7.0	-0.08	-3.26	5.47	1.99	1.67	-1.98	-5.40
1987	7.2	-0.10	-3.35	6.25	1.21	1.11	-0.95	-4.31
1988	7.4	-0.59	-3.93	6.48	0.87	0.79	-1.47	-4.89
1989	7.5	-0.53	-3.74	6.09	0.49	1.25	-1.09	-4.36
1990	7.7	-0.01	-3.22	6.01	1.07	1.77	-1.16	-4.35
1991	7.9	-0.49	-3.69	6.26	0.35	2.08	-0.48	-3.65
1992	8.0	-0.59	-3.76	6.57	0.01	1.35	-0.84	-3.99
1993	8.1	-0.03	-3.37	7.05	0.34	1.21	-0.51	-3.75
Average	7.7	-0.26	-2.95	5.96	0.91	1.81	-1.18	-3.89

a Quota sugar imports. An import quota was applied under US sugar policy during most of the 1970s and 1980s. The import quotas were temporarily removed from the 1979-80 crop year until 4 May 1982. b Net imports. Includes 0.53 Mt quota imports made after the reimposition of quotas on 5 May 1982.

Source: Model estimation and US Department of Agriculture, 1994

The US sugar support arrangements, through maintaining domestic prices at well above world market prices, impose substantial costs on the US economy, as is shown in table 5. The costs to consumers arise from them paying higher prices for sugar which reduces their consumption relative to levels which would have applied had US policies been completely liberalised. It is estimated that over the twelve year period from 1982 to 1993, US consumers of sugar and HFCS suffered a welfare loss averaging US$2255 million per year in constant 1994 values as a direct result of policy interventions. However, from this amount should be subtracted an estimated gain of US$259 million per year by sweetener users arising from the substitution of HFCS for sugar. After allowing for this substitution effect, the welfare loss to sugar and HFCS consumers averaged US$1996 million per year.

Table 5: **Effects on US economy of its sugar policy - from the full US liberalisation level (In 1994 US dollars - millions per year)**

Period	Welfare gains to US producers	Welfare cost to sugar and HFCS consumers net of welfare gains to HFCS producers without the effect of HFCS substitution for sugar	Welfare gains to sugar and HFCS consumers from substitution of HFCS for sugar	Net welfare loss to US Economy
1982-84	2180	3720	255	1285
1985-87	910	2050	290	850
1988-90	950	1820	290	580
1991-93	705	1430	200	525
Average	1186	2255	259	810

The welfare loss to US consumers of sugar and HFCS has been well above the benefits derived by US sugar producers as a result of the policies, which averaged US$1186 million per year in constant 1993 values during the same twelve years. This results in a direct welfare loss to the economy of US$810 million per year.

It should be noted that the high fructose corn syrup is liquid and is not a perfect substitute for sugar in many baking applications. However it is a good substitute for sugar in other applications such as soft drink manufacture. Because uses of HFCS are more constrained than those for sugar, and substantial gains have been made in reducing costs of HFCS production through exploiting economies of scale, its competitively determined price is lower than the US domestic price for sugar. But, for items in which it is a good or perfect substitute for sugar, cost savings to users can be effected through substituting the syrup for sugar, given the high US domestic price for sugar. It is important to recognise that, even at prices below the US domestic price for sugar, US prices for HFCS are still higher than world prices for sugar, so US consumers of that syrup are still incurring costs relative to levels which would apply if they had access to sugar at world prices.

Cost and benefits to foreign suppliers

US protection for its sugar industry depresses world market prices. In turn the reduced world prices result in welfare costs to exporting countries. As world prices for sugar are volatile and the effects of US policies on world prices also vary markedly from year to

year, the losses in export revenue incurred by exporting countries as a result of the policies vary greatly. These losses peaked over the period 1985-87 when exporting countries lost an estimated US$8548 million per year of export revenue as a result of the depressing effect of the US policies on world prices (table 6). These losses in export revenue were only partly offset through gains of an estimated US$800 million per year as a result of access to the high price US market, giving an average net loss of US$7748 million per year. More recently, with higher world prices and a lesser consequential effect of US policies, the losses in export revenues to exporting countries have been lower but still substantial in absolute terms. From 1991 to 1993, the net losses averaged an estimated US$4326per year. It should be noted that the estimated losses in export revenue is also partly offset by some gains to consumers in these exporting countries. However, these gains were not measured in this study.

Table 6: **Changes in world aggregate export revenues**
In 1993–94 US dollars

	1982–84	1985–87	1988–90	1991–93
	US$m	US$m	US$m	US$m
With HFCS substitution				
Loss to lower world price	–2093	–8548	–5103	–4326
Gains from higher US prices	947	800	429	598
Net change	–1146	–7748	–4673	–3728
Without HFCS substitution				
Loss to lower world price	–1197	–4055	–759	–617
Gains from higher US prices	1461	1535	854	796
Net change	264	–2520	95	181

The losses from US sugar policies could have been much smaller if there was no policy induced HFCS substitution for sugar (table 6). The policy induced HFCS substitution is estimated to have contributed to 66 per cent of exporting countries losses over the 12 years to 1993. Policy induced substitution has also reduced the quota rent from the levels otherwise would have as a result of lowering of import quotas.

The effects of US sugar support policies on the individual sugar exporting countries depend on the extent to which those countries have access to the US market. Those countries which attain access for their sugar to the US market obtain the internal US supported prices for the quantities exported to the United States. If such exports to the United States are large relative to total exports, an exporting country may even gain from the US policies. Gainers in the early 1980s were the Caribbean countries (table 7). However, US sugar policies cost

major sugar exporting countries like Australia, Thailand and Brazil whose exports to the United States were small relative to total exports.

Table 7: **Changes in export revenues for selected countries**
In 1993–94 US dollars

	1982–84	1985–87	1988–90	1991–93
	US$m	US$m	US$m	US$m
Australia				
With HFCS substitution				
Loss to lower world price	–187	–850	–525	–468
Gains from higher US prices	91	52	36	33
Net change	–96	–798	–489	–436
Without HFCS substitution				
Loss to lower world price	–104	–382	–76	–65
Gains from higher US prices	60	216	65	55
Net change	–44	–166	–11	–10
Brazil				
With HFCS substitution				
Loss to lower world price	–212	–981	–481	–335
Gains from higher US prices	160	91	63	57
Net change	–52	–890	–418	–278
Without HFCS substitution				
Loss to lower world price	–125	–475	–65	–47
Gains from higher US prices	227	164	66	43
Net change	102	–311	1	4
Thailand				
With HFCS substitution				
Loss due to lower world prices	–109	–474	–407	–392
Gains from higher US prices	15	9	6	5
Net change	–94	–465	–401	–386
Without HFCS substitution				
Loss to lower world price	–60	–216	–65	–55
Gains from higher US prices	22	16	6	4
Net change	-38	–200	-58	-51
Caribbean countries				
With HFCS substitution				
Loss due to lower world prices	–127	–403	–219	–213
Gains from higher US prices	381	217	150	136
Net change	254	–186	–70	–77
Without HFCS substitution				
Loss to lower world price	–71	–185	–31	–28
Gains from higher US prices	541	391	156	103
Net change	470	206	125	75

Conclusions

Sugar import quotas have been used as a major instrument to maintain domestic US prices at well above world prices and thereby to support returns to US sugar producers. They have also been used as an instrument of foreign policy. In the early 1980s, the policies provided significant transfers to Caribbean Basin countries. However, since 1985, US sugar policies are estimated to have imposed a small cost on Caribbean countries as a group. US producers of HFCS and other alternative sweeteners have benefited indirectly but extensively due to the policy induced substitution of HFCS for sugar. US sugar policies have depressed the world price markedly, and the substitution of HFCS for sugar brought about by US sugar policies has contributed a major part of this price depressing effect. Current US sugar policies impose substantial costs on US consumers, the US economy and sugar exporters, most of which are developing countries.

Appendix A
Estimating the sugar demand shift due to HFCS substitution

In the SUGABARE model, per person sugar consumption in the United States is modelled as a function of price of sugar relative to price of HFCS, per person income and a time trend.

Per person consumption in year t is given in equation 1.

$$Q_t = a_t - b_t . P_t^s \qquad (1)$$

Where:

$a_t = a + c.Y_t + d.t$

$b_t = b(\frac{1}{P_t^f})$

Q_t = per person consumption in year t

Y_t = per person income in year t

t = 1, 2, ... , n. (also time trend)

P_t^s = price of sugar

P_t^f = price of HFCS

Per person consumption in year 1 can be given in equation.

$$Q_1 = a_1 - b_1 . P_1^s \qquad (2)$$

Where:

$a_1 = a + c.Y_1 + d$

$b_1 = b(\frac{1}{P_1^f})$

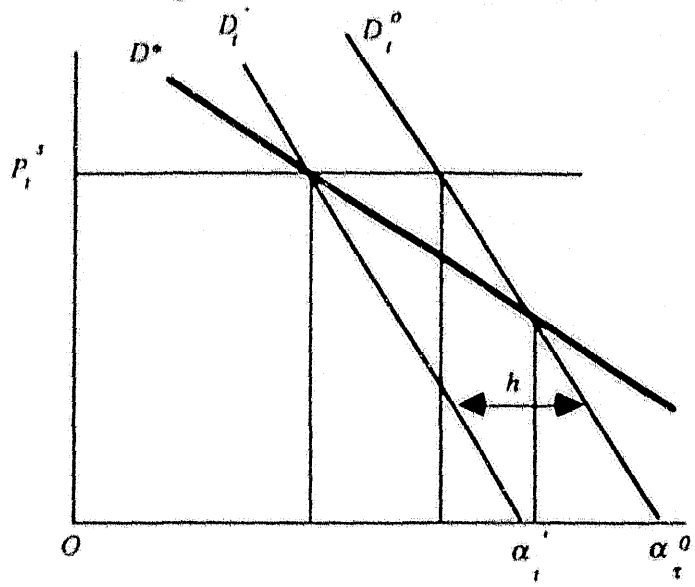
The sugar demand curve, if there was no HFCS substitution (D_t^0) can be approximated by multiplying year 1 per person consumption equation (equation 2) by year t population. This is given in equation 3 .

$$D_t^0 = \alpha_t^0 - \beta_t^0 . P_t^s \qquad (3)$$

Where:

$\alpha_t^0 = a_1 * N_t$

A Shift in US sugar demand with HFCS substitution



and $\beta_t^0 = b(\frac{P_t^1}{P_t^1})N_t$

The substitution of HFCS for sugar is captured through the change in the price of sugar relative to the price of HFCs and the negative time trend in the demand equation. The negative time trend which captures the inward shifts in the demand curve over the years reflects the preference by the industrial users, particularly the US beverage industry for HFCS over sugar. Leu, Schmitz and Knutson (1987) in their study of US sugar policy also treated substitution of HFCS for sugar as being driven by a these factors.

The sugar demand curve with HFCS substitution can be derived as follows. After assigning income at year 1 level and then multiplying equation 1 (per person consumption in year t) by population in year t (N_t) we get

$$D_t^1 = \alpha_t^* - \beta_t^* . P_t^1 \text{.....(4)}$$

Where: $\alpha_t^* = a_t^* * N_t$

$a_t^* = a + c.Y_t + d.t$

$$\beta_t^{\cdot} = b\left(\frac{1}{P_t^f}\right)N_t$$

However, $$\beta_t^{\cdot} = \left[\beta_t^0 + b\left(\frac{1}{P_t^f}\frac{P_1^r}{P_1^f}\right)N_t\right]$$

after substituting this to equation 4 and re-arranging terms

$$D_t = \alpha_t^{\cdot} - b\left(\frac{1}{P_t^f}\frac{P_1^r}{P_1^f}\right)P_t^r N_t - \beta_t^0 . P_t^r$$

assigning $\alpha_t^{\cdot} = \alpha_t^{\cdot} - b\left(\frac{1}{P_t^f}\frac{P_1^r}{P_1^f}\right)P_t^r N_t$, this can be simplified as

$$D_t = \alpha_t^{\cdot} - \beta_t^0 . P_t^r \text{.....(5)}$$

As the second term on the right hand side of both equation 5 and 3 are now identical, the horizontal shift in US sugar demand in year t (h) can be approximated by subtracting the intercept of the demand equation with HFCS substitution ($\alpha_t^{\cdot}$) from the intercept of demand equation without HFCS substitution (α_t^0) with HFCS substitution . This is given by the distance h in figure A.

The horizontal demand shift for each year from year 1 can be approximated in a similar fashion (table 1).

The SUGABARE baseline simulation with HFCS substitution was obtained using $D_t^{\cdot}$ and the baseline without HFCS substitution was obtained using reconstructed D_t^0. The estimated value of $\alpha_t^{\cdot}$ and α_t^0 are given in table below.

By 1987, the US sugar demand curve has had shifted by an estimated 3.25 million tonnes from its estimated position in 1981. By around this time HFCS appeared to have used up most of the substitution opportunities in US sweetener market. A shrinking of the estimated horizontal distance since 1987 could be due to HFCS substitution reaching its peak and also due to a reversal of the past declining trend in per person consumption of sugar around that

time. Per person consumption of sugar in the United states declined from 36 kg in 1992 to 30 kg in 1987, before it started to increase to 31.4 kg in 1993 .

Year	α_t (Mt)	α_t^0 (Mt)	$h = \alpha_t^0 - \alpha_t$ (Mt)
1982	9.16	9.94	0.78
1983	8.73	10.04	1.32
1984	8.49	10.15	1.66
1985	7.60	10.25	2.65
1986	7.17	10.35	3.18
1987	7.19	10.45	3.25
1988	7.21	10.55	3.34
1989	7.45	10.66	3.21
1990	7.53	10.74	3.21
1991	7.63	10.82	3.20
1992	7.74	10.91	3.17
1993	7.65	10.99	3.34

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