REVIEW OF MARKETING AND AGRICULTURAL ECONOMICS
VOL. 51, No. 1 (*April*, 1983)

Development of High Fructose Syrup in the US and its Implications for Australia

D. Jane Niall* and Rhonda L. Smith†

Sugar is an important agricultural export for Australia, hence developments affecting the world market are of concern. Alternative sweeteners, in particular High Fructose Syrups, are making inroads into the United States sugar market, one of the traditional destinations for Australia sugar exports. With sugar currently in oversupply on the world market Australia is affected by this development both through erosion of her markets and through lower prices. In this paper the development of the High Fructose industry in the United States and the implications for Australia are considered.

Introduction

Sugar cane is one of the major crops produced in Australia, accounting for an average of 11 per cent of the gross value of production of all crops for the period from 1959–60 to 1980–81. After iron ore, wheat, coal, wool and meat, sugar is Australia's sixth largest export earner. Australian sugar production is likely to expand in the future. Currently the Queensland industry is operating below its potential capacity, with the likelihood of more land suited to cane growing being available if the Burdekin Dam goes ahead. In addition, the Western Australian government has announced its intention to develop a sugar industry on the Ord River, producing around 160 000 tonnes a year. As the domestic market could not absorb this extra output (unless the cane were used as feedstock for the production of fuel alcohol) Australia will have to place it on the export market if it finally eventuates. However, the export market is already under pressure, and the world price of sugar is very low due to an excess of output over consumption. In addition to the problems caused by the dumping of EEC surplus sugar on the world market, world sugar production looks set to rise as many developing countries have plans to increase their domestic output. While this sugar may not actually enter world trade, as the developing countries offer the greatest potential for growth in consumption, increases in their domestic output could well absorb the increased demand leaving the world market unchanged. On the demand side, the import requirements of two major importers from the world sugar market, the US and Japan, are being eroded by the increasing substitution of High Fructose Sweeteners (HFS) for sugar. The effect of this on the sugar market has been exacerbated by government policies aimed at maintaining the level of domestic production[1].

---

* Research Fellow, Institute of Applied Economic and Social Research, University of Melbourne.

† Senior Lecturer, Faculty of Economics and Commerce, University of Melbourne.
This project has been supported by A.R.G.C. grants.

[1] For a discussion of recent US sugar policy see Bohall and Davis (1982a).

For Australia the effect of the HFS industry is likely to be felt through its impact on sugar exports rather than directly on the domestic market. Although Australia has a small dextrose/starch industry, it does not currently have an HFS industry. Should such an industry be developed the costs would be higher than in the US. The feedstock used in Australia would be wheat, the saleable by-product of which is gluten, a product which has a limited market which is extremely sensitive to increased production. The major feedstock used for HFS production in the US is corn, which yields corn oil and high protein animal feeds which are used by the livestock industry. Thus by-product returns in the US significantly reduce the original starch cost. In addition the geographical spread of the Australian market precludes the establishment of large low cost plants as in the US, and this will remain a problem until difficulties in transporting and storing HFS are solved. Investigations have been made into the feasibility of setting up an HFS industry in Australia, and the fact that as yet this has not occurred leads to the conclusion that at this stage HFS produced in Australia could not compete with the relatively low cost and efficient sugar industry.

Currently competition from HFS affects the sugar markets in the US, Japan, the EEC[2] and to a lesser extent Canada and Korea. With the exception of the EEC all are important importers of Australian sugar (Table 1). Excluding Korea all are developed countries where total consumption of sweeteners is unlikely to increase at a rate faster than the population growth. Therefore, competition from substitutes in these markets constitutes a threat to the sugar industry, particularly for exporting countries like Australia. Because of a determination by governments to support and/or retain their domestic sugar industries, any reduction in sugar consumption in these countries will feed through to the world free sugar market[3] where most of Australia's sugar is sold.

The US is the largest purchaser of sugar from the world free market, since 1974 importing around 25 per cent of the tonnage traded. Exports from Australia to the US averaged more than 350 000 tonnes a year between 1974–75 and 1977–78. After a marked fall to around 160 000 tonnes a year in the next two years due to restrictions imposed by the International Sugar Agreement (ISA), the US took 460 000 tonnes in 1980–81, or 18 per cent of Australian exports. In 1982 this is expected to fall to 120 000 tonnes, following the imposition of country-by-country quotas by the US in an attempt to support its domestic sugar industry.

---

[2] Since 1979 HFS production in the EEC has been controlled under the sugar protocol of the Common Agricultural Policy, with an "A" quota of 146 245 tonnes for which a full price guarantee is received, and a "B" quota of 40 217 tonnes on which a production levy is paid. HFS production in excess of this must be exported at full producer risk, and in fact very little "over quota" HFS is produced.

[3] The world free sugar market includes all sugar traded except that covered by certain Special Arrangements. This includes around 1.4 million tonnes of sugar traded under the Lome Convention, an agreement between the EEC and a number of developing countries, and the sugar traded between Cuba and the USSR and Eastern Europe (generally around 5 million tonnes). Sugar covered by long term contracts other than the above is classed as "free market" sugar. Since 1974 the free market has accounted for around 80 per cent of world sugar trade.

Table 1: *Australian Exports of Sugar: By Destination: Tel quel*

Item	1974–75	1975–76	1976–77	1977–78	1978–79	1979–80	1980–81
	kt	kt	kt	kt	kt	kt	kt
Raw sugar in bulk—							
Canada	378.9	379.7	469.8	617.3	278.0	368.9	309.0
China	41.4	101.5	218.1	210.0	113.3	273.8	263.8
Japan	225.3	558.8	732.7	697.8	688.0	733.6	691.1
Republic of Korea	154.9	206.9	200.8	270.3	216.1	270.7	308.2
Malaysia	255.4	198.7	266.8	46.0	224.7	287.0	297.9
New Zealand ..	124.6	20.6	107.9	92.2	98.7	34.4	123.6
Singapore	81.5	91.5	87.1	67.6	35.9	52.0	81.0
United Kingdom ..	266.4	63.9	121.5	28.7	..	..	..
U.S.A.	389.1	352.8	319.8	428.5	158.2	153.7	460.7
U.S.S.R.	51.7	..	..	..	..	..	..
Other countries ..	0.1	..	5.6	..	0.7	1.2	0.3
Total	1 969.3	1 974.4	2 530.1	2 458.4	1 813.6	2 175.3	2 535.7
Raw sugar in bags ..	0.3	0.3	0.2	0.2	0.5	1.1	1.1
Refined sugar.. ..	26.2	25.2	25.4	30.0	25.9	24.6	24.7
Grand total ..	1 995.8	1 999.9	2 555.7	2 488.6	1 840.0	2 201.0	2 561.5

Source: ABS, *Overseas Trade*, Reference 5403.0, Canberra (various issues), as published in BAE Sugar Situation and Outlook 1982.

A fall in US sugar import requirements is forecast between 1983 and 1986 (Bohall and Davis 1982a). This reflects slow growth in consumption of all nutritive sweeteners—sugar, corn syrup, honey and edible syrups, with an actual fall in sugar consumption expected, along with a rise in the consumption of HFS. In the absence of preferential treatment for Australian sugar along the lines of the proposed Caribbean Initiative, exports to the US can be expected to be affected to a greater extent than the gross figures indicate.

Owing to the importance of the US market to the Australian sugar industry, the threat to that market from the development of alternative sweeteners, particularly HFS, is of considerable concern. Thus, this paper examines the development of the HFS industry in the US. Section I presents a general outline of the sweetener industry, while Section II details the HFS industry in the US. In Section III the interdependence of sugar and HFS in the US is discussed and the implications of this for Australia are considered.

Section I Alternative Sweeteners

Although the major sweetener consumed is sucrose, during the last decade alternative sweeteners have captured an increasing proportion of the market. The alternative sweeteners include the non-nutritive sweeteners such as cyclamates and saccharin, as well as the nutritive sweeteners including honey, edible syrups, and the starch based sweeteners, HFS, glucose and dextrose. The major growth area, and that which has attracted attention recently, is the starch based sweeteners. Conventional starch based sweeteners include glucose (corn

syrup), and dextrose. Neither product is a strong competitor for the sugar market, and until the early 1970s the consumption of corn sweeteners grew at a rate reflecting little more than population changes. From 1950 to 1973–74 this group held around 4 per cent of the world sweetener market (McDowell and Murphy 1980). With the development of new technology in the late 1960s the high fructose syrups (usually called high fructose corn syrup (HFCS) in the US, referred to as isosyrups in the UK) became commercially viable and this changed but the situation for the starch based sweetener industry. Commercial production of HFS in the US began in 1972 (Brook 1977). This development has been hailed by some às the most significant development in the sweetener industry since the introduction of sugar beet to Europe. Since 1970 world consumption of starch based sweeteners has risen from 3.6 million tonnes to 7.5 million tonnes in 1980, increasing the share of this group from 4.1 per cent to 6.7 per cent of the sweetener market (Chilvers and Foster 1981), and this increase is mainly due to the growing consumption of HFS. The HFS industry is small compared with the sugar industry, with world wide consumption in excess of 90 million tonnes. In the early 1980s of the 8 million tonnes of starch based sweeteners consumed annually throughout the world, around 3 million tonnes was HFS—a volume which in the main has replaced sucrose.

The starch based sweeteners are derived from a number of crops including corn (maize), sweet potato, potato, wheat, cassava and rice. Corn is currently the most widely used starch source, as it is relatively cheap and abundant in the US, the major producer of starch based sweeteners. The first step in the production of corn sweeteners is the wet milling of the corn. Then, depending on the wet millers plant, the output can be starch, glucose syrup, dextrose, HFS or ethanol. In addition there are valuable by-products, corn oil, and high protein animal feeds the sale of which reduces the net corn cost, making it an economically attractive feedstock particularly in a country with significant livestock enterprises such as the US. However, a significant increase in the production of high protein animal feeds may adversely influence prices thus lowering by-product returns.

Of all the starch based sweeteners HFS is the one with the greatest potential to compete successfully for a significant portion of the sugar market. HFS currently exists commercially only in liquid form and so is suitable only for use in industrial processes which would otherwise utilize liquid sweeteners, of which the most commonly used is invert sugar (a mixture of glucose and fructose produced by making sugar react with water) or liquid sucrose. Three grades of HFS are now available—42 per cent, 55 per cent and 90 per cent. First generation, or 42 per cent fructose syrup, is slightly less sweet than sugar, and is used primarily in the baking, canning, beverage and processed foods industries. Normally it is mixed with sugar or other corn sweeteners. New technology allowed production of the second generation high fructose syrups which are more closely equivalent to sugar. In the case of the 55 per cent fructose syrup, the major use is in the making of beverages. The 90 per cent fructose syrup has been used as a marketing tool for replacement of sugar with "natural fruit sugar"—it is also used by the health food industry as a substitute for non-nutritive sweeteners (cyclamates, saccharin) in response to concern about health risks attendant with their use. Fructose can be crystallized from the 90 per cent syrup.

Since the development of 55 per cent HFS in 1979 there have been large increases in the usage of this product. The changing market mix between 42 per cent and 55 per cent HFS in the US is shown in Table 2, along with projections to 1985. From this it is clear that the major growth area in the future is the 55 per cent fructose syrup.

Table 2: Estimated HFS Deliveries by Product in the US for 1978, 1980 *and* 1985.
('000 tonnes dry)

Product Type	1978	HFS % Total	1980	HFS % Total	1985	HFS % Total
42%	1 085	89	1 293	68	1 636	41
55%	136	11	612	32	2 354	59
	1 221	100	1 905	100	3 990	100

Source: Vuilleumier (1981, p. 6.)

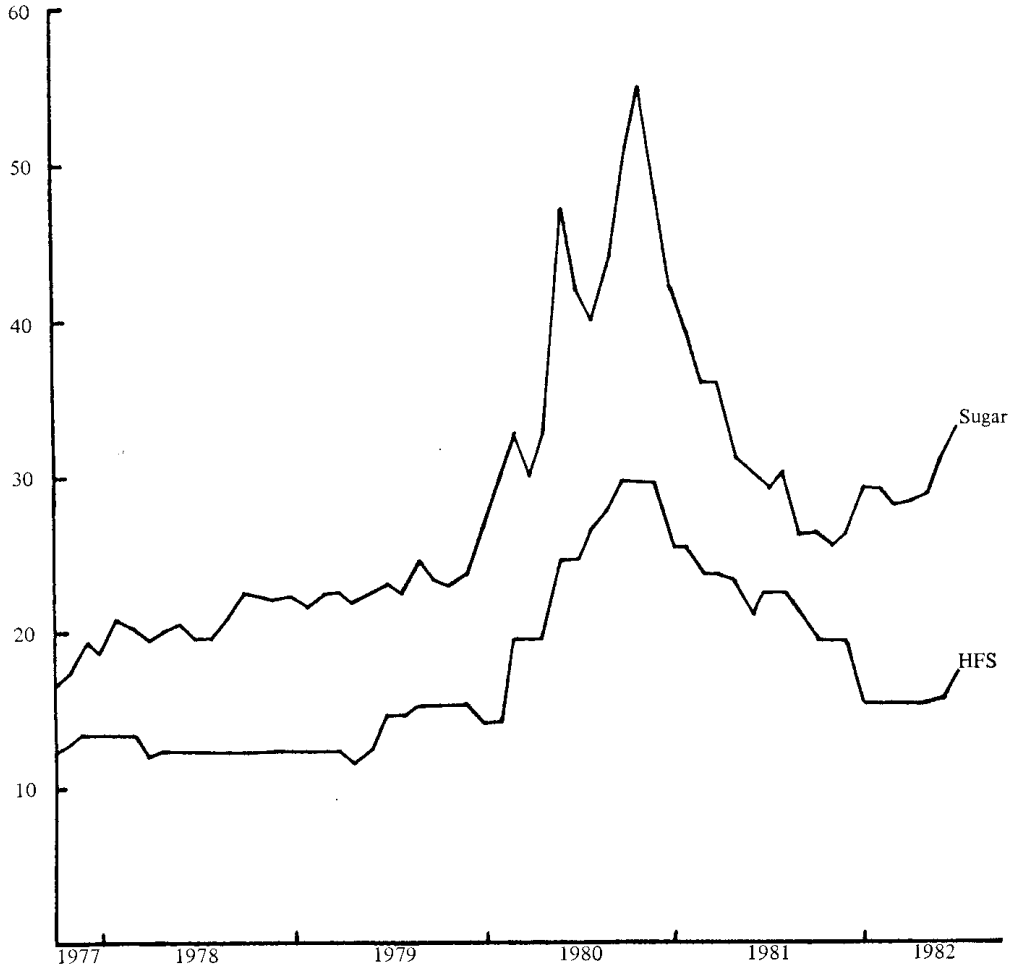
Although HFS is produced and/or consumed in 35 countries, three countries dominate the industry—the US, Japan and Canada. Production of HFS is concentrated in the developed countries for several reasons. First, the industry is highly capital intensive, with an estimated requirement of over $112,000 per tonne daily grinding capacity (with HFS finishing capability (Bohall and Davis 1982b)). Most plants in the US have daily grinding capacity of between 250 and 2 500 tonnes per day representing a capital cost of between $28 million and $280 million.[4] In addition, technological requirements include accessibility to enzymes, processing chemicals and specialized labour to operate the complex production equipment, all of which are more likely to be available in industrialized countries. An HFS industry would only be considered if the processed food and beverage industries accounted for a significant proportion of total sugar usage as these industries are capable of using liquid sweeteners. The fact that HFS is not yet available in crystallized form presents problems in other areas of manufacturing such as confectionery and baking as well as effectively excluding domestic use. The consumption of processed foods and beverages increases as per capita income increases thus the HFS industry will tend to be in developed countries. Countries which are self-sufficient in sugar, or do not have a readily available starch source are also unlikely to consider setting up a large HFS industry. This is also true of countries which do not have an intensive livestock industry, as it is this industry which is the major purchaser of the by-products from HFS production. Thus, in the foreseeable future, growth of HFS production is likely to remain concentrated in the developed countries.

[4] This figure was taken from World Sugar Journal Special Edition (1981, p. 25). There are problems associated with determining capital costs of HFS production. First, the plant may produce other corn products including starch, glucose, dextrose or alcohol, with the mix of end products being determined by market conditions. Thus apportionment of capital cost between end products can prove difficult. Second, the capital cost will vary depending on whether the plant is part of an existing mill or is a new one. Bohall and Davis (1982b) estimated the plant cost at between $A28m. and $A280m.

Section II HFS in the US

Corn sweetener production has increased rapidly in the US, rising from 24 per cent of total sweetener deliveries in 1975 to 33 per cent in 1980. On the other hand deliveries of sucrose, after peaking at 9.4 million tonnes in 1978 had fallen to 8.6 million tonnes in 1980. Sucrose production, milling and refining capacity has been declining in the US since 1976. Domestic production in 1982 is expected to reach 5.3 million tonnes, compared with a peak of 6.4 million tonnes in 1976. As discussed in more detail below passage of the US Agriculture and Food Act of 1981 should stabilize US domestic sucrose production, meaning that further inroads into the sweetener market by corn sweeteners will affect the level of imports. The economics of HFS production is particularly favourable in the US. A source of starch is readily available as the US is the world's largest corn producer, producing 164 million tonnes of corn in 1980, 43 per cent of world production. In addition the required capital is accessible. The US has traditionally imported around half of her sugar requirements, so there is potential for import replacement. The US domestic sugar industry is relatively high cost, and during times of low world sugar prices has been insulated from low cost imports through government programs which have

Graph 1: HFS and Sugar Prices—New York cents per lb.



successfully maintained high domestic prices. Thus, while increases in HFS production have been import replacing, the relevant costs to consider are in fact the domestic costs of production, as these influence the support prices behind which the HFS industry can shelter. According to Brooke (1977) HFS has at times enjoyed considerable cost advantages over sugar in the US. HFS prices vary across the US, generally being 1–2 cents per lb higher in New York and Chicago than in California. However, even during the very low sugar prices in the late 1970s the annual average quotes for HFS were consistently below those for beet sugar although during this period the discounts were smaller than when prices were high (Graph 1).

In September, 1979, a study was made at Purdue University of the costs of producing HFS.[5] An updated version of this (Flavell 1980) arrived at a cost of production, with 50 per cent by-product returns and excluding capital costs, of between 9 and 13 cents per lb (dry) for 42 per cent HFS, and about 7 to 15 per cent higher for 55 per cent HFS.[6] Estimates for 1982 based on this study put the cost of production of HFS at between 12 and 16 cents per lb (Bohall and Davis 1982a). This is below the US minimum support price of refined sugar which until the end of September, 1982, was 19.16 cents per lb for refined beet sugar, subsequently rising to 19.70 cents per lb.

The variable costs of HFS production have been apportioned as follows (Vuilleumier 1981, p. 3):

Corn (gross)	50 per cent
Energy	20 per cent
Labour	10 per cent
Chemicals	10 per cent
Enzymes	5 per cent
Other	5 per cent

As mentioned earlier, however, there are valuable by-products, corn oil, and high protein meal, the sale of which can recover up to 50 per cent of the gross corn costs.[7] The level of returns for these by-products has an important effect on the cost structure of the industry, and is one economic factor which gives corn its advantage as a feedstock for HFS production in the US. The wet milling process requires 2.2 bushels[8] (123 lb or 56 kg) of corn to produce

---

[5] Department of Agricultural Economics, Purdue University (1979), *Cost of Producing High Fructose Corn Syrup: An Economic Engineering Analysis*, Station Bulletin No. 239, Purdue University, West Lafayette.

[6] This study assumed a 72 000 bushel per day plant operating for 330 days a year with corn costing $3.50 per bushel.

[7] Smith (1978) produced figures demonstrating the impact of corn prices and by-product returns on net starch cost. The two levels of by-product returns he used were 40 per cent and 70 per cent. Net starch costs varied between 3.64 and 1.81 cents per lb at a corn price of $2.00 per bushel, and between 4.85 and 2.72 cents per lb at a corn price of $3.00 per bushel. After adding in processing and transport costs production costs for HFS ranged between 11.06 cents and 14.10 cents per lb.

[8] The rule of thumb figure used is 3 bushels. This would, under the circumstances quoted here, lead to a $1.50 increase in HFS production costs for every $1.00 increase in per bushel corn costs.

100 lb (wet) of HFS. Assuming by-product returns at 50 per cent, for every one dollar rise in the price of a bushel of corn, a change occurs in HFS production costs of $1.10 per 100 lb (wet) (Vuilleumier 1981).[9] The most significant variable cost item is corn. As the volume of HFS or other end products of the wet milling process increases, and the quantity of by-products offered for sale rises the price obtained by these products could fall, effectively raising the corn cost to HFS producers.

During the 1970s about 80 per cent of the increase in the volume of sweeteners produced by the wet milling industry has been accounted for by HFS. The success of this product has exceeded expectations—in 1978 it was stated that the maximum proportion of US sugar consumption which could be replaced by HFS was 22.6 per cent (Brook 1978). Following the development of the second generation product it was estimated that there could be a further 10 per cent increase in substitution of sucrose, bringing the total to 33 per cent (the level in 1980). This is well below recent forecasts of 48 per cent in 1985 (Table 3). This growth potential lies in the area of second generation HFS, and between 1980 and 1985 it is projected that this product will increase its share of the HFS market from 32 to 55 per cent.

Table 3: Estimated United States Nutritive Sweetener Deliveries 1975–1985
1 000 metric tons dry

Year	Sucrose	Corn (glucose) Syrup	HFS	Dextrose	Total Corn	Total Sweetener*a*	% Corn	% HFS
1975	8 734	1 714	482	494	2 690	11 424	24	4
1976	9 235	1 728	715	499	2 942	12 177	24	6
1977	9 410	1 760	942	413	3 115	12 645	25	8
1978	9 232	1 796	1 233	386	3 415	12 785	27	10
1979	9 119	1 819	1 570	390	3 779	13 044	29	12
1980	8 638	1 882	1 972	398	4 252	13 021	33	15
1981	8 283	1 920	2 427	406	4 753	13 181	36	19
1982	8 139	1 932	2 685	408	5 026	13 311	38	20
1983	7 970	1 960	2 957	417	5 334	13 453	40	22
1984	7 800	1 987	3 230	426	5 642	13 592	42	24
1985	7 630	2 014	3 502	435	5 951	13 732	44	26
1986	7 461	2 041	3 774	444	6 223	13 871	45	28

a Includes Honey (around 100 000 tonnes a year) and Edible Syrups (around 45 000 tonnes a year).

All figures on a calendar year basis. Sugar figures refined value.

1975–80 figures U.S.D.A.

1980–86 Updated from Bohall and Davis (1982*b*).

Sources: Vuilleumier (1981, p. 5), Bohall and Davis (1982*a*,*b*, p. 214 and 218).

[9] Smith (1978) estimated that the level of by-products returns varied between 40 and 70 per cent in the US. This work showed that the level of the by-product returns had a marked effect on the costs of HFS production.

An estimate by the USDA in 1979 showed a total of 40 per cent of HFS deliveries going to soft-drink manufacturers, and about 20 per cent being used for bakery products. As shown in Table 4 the market share of HFS sales held by beverages had increased to 51 per cent in 1980, and this is forecast to rise to 70 per cent by 1985. In 1980 there was a major breakthrough for the HFS industry when the Coca-Cola company permitted the replacement of all sugar in a number of its products with 55 per cent HFS. (Prior to this only a 75 per cent mix with sucrose had been permitted.) In Coca-Cola itself, the product in which 80 per cent of the sucrose bought by the company was used, a 50 per cent mix of HFS and sucrose was allowed. At this time the Coca-Cola company consumed around 1 million tonnes of sucrose annually, or 10 per cent of total US annual consumption, and this decision was a significant blow to the sugar industry. A similar blow came when Pepsi Co. Inc., the makers of Pepsi Cola and the second largest soft drink producer in the US approved a 50 per cent mix of HFS and sucrose in the company's major product, Pepsi Cola. Together Coca-Cola and Pepsi Cola account for just over 50 per cent of all sweeteners consumed by the soft drink industry (Vuilleumier 1981).

Table 4: *HFS Usage in the United States*

Major Markets for HFS	HFS Estimated Market Share and Quantity Consumed			
	1980		1985	
	per cent *a*	thousand tonnes *c*	per cent *b*	thousand tonnes *c*
Beverages—carbonated and non-carbonated	51.0	1 006	70.0	2 452
Baking	20.0	394	12.0	420
Canning	15.0	296	10.0	350
Dairy Products	9.0	177	5.0	175
Processed foods including jams, preserves	4.5	89	2.8	98
Confections	0.5	10	0.2	7
	100.0	1 972	100.0	3 502

Sources: a Vuilleumier (1981, p. 6).
b Vuilleumier (1982, p. 2).
c Forecast total volume Bohall and Davis (1982*b*, p. 218).

The potential impact of the loss of the beverage market on the sugar industry is evident from the fact that beverages accounted for almost 23 per cent of the 8.5 million tonnes of sugar deliveries in the US in 1980. The maximum level of HFS penetration of this market is theoretically 90 per cent, equivalent to 3 million tonnes of sucrose, over twice the beverage industry's estimated HFS consumption, equivalent to 1.3 million tonnes of sucrose in 1981. Estimates by McKeany-Flavell Company Inc., Sweetener Brokers, of the maximum levels of market penetration theoretically possible in other markets are shown in Table 5. High levels of penetration are possible in all but the confectionery industry. Compared with current levels little further penetration is expected in the areas of baking and dairy products. Based on the limits to HFS penetration deliveries of this product are forecast to rise to 4 million tonnes by 1985, representing a market loss to the sucrose industry of a further 1.5 million tonnes.

Table 5: 1981 *Estimated Industrial Sugar and HFS Deliveries by Market*
1 000 metric tons dry

	Sugar Deliveries 1981	HFS Deliveries 1981	HFS % Sweetener Market	Long term Theoretical Penetration %	Theoretical Maximum HFS Deliveries 1981
Beverages ..	1 960	1 302	40	90	2 900
Baking	1 135	391	25	25	380
Canning	405	305	43	60	430
Dairy Products ..	432	176	29	30	180
Processed Foods	396	101	20	40	100
Confections ..	816	11	1	5	10
Total Industrial	5 144	2 286	31	..	4 000

Source: Vuilleumier (1981, p. 8).

Relation between Sugar Prices and the Price of HFS

With the increases in demand and the forecast potential for 55 per cent HFS, US corn wet millers are planning to increase production capabilities, either by enlarging existing plant or by building new facilities, or by changing the mix of existing facilities (Vuilleumier 1981, p. 9). This follows a period of slow growth during the time when sugar prices were depressed, particularly in 1978 and 1979.[10] Prior to 1973 there had been excess capacity in the corn wet milling industry, as many plants had been brought on stream during the 1960s. Then, with the rise in the price of sugar in 1974 this capacity was mopped up with increased production of HFS.

Even before the 1981 sugar legislation the HFS industry was described as "expanding under a protective umbrella", and the new legislation has certainly strengthened this protection. Cromarty (1981) puts forward the argument that sugar legislation in the US has benefited the corn wet milling industry more than any other group in the sweetener industry. The result has been to increase the rate of development of this industry, as the "sugar price umbrella" has decreased planning uncertainty for HFS producers and led to increased short term profits. The result could well be an increase in the rate at which the industry expands up to its maximum potential or saturation level (Table 5). Increases in HFS capacity were planned after 1979 leading to a total capacity of just under 4 million tonnes in 1983, close to the projected saturation level.[11] These plans were announced before the 1981 Agriculture and Food Act containing sugar price support provisions was passed by the US Congress. The

[10] Smith (1978) suggested that with sugar prices below a base level of 12–13 cents per lb the profit margins on HFS production would have been insufficient to justify expansion of plant.

[11] Estimates of the theoretical HFS production capabilities of the various firms in the US industry are shown in Table 6.

US Market Stabilization Price for raw sugar has been set at US 19.88 cents per lb raw for 1982 (equivalent to US 23.35 cents per lb for refined beet sugar), a level apparently comfortably in excess of the minimum required by corn millers. Bohall and Davis (1982a) point out that, as a result of the three to four year time lag in bringing new HFS plants on stream, the impact of the 1981 US sugar legislation is unlikely to be reflected in increased HFS production capability until around 1986. However, without a technological breakthrough to alter the demand forecasts, a massive increase in capacity is unlikely. Expansion in the late eighties could also be hampered by the uncertainty surrounding US sugar legislation after the 1985 crop year.

Table 6: *Estimated US Theoretical HFS Production Capabilities in June*, 1982

Company	million lb dry		
	42%	55%	total
1. American Maize	140	270	410
2. Amstar	150	200	350
3. ADM/Corn Sweeteners	1 000	1 250	2 250
4. CPC	760	100	860
5. Cargill	400	620	1 020
6. Clinton	370	300	670
7. Great Western	30	70	100
8. Hubinger	320	170	490
9. Holly Sugar	0	0	0
10. A. E. Staley*a*	695	1 275	1 970
Total	3 865	4 255	8 120

a A. E. Staley expected to have additional 400 m lb HFS capacity commencing during 1982, with complete flexibility between 42% and 55%, however, in June, 1982, this was still listed as "expected". It is therefore not included in the totals.

Source: McKeany-Flavell Co. Inc, June, 1982.

Section III The Interdependence of Sugar and HFS and its Implications

In 1981 there were 10 HFS producers in the US with productive capacity of approximately 3.8 million tonnes, comprising 42% and 55% in approximately equal proportions. Of these, nine were capable of producing 55% HFS in 1982. While ADM/Corn Sweeteners and A. E. Staley each provide some 25 per cent of total industry capacity, CPC, Cargill and Clinton together represent a further 33 per cent of productive capacity.[12] Thus the structure of the industry is oligopolistic as illustrated in Figure 1b.

[12] McKeany-Flavell Co. Inc., *Sweetener News*, June, 1982.

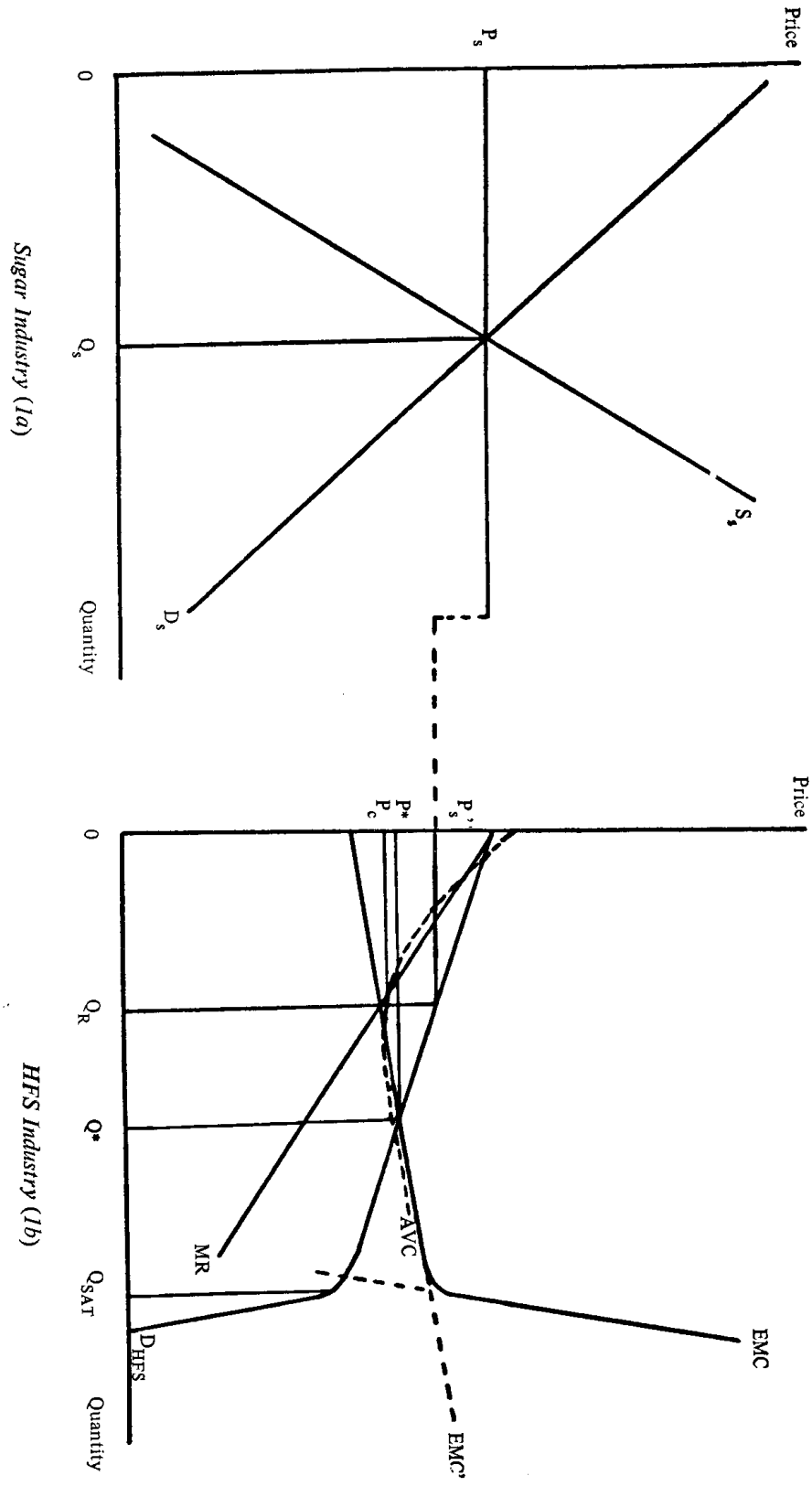

Price
P_s
0
Q_s
Quantity
S_s
D_s
Sugar Industry (1a)
Price
P_s'
P^*
P_c
0
Q_R
Q^*
Q_{SAT}
Quantity
MR
AVC
EMC
EMC'
D_{HFS}
HFS Industry (1b)

Figure 1

Given current technology, the maximum quantity of HFS readily consumed for any given demand for total sweeteners is represented by Q_{sat} in Figure 1b. This maximum level of market penetration by HFS is assumed to be fixed in terms of market share relative to sugar but may change absolutely if the demand curve for total sweeteners shifts, an event which could occur even in the short run. For example, a secular increase in the demand for soft drinks would increase total sweetener demand and would have a greater impact on the demand for HFS than on the demand for sugar. At output levels below Q_{sat} HFS is a close substitute for sugar (or may even be preferable) in a number of industrial processes. Within this range of output, the demand for HFS (D_{HFS}) is relatively price elastic. Beyond this output, due mainly to the fact that it exists only in liquid form, HFS would be considered an inferior product, hence relatively large changes in price would be required to cause an increase in quantity demanded. Thus there is a kink in the demand curve at Q_{sat}, with demand being price inelastic at higher levels of output.

It is difficult to specify a supply schedule for an oligopolistic industry as there may not be a "schedule" but simply a set of points. However, an aggregate marginal cost curve for the industry EMC can be obtained by lateral summation and this also kinks in the vicinity of Q_{sat}. This implies that to produce more than Q_{sat} additional costs would be incurred. For example, to sell the extra output, marketing effort and therefore costs would increase. As a result EMC becomes the relevant aggregate marginal cost curve rather than EMC' from around Q_{sat}. An additional problem arises here because the aggregate marginal cost and the demand curve become interdependent—the demand curve will pivot from the "kink" becoming more elastic, the more successful the additional marketing expenditure. Interdependence makes analysis within this region rather difficult.

As there are only a few large HFS producers, the decisions of each producer influence the others and one producer cannot be certain how other producers will react to his decisions. The producers in the industry may therefore collude to reduce this uncertainty. As the industry is highly capital intensive,[13] economies of scale are substantial and individual firms may see collusion as a means of deterring entry and preserving their market share. Furthermore as they jointly face the prospect of competing their market away from the sugar industry there is a strong incentive to collude and set their price below the sugar price in order maximize long run (if not short run) profits. Although explicit collusion is illegal in the US it continues to occur and there is strong evidence to suggest that there is tacit collusion among HFS producers. This is supported by market commentaries such as those in *Milling and Baking News*.[14]

Graph 1 supports the hypothesis that the sugar industry acts as a price leader for the HFS industry, with the sugar price as the ceiling price for HFS. The extent to which the HFS price will be discounted relates to industry objectives such as market penetration by a relatively new product, as well as

---

[13] Current estimates place plant cost at $28m. to $280m. depending on size (Bohall and Davis 1982b, p. 220).

[14] A typical comment is "Major processors raised prices 1.15c per lb. Other processors had advanced their prices 0.80c to 1.40c a lb in the preceding week" (*Milling and Baking News*, May 29, 1979, p. 19).

to the cost structure of the industry. Thus it is assumed that the HFS producers either collude or that they have similar cost structures and motives and so select the same discount rate.[15] This discount rate is assumed to be constant irrespective of the price of sugar (an assumption which will be varied later). At levels of output in the vicinity or greater than Q_{sat} the sugar price umbrella ceases to be relevant and price and output will be determined by oligopolistic competition, as at these output levels there is no longer growth in demand for HFS and individual companies can only expand at the expense of others.

Figure 1a depicts the US sugar industry. For the present it is assumed that there is a free market so that the equilibrium price is P_s and the equilibrium quantity is Q_s. Once the price of sugar is determined the appropriate demand curve for HFS is identified. The price for HFS could be set at any price from the ceiling price set by sugar, P_s, to P_c, where P_c is the minimum price for firms in the short term as they are just covering their variable costs. The discount rate on the sugar price selected by the colluding producers will depend on their motives which could include maximizing growth or market penetration as well as profits. The former is likely to be seen by the producers as a means of maximizing long run profits and so the earlier assumption of maximizing industry profits is retained. Industry output would be restricted to Q_R compared with Q^* under perfectly competitive conditions, and the HFS price would be P_s.'[16] As HFS is still a relatively new product and for some purposes is inferior to sugar, the price elasticity of demand for HFS will be greater than that for sugar at a given price. Thus any given price increase will have a greater impact on HFS sales than on sugar sales.

The price of sugar is not, however, determined on the free market and as discussed above the Food and Agriculture Act, 1981, has imposed a minimum price for sugar. Figure 2a shows US sugar supplies, domestic (S_{DOM}) and total (S_S). Without intervention OQ_D of the equilibrium quantity will be supplied domestically and Q_DQ_S will be imported from countries such as Australia. The introduction of the minimum price P_{sup} causes an increase in domestic supplies to Q_D', but a reduction in imports to $Q_D'Q_M$ as sugar consumption has fallen by Q_MQ_S.

---

[15] Perhaps an example of Focal Points (Scherer 1980, p. 190 ff.).

[16] It has been assumed that because the variable costs of producing HFS appear to be lower than those for sugar and given the similar capital structure, the profit maximizing price for HFS will be lower than the market determined sugar price. Yet as the output of HFS is being restricted relative to what it would have been under perfectly competitive conditions, this may not be the case. If the profit maximizing price of HFS is higher than the sugar price the outcome is uncertain. HFS producers may decide to continue to produce the profit maximizing output but to select a price below the sugar price to allow market penetration and subsequently higher profits. Perhaps more likely would be the decision not to produce the profit maximizing output but to produce the amount demanded at the selected discounted sugar price. This outcome will be less favourable for the sugar industry but the price and output for HFS are indeterminate. However, it is less likely that the HFS price will exceed the sugar price once the minimum sugar price is determined by legislation. Consequently this case is not considered further.

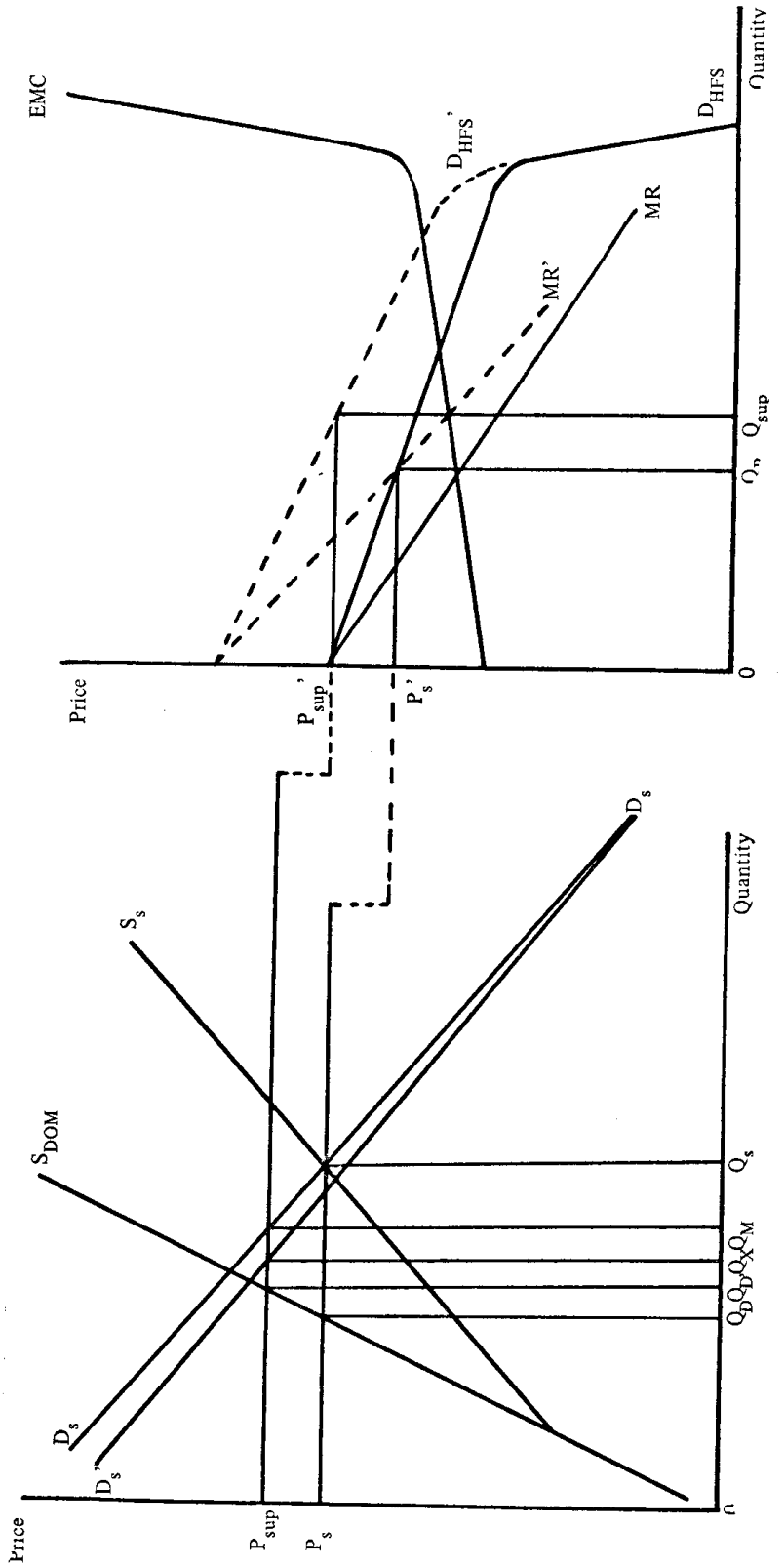

EMC
D_{HFS}'
D_{HFS}
MR
MR'
Quantity
Price
P_{sup}'
P_s'
Q_{sup}
0
HFS Industry (2b)
D_s
S_s
S_{DOM}
D_s'
Quantity
Q_s
Q_M
Price
P_{sup}
P_s
Sugar Industry (2a)

Figure 2

Given that the sugar industry acts as a price leader for the HFS industry, HFS prices would be expected to rise proportionately with the sugar price (still assuming constant discount rates). However, the increased sugar price causes the HFS demand curve to move across to the right. Given the product characteristics of HFS which were discussed above, the increase in HFS demand is assumed to be greater at high sugar prices and less at low prices. This shift of the demand curve means that instead of the higher HFS price causing a reduction in the quantity demanded, demand increases from Q_R to Q_{sup}. The HFS industry gains in terms both of a higher price and a greater output relative to its position prior to intervention in the sugar market. Further, the introduction of a minimum price for sugar may strengthen the desire to collude to the extent that the restriction on output is less.

Although the analysis suggests an expansion of HFS production, is this likely to occur? Bohall and Davis (1982a) state that USDA analysts believe that the passage of the US Agriculture and Food Act of 1981 probably will have little impact on HFS *production* before 1986 since construction plans and investment commitments have already been made. However, as mentioned above, the wet milling industry currently has the capacity to produce 3.8 m tonnes of HFS but only about 63 per cent of this capacity is being used. This implies that production (though perhaps not *capacity*) could be expanded quite significantly over the period to 1986.

To this point it has been assumed that the discount rate on HFS remains constant as the price of sugar changes. However, Graph 1 indicates that this is not the case. Given the lower cost structure of the HFS industry (see earlier) periods of high prices will be used to compete for a greater market share and discount rates will be greater. Producers are prepared to accept less than maximum profits in the short term in the hope of gaining higher long term profits.

A change in the HFS discount rate causes the price of HFS to change relative to the price of sugar. Hence the demand for sugar will be reduced and, given differential discount rates, the demand for sugar will be reduced by more at high prices than at low prices (from D_s to D_s, in Figure 2). Assuming that the legal minimum sugar price is not adjusted, this will cause some further cutback in the demand for imported sugar (from OQ_m to OQ_x). These import cuts are likely to fall more heavily on suppliers such as Australia than on those protected by agreements such as the Carribbean Initiative (see Bohall and Davis 1982a).

So far no account has been taken of the fact that the HFS producers sell mainly to a few large buyers (oligopsonists). These buyers are the large soft drink companies, including Coca-Cola and Pepsi Co. which alone account for just over 50 per cent of HFS sales. Hence the industry is a bilateral oligopoly. Scherer (1980) in discussing bilateral oligopoly argues that buyer power is greatest when, among other things, the suppliers supply function is fairly elastic and when buyers face substantial competition in their end product markets. Both these conditions apply to HFS. Strong buyers restrain the pricing power of oligopolistic sellers in various ways, including concentrating orders to obtain a price discount and playing one seller off against another to gain price concessions. The short storage life of HFS limits the possibility of the former. However, the latter may occur and could undermine the agreement to collude. Such pressure is likely to be most effective when demand is slack

and/or as Q_{sat} is approached because producers have excess capacity which could be profitably utilized. In the case of the HFS industry the result of buyer (or countervailing) power would be to increase still further the HFS discount rate on sugar (particularly at high prices) causing a greater shift in the demand curve for sugar and a greater cutback in imports than postulated above. Scherer discusses the factors which determine whether the cost saving achieved in this way by HFS users is likely to be passed on to their customers, the end product users. If the final consumer benefits from a lower price this may shift the demand curve for total sweeteners to the right, with most of the extra demand going to the HFS producers.

It has been postulated that with the increase in the supply of gluten associated with the growth of corn wet milling, from which HFS is only one end product, the price of gluten is likely to fall. This would lower by-product returns to HFS producers, thereby raising the costs of producing HFS. To the extent that this results from additional HFS production it should be incorporated into the existing HFS aggregate marginal cost curve. However, to the extent that it results from increased production of other products the HFS aggregate marginal cost curve would shift to the left, and would be less elastic. The new aggregate marginal cost curve for HFS is unlikely to be parallel to the old curve as the reduction in gluten prices is likely to increase when HFS production is at higher levels. The level of output from which the new aggregate marginal cost curve commences determines the effect this situation will have on the problem under review. If the new aggregate marginal cost curve begins at an output of at least Q_{sup} in Figure 2 the only effect will be to reduce the restriction on HFS production resulting from collusion thereby strengthening the collusion. However, if the new aggregate marginal cost curve begins below Q_{sup} the quantity of HFS supplied at P_s' and P_{sup} would be reduced and the discount rate would be less if producers are to continue to maximize profits. This would cause the price of HFS to rise relative to sugar and so the demand curve for sugar would move to the right, causing some expansion in imports.

In the long term, say by the mid 1980s, existing firms may build new plant and/or if the barriers to entry are not too strong new firms may enter the industry. Theory suggests that the long run supply curve may be more elastic than the short run supply curve. For a given level of demand for total sweeteners this would speed the approach to Q_{sat} and would possibly put pressure on the agreement to collude. The HFS industry will probably approach Q_{sat} over the next 3 or 4 years. As explained above Q_{sat} is fixed if the total demand for sweeteners is fixed and HFS is an imperfect or unsatisfactory substitute for sugar for some purposes. Thus the market available to HFS producers expands through increases in the price of sugar and/or changing tastes. The rate of market growth due to the latter will decline through time as the new product becomes established and accepted. However, the approach to Q_{sat} will be hastened by any event which encourages increased production by existing and/or new firms.

In the vicinity of Q_{sat} the HFS industry will emerge from under the sugar price umbrella as pressure on the agreement to collude increases. This will occur partly because output restraint will become more onerous but also because as the number of firms in the industry increases it becomes more difficult to

"police" the agreement. Pressure will be greater if firms have expanded/established in the expectation that the market will continue to grow at the same rate as before and thus find their plant underutilized. Scherer argues that highly capital intensive firms (such as those in the HFS industry) are more likely to undertake price cutting when operating below capacity than less capital intensive firms. It has been claimed that in this situation

> ". . . each seller realizes that if every other seller follows his price, all will make smaller profits or greater losses and no permanent cure to depressed demand will be achieved, since only the most ruthless price war will eliminate enough capacity to improve the price situation. Under such circumstances only the most sanguine or the most foolhardy seller will start an open price war (though none would be averse to making secret concessions up to the point where an open price war threatened to start)."[17]

However, these secret concessions will become known to other producers and the agreement to collude is likely to breakdown. Oligopolistic competition may take the form of product differentiation and in this industry corn wet millers, as already mentioned, have the choice of a number of end products. It is also likely to result in price cutting and there are reports of this occurring in the HFS industry when there are excess supplies.[18] Only under simplistic conditions is the outcome of such action determinate. Using Stackelberg's model[19] it can be shown that if all firms in the industry act as followers a stable equilibrium can be achieved after a period of price adjustment. On the other hand, if every firm attempts to act as a price leader, price adjustment will allow an unstable rather than a stable equilibrium to be achieved. In this latter case market changes are likely to result in a renewed period of price warfare. A different approach to analysing the effects of oligopolistic competition is based on probability theory. It is postulated that the entrepreneur makes decisions based on the probability that his competitors will respond in a given way.

It seems probable that in the region of Q_{sat} there will be periodic price wars with longer periods of price stability. Two additional factors should be recognized. Firstly, in the vicinity of Q_{sat} the oligopolistic pressure mentioned earlier is likely to become considerably more effective and may hasten the demise of the agreement to collude. Secondly, if economic conditions in the US worsen over the period to 1985 this may adversely affect the demand for all sweeteners but particularly the demand for HFS.[20] This would cause the saturation output for the HFS industry to be reduced as well as causing the HFS demand curve to shift.

---

[17] Alfred Neal, quoted by Scherer (1980, p. 209).

[18] Market reports such as the following from *Milling and Baking News*, January 5, 1982 Illustrate his point. "Offers of 42% high fructose corn syrup (HFCS) were reduced . . . at a number of points. Reductions were consistent with widespread price cutting, and many corn refiners continued to discount list prices".

[19] Marktform und Gleichgewicht (1934); discussed in Cole (1973).

[20] Consumption of soft drinks and commercial baked products is likely to be reduced and possibly replaced by home preparations which would use sugar rather than HFS.

Conclusion

Prior to the development of HFS the corn wet milling industry did not directly compete with the sugar industry. However, since the early seventies when HFS first was produced, and particularly since 1976 when the "second generation" product was developed, there has been a rapid expansion of the industry. Production of HFS is confined to only a small number of countries, mainly the developed importing countries, the US, Japan and Canada. In these countries HFS competes directly with imported sugar, and in 1980 had replaced around 2.5 million tonnes of sugar, over 10 per cent of the sugar traded on the world free market.

Unless there is a technological breakthrough, and the production of crystallized HFS becomes economically viable, the expansion of this industry is limited to the quantity of liquid sugar required by food processors. However, in the US alone this theoretical maximum is around 4 million tonnes. When added to the forecast 1985 HFS usage in Japan of 0.8 million tonnes and Canada of 0.3 million tonnes there is the potential for the replacement of 25 per cent of sugar traded on the free market.

In all the major HFS producing countries government policy has affected the rate of penetration of the sugar market by HFS; for example, in the US the domestic sugar price is now insulated from world prices by a Loan Program so there will be no reduction in the rate of HFS penetration in this market even if world prices plummet. The overall impact of HFS on the sugar industry has been increased in the short term by these government policies, leading to problems of adjustment and a greater impact on imports. Bohall and Davis state that "For Australia, under the US quota scheme, sugar exports would decline . . . to around 229 kt by 1986, compared with an average of 375 kt in recent years . . .".[21] Yet our analysis suggests that the interactions between the sugar industry and the corn wet milling industry which produces HFS are both direct and indirect and there is no indication that this prediction takes account of the latter. Any movement in the demand for total sweeteners between now and 1986 will probably have a greater impact on HFS production than on the sugar industry. For example, the income effects associated with improved/worsened economic conditions are likely to affect the demand for products such as soft drinks produced using HFS. By 1986 HFS production will probably be approaching market saturation and will be moving out from under the price umbrella. Under oligopolistic competition the outcome is uncertain. It is also evident that the oligopsonistic nature of the HFS buyers must be taken into account, particularly as market saturation is approached.

[21] Bohall and Davis (1982a, p. 216).

References

BOHALL, R. and DAVIS, C. (1982a), "US sugar policies: recent developments and their implications for Australia", *Quarterly Review of the Rural Economy* 4 (3), 207–216.

BOHALL, R. and DAVIS, C. (1982b) "The corn sweetener industry: growth and economic development", *Quarterly Review of the Rural Economy* 4 (3), 217–221.

BROOK, EZRIEL M. (1977), *High Fructose Corn Syrup: Its Significance as a Sugar Substitute and Its Impact on the Sugar Outlook*, The World Bank Commodity Paper No. 25.

CHILVERS, LLOYD and FOSTER ROBIN, (1981), *The International Sugar Market Prospects for the* 1980s, E.I.U. Special Report No. 106, London.

COLE, CHARLES, L. (1973), *Micro Economics: A Contemporary Approach*, Harcourt Brace Jovanovich Inc., US.

CROMARTY, WILLIAM A. (1981), "The impact of US legislation on the sweetener industry", in *World Sugar Journal Conference' International Policy and Legislation on Sweeteners and Alcohol, Proceedings*, Bal Harbour.

FLAVELL, EDGAR (1980), "Cost of high fructose corn syrup, analysis of Purdue university publication", McKeany-Flavell Company Inc., April.

MCDOWELL, CHRIS and MURPHY SUSAN (1980), *Production and Consumption of Sugar Substitutes: Implications for the Australian Sugar Industry*, Bureau of Agricultural Economics, Occasional Paper No. 57, Canberra.

MCKEANY-FLAVELL, *Sweetener News*, various issues.

MANSFIELD, EDWIN (1975), *Micro Economics: Theory and Applications*, W. W. Norton & Co. Inc., New York, 2nd Edition.

Milling and Baking News, various issues.

SCHERER, F. M. (1980), *Industrial Market Structure and Economic Performance*, Rand McNally College Publishing Co., Chicago, 2nd Edition.

SMITH, I. (1978), "The development of natural sweeteners as alternatives to cane and beet sugar", *Journal of Agricultural Economics* 29, 155–163.

VUILLEUMIER, STEPHEN (1981), "World corn sweetener outlook", paper presented to the 1981 World Sugar Research Organization Annual Meeting, Buenos Aires, Argentina, March.

World Sugar Journal (1981), "Sweetener outlook in the USA", January, p. 26.

World Sugar Journal Special Edition (1981), "National fuel alcohol plans", World Commodity Publishing Inc., London.