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COMPETITIVENESS OF REGIONAL SUGAR PRODUCTION UNDER ALTERNATIVE PRODUCTION CONDITIONS AND POLICIES

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Executive Summary

This study analyzed the impacts of existing and alternative sugar programs and trade policies on the U.S. sugar industry and the Red River Valley's competitiveness in producing sugar.

The method used for this study was a spatial equilibrium model based on a mathematical programming algorithm. Sugar was divided into cane and beet sugar to incorporate unique characteristics in producing cane and beet sugar. In the model, the United States is divided into 11 producing regions and 36 consuming regions based on 5 distribution centers. The model also included 7 processing plants for sugarbeets, 4 processing plants (mills) for sugarcane, and 16 raw sugar refineries. The objective function of the model was to maximize net returns generated by the North American sugar industry through sugarbeet and sugarcane production, processing, distribution, and imports. This objective function was optimized subject to a system of linear constraints associated with production, processing, distribution, and import activities.

The results of the study are summarized as follows:

1. Total amount of sugar produced in North America is 7.17 million tons in the base model: 3.85 million tons for beet sugar and 3.32 million tons for cane sugar. In general, beet sugar production is more competitive than cane sugar production in the United States. The Red River Valley and the Pacific Northwest Regions have a competitive advantage over other regions in producing sugarbeets, and Florida has a competitive advantage in producing sugarcane.

2. Some cane sugar production is replaced with beet sugar production as producing regions are allowed to increase their production and processing capacities. The industry's net return is higher with increases in production capacities than in the base model, implying that allowing producing regions to increase their production capacities makes the industry more competitive. This is especially true in the Red River Valley and Northwest Regions where they produce sugar at their maximum capacities after increasing capacity constraints by 50 percent. This study indicates that the Red River Valley and the Northwest Regions should increase their production by more than 50 percent to maximize their net profit.

3. When the U.S. government increases imports by relaxing the sugar import quota, the U.S. cane sugar industry is adversely affected more than the U.S. beet sugar industry. However, cane sugar refineries operate at near capacities to refine additional raw sugar imported from foreign countries. The study also indicates that the industry's net revenue is reduced substantially with increases in imports. The Red River Valley will grow sugar at the current production level with a 100 percent increase in sugar import, but the region's profit will decrease substantially.

4. Domestic sugar production will be completely replaced with imported raw sugar if the U.S. government eliminates unilaterally the sugar programs. All producing regions produce sugarbeet and sugarcane at their minimum levels, indicating that none of these regions are competitive under the free trade condition. However, cane sugar refineries operate at their full capacities and need additional capacities since raw sugar imported from foreign countries will be refined in the facilities. This implies that substantial increases in sugar imports will hurt sugarbeet and sugarcane producers, but benefit refineries.

5. Decreases in domestic sugar prices up to 15% shift sugar production from high cost producing regions to low cost producing regions, resulting in increases in beet sugar production and decreases in cane sugar production. The Red River Valley produces sugar at its maximum capacity with the 15 percent decrease in domestic prices. However, the industry's net revenue decreases substantially.

In summary, the Red River Valley has a competitive advantage over other regions in the United States in producing sugar, but the region is not competitive in the global market under the given production conditions and policies. Restricting sugar imports may be important for the U.S. sugar industry. The Red River Valley will experience adverse effects if sugar imports exceed about 2.0 million tons annually. Increases in sugar imports will benefit only cane sugar refineries. Flexible farm programs, including lowering loan rates and relaxing or eliminating marketing allotments, will benefit the U.S. beet sugar industry but will adversely affect the cane sugar industry. The Red River Valley should increase its sugar production by more than 50% of the current production level to maximize the region's net profit.

Competitiveness of Regional Sugar Production Under Alternative Production Conditions and Policies

Won W. Koo and Richard D. Taylor*

Introduction

Sugar is one of the most protected commodities in the world. Protection takes the form of border measures, such as tariffs and quotas, and of direct domestic support, including fixed producer and consumer prices. Only a small proportion of the world's sugar (30%) is traded each year, and a large proportion of that sugar is traded under long-term agreements, quotas, and allotment systems. In recent years, only Canada and India were involved in free trade.

With NAFTA and GATT, internal support and border protection will be reduced, and more countries will be involved in sugar trade. The impacts of liberalizing sugar trade policies in the United States and other countries on the U.S. sugar industry must be evaluated.

The objective of this study is to analyze the impacts of existing and alternative sugar programs and trade policies on the U.S. sugar industry. Special attention is given to the competitiveness of the Red River Valley sugar industry.

The United States produced 7.16 million tons of sugar in 1992: 3.73 million tons of beet sugar and 3.43 million tons of cane sugar. The United States imports 1.7 million tons of raw sugar annually. About 23 percent of the imports (0.4 million tons) are exported after refining. U.S. imports are about 5% of the traded world sugar and approximately 20% of sugar consumed in the United States. U.S. sugar imports have declined substantially from 5.3 million tons in 1970 to 1.2 million tons in 1992. The decline was due mainly to about a 15% increase in domestic sugar production and about a 15% decrease in sugar consumption over the period. Sugar consumption has been replaced by less expensive high fructose corn syrup (HFCS) and low calorie sweeteners. Major exporters today are Cuba, European Community (EC), Ukraine, Australia, Thailand, and Brazil. Major importers are Russia, United States, Japan, China, and Canada.

More than one-third of the nation's sugarbeet production and processing capacity is in the Red River Valley and west central Minnesota. The sugarbeets are produced on 550,000 acres and are converted into refined sugar in seven processing facilities owned by three farmer-owned cooperatives. Total production and processing expenditures added $575.5 million to the region's economy in 1992. The spending generated another $1.06 billion in economic activity for a total economic impact of $1.635 billion. The sugarbeet cooperatives also employ 20,942 full-time equivalent jobs (Bangsund and Leistritz).

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Government support for sugar operates under a nonrecourse loan program that effectively provides a floor price for sugar. Because sugarcane and sugarbeets, from which sugar is produced, are not storable, the Commodity Credit Corporation (CCC) provides loans to processors rather than to producers, with sugar as collateral. Processors pay growers a minimum price for cane and beets, established each year by the U.S. Department of Agriculture. To prevent costs associated with loan forfeitures to the CCC, the government calculates a raw sugar price target called a market stabilization price (MSP). The MSP represents a price level where commercial sales of raw sugar are more profitable than forfeiture of sugar used as collateral for the CCC loan. To achieve a supply sufficient to meet the domestic demand at the MSP, USDA estimates an import target and uses specific country quotas to achieve the import target level. However, the current sugar quota system is in conflict with the principles of GATT and will be under scrutiny in subsequent rounds of GATT negotiation. The U.S. government has converted the import quota to tariff-rate quota and introduced domestic market allotments under the current farm act. The 1995 farm bill may alter the current sugar program to lower the price support provided to the U.S. sugar industry. It is not clear what would be impacts of the tariff-rate quota and changes in the sugar program on this region's sugar production and its competitiveness.

Overview of the World Sugar Industry

Sugar is grown in many diverse locations around the world. Sugarcane, which is grown in tropical areas, provides the largest proportion of the world's sugar production. Sugarbeets, grown mainly in North America and Europe, provide the balance.

Sugar is traded in two forms, raw sugar and crystalline or refined sugar. Raw sugar is the direct product of a sugarcane mill, and refined sugar is the product of the refining of raw sugar or the direct product of a sugarbeet processing plant.

World Sugar Production and Trade

Figure 1 shows the distribution of world sugar production by major producers in 1992. India is the largest producer of sugar (11%), followed by Brazil, China, the United States, the Former Soviet Union, and France. The largest consumers of sugar are India (12%), the Former Soviet Union (10%), the United States (7%), China (7.4%), and Brazil (6.7%). Brazil's sugar consumption is large because of the substantial ethanol production. The largest exporters and importers of sugar are shown in Figure 2. Cuba, Thailand, and France are the largest exporters while the Former Soviet Union, Japan, and the United States are the largest importers. Cuba's main trading partners are the Former Soviet Union, Eastern Europe, and Canada. Thailand's main trading partner is Japan. France trades mainly with EU members and Northern Africa. The United States imports from the Caribbean and Australia.

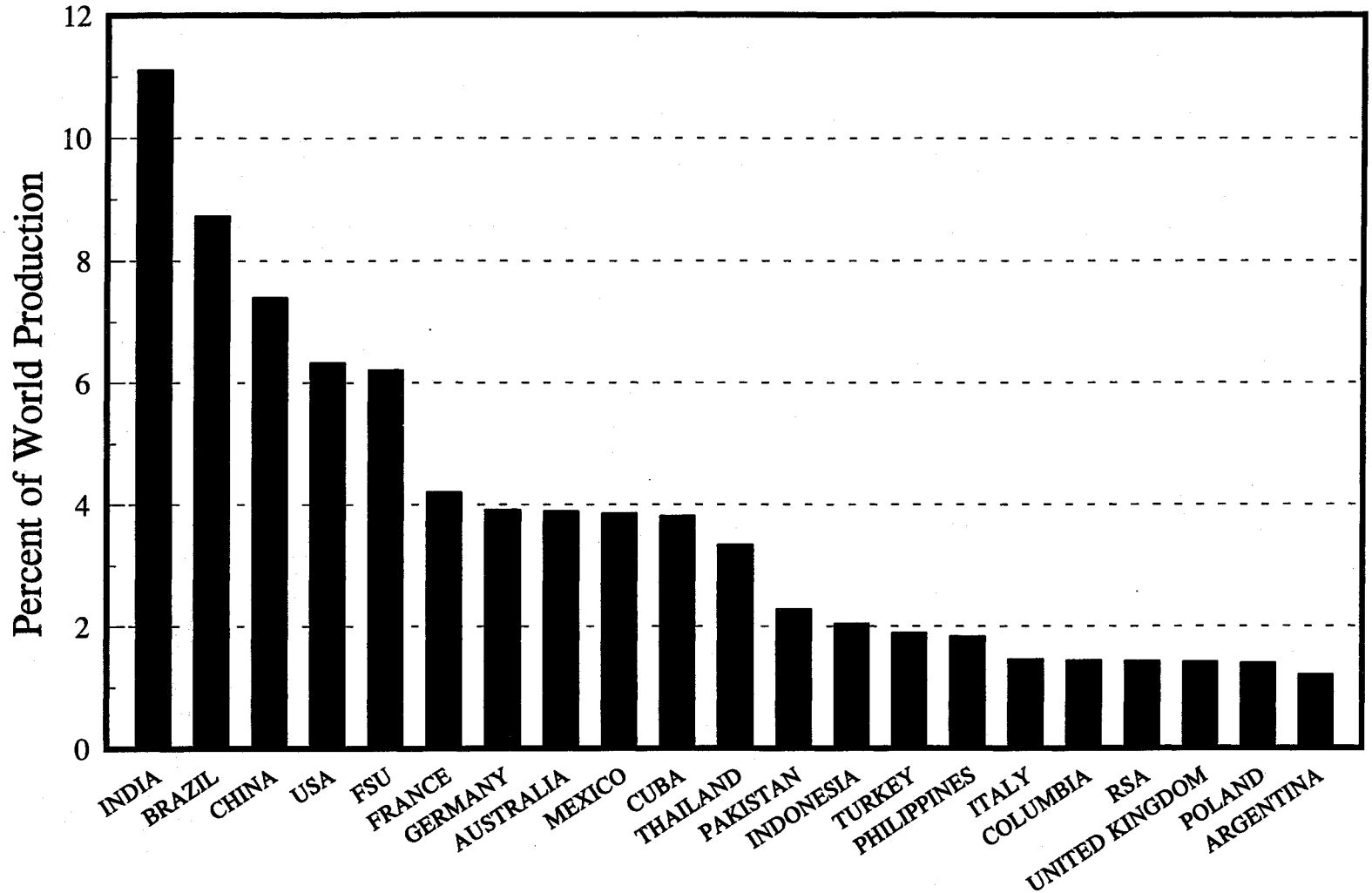


Figure 1. Percent Share of World Sugar Production, by Major Producers, 1992

Source: Production Yearbook, FAO.

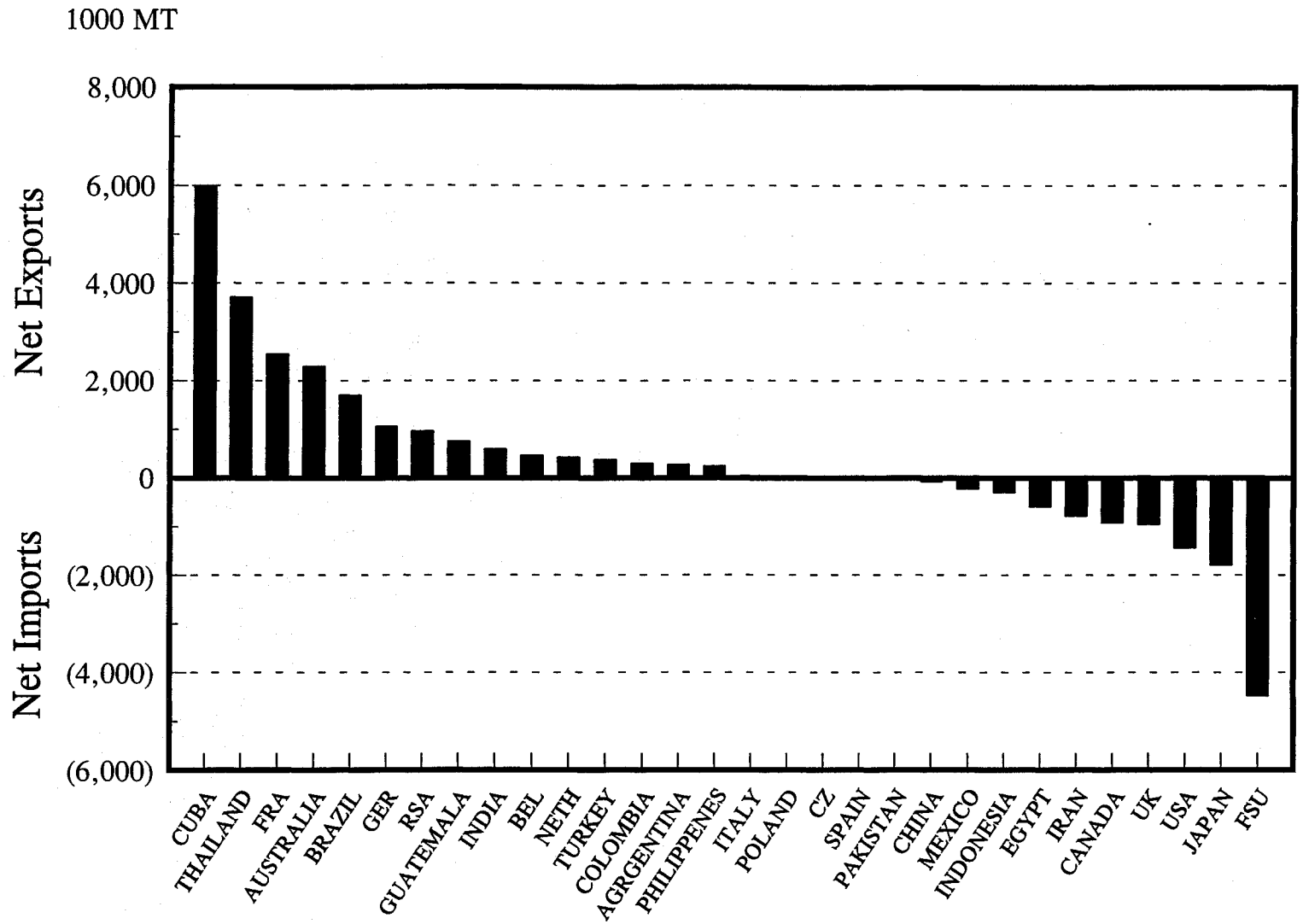


Figure 2. World's Exporters and Importers of Sugar, 1992

Source: Production Yearbook, FAO.

The United States Sugarcane Production

Sugarcane, in recent years, has provided 45% to 50% of the sugar produced in the United States. It is grown in four regions within the country: Florida, Louisiana, Texas, and Hawaii. In 1992, 870,400 acres were grown, with Florida harvesting 426,000 acres. Table 1 shows the raw sugar equivalence that was produced in the four cane growing regions. In 1992, Cane sugar production has increased 68.2% during the past 28 years. Cane sugar production was the largest in Florida followed by Louisiana, Hawaii, and Texas. Florida has increased its production from 574,000 tons (28.5%) in 1964 to 1.8 million tons (52.4%) of total U.S. cane sugar production in 1992. Hawaii's production has fallen from 43.2% to 19.3% of U.S. cane sugar production during the same time period.

Raw sugarcane requires processing into raw sugar within a few hours of harvesting. Sugarcane mills are located within a few miles of the cane fields to reduce transportation costs and delivery time. The mill grinds the cane stalks allowing the juice to be extracted, clarified, boiled, and crystallized. The raw sugar is shipped to refineries for further processing.

Table 1. U.S. Cane Sugar Production by Regions

Year	Hawaii	Florida	Louisiana	Texas	Total
	----------(thousand tons)----------				
1964	871.1 (43.2)	574.4 (28.5)	572.9 (28.4)	0.0 (0.0)	2,018.4
1971	1,034.3 (46.2)	634.7 (28.3)	571.1 (25.5)	0.0 (0.0)	2,240.1
1978	942.0 (37.3)	971.9 (38.5)	549.8 (21.8)	61.0 (2.4)	2,524.7
1985	1,011.7 (31.9)	1,436.8 (45.3)	625.0 (19.7)	101.8 (3.2)	3,175.3
1992	655.2 (19.3)	1,779.6 (52.4)	867.9 (25.6)	92.9 (2.7)	3,395.5

Note: Numbers in parentheses are production share by region (%) in the given year.
Source: USDA, *Sugar and Sweetener Situation and Outlook*

Table 2 shows the grinding capacity and the average length of the harvest campaign. Florida's mills are the largest and most modern in the country, whereas Hawaii's mills are the smallest. Louisiana has the shortest campaign days because of the weather conditions in the delta area. Thus, Florida has a comparative advantage in producing raw sugar over other cane sugar producing regions.

The Florida sugar industry is vertically integrated. Most milling companies own farmland and grow cane. The U.S. Sugar Corporation (Clewiston, FL) produces 40.8% of the state's raw sugar, followed by Okeelanta Sugar (South Bay, FL) and Sugarcane Growers Cooperative (Belle Glade, FL). Florida is the largest sugar producing area in the United States. The industry has increased acreage and utilization of mill capacity.

Table 2. Average Processing Capacity and Length of Campaign Days of Sugarcane Grinding Mills, 1992

	Number of mills	Average daily grinding capacity	Total daily grinding capacity	Average length of campaign
		----------tons----------		-------days------
Hawaii	13	4,530.8	58,900	100
Louisiana	20	7,050.0	141,000	76
Texas	1	10,500.0	10,500	118
Florida	7	16,964.3	118,750	125

Source: USDA, *Sugar and Sweetener Situation and Outlook*

Sugarcane is grown on organic soils south of Lake Okeechobee, and between the lake and the Everglades. Water from the lake passes through the sugar growing areas before draining into the Everglades. The cropping cycle is normally 3 to 4 years, with 2 or 3 crops being harvested before replanting. The Florida industry is facing strong pressure from environmental groups and government agencies. The industry is facing chemical restrictions and rising costs.

Louisiana began growing cane in 1795. During the past century sugarcane became the major agricultural crop in the area. Sugarcane is grown in the alluvial deposits along the Mississippi River. Cane is grown as a perennial crop in rotation with wheat and hay. Two crops are harvested before the roots are plowed down. Unlike Florida, most cane producers in Louisiana are independent growers or members of a co-op. The cane is contracted to local mills for processing. Most of the raw sugar is shipped by rail to local refineries.

Texas began growing sugarcane in 1973 along the lower Rio Grand Valley. All cane production is irrigated. W.C. Cowley Sugar Mill is the only mill in Texas, and the raw sugar is shipped to Sugarland, Texas, or Louisiana for refining. The mill is a modern and efficient plant, but, because of down time during harvest caused by poor weather conditions, the plant utilization is the lowest in the industry. The cropping cycle in Texas is longer than in other areas. Sugarcane is harvested 4 or 5 times before replanting. Alternative crops are cotton and grain sorghum. High water tables, excessive salinity in irrigation water, and undependable water supply limit production of sugarcane.

Sugarcane production began in the mid 1800s in Hawaii. The sugar industry provides a large proportion of the island's economy. Hawaii sugar production has decreased during the last 20 years. In 1972, 1.1 million tons of sugar were produced; and in 1992, 613,000 tons were produced. Vertically integrated companies grow, harvest, and mill their own cane. The raw sugar is marketed through an agricultural cooperative marketing association. The C&H Sugar Corporation owns two refineries: a small one on Oahu for local demand and a large refinery in California for the remainder.

Cane yield in Hawaii is the highest in the United States. Hawaiian growers allow the cane to grow for 24 months before harvesting. The crop is replanted every two years. The mills are older and smaller, but in recent years, there has been a trend toward modernizing the mills.

The North American Sugarbeet Production

Sugarbeets provide 50% to 55% of the sugar produced in the United States. Sugarbeets are grown in 13 states, including Minnesota, North Dakota, Idaho, and California, which account for 66% of the total acreage, and in two regions in Canada. Table 3 presents sugarbeet growing regions in North America and their processing capacities. The Red River Valley of Minnesota and North Dakota is the largest sugarbeet producing area in the United States. The Pacific Northwest Region, including Idaho and Oregon, has the second largest processing capacity. The Red River Valley and the Northwest Regions have the longest and second longest campaign days, respectively, indicating that these regions have a comparative advantage over other regions in producing sugar.

Table 3. Slicing Capacity and Length of Campaign Days in Sugarbeet Processing Regions in North America

Region	Number of plants	Avg. slicing capacity/day	Total slicing capacity/day	Length of campaign
		----------(000) tons----------		----days---
Great Lakes	6	4,283	25,700	137
Red River Valley	7	6,275	43,925	231
N. Great Plains	5	1,880	9,400	172
C. Great Plains	5	3,840	19,200	121
S. Great Plains	1	7,700	7,700	127
Northwest	4	9,000	36,000	147
California	8	4,700	37,600	105
Manitoba	1	4,230	4,230	130
Alberta	1	6,780	6,780	130

Source: USDA, *Sugar and Sweetener Situation and Outlook*

Table 4 shows sugarbeet production in each producing region from 1964 to 1992. Sugar production has grown from 3 million tons in 1964 to 3.8 million tons in 1992. The majority of the increase has been in the Red River Valley. This regional production increased from 257 thousand tons in 1984 to 1.3 million tons in 1992. On the other hand, sugarbeet production has reduced substantially in the central plains and California.

Table 4. United States Beet Sugar Production by Regions

Year	G.Lakes	Red River	N.Great	C.Great	S.Great	NW	Calif.	Total
	----------thousand tons----------							
1964	246	257	249	675	77	548	1,025	3,075
	(8.0)	(8.3)	(8.1)	(21.9)	(2.5)	(17.8)	(33.3)	
1971	302	389	281	666	61	736	1,046	3,482
	(8.7)	(11.2)	(8.1)	(19.1)	(1.8)	(21.1)	(30.0)	
1978	276	1,023	230	460	58	601	597	3,245
	(8.5)	(31.5)	(7.1)	(14.2)	(1.8)	(18.5)	(18.4)	
1985	344	1,001	246	170	111	508	622	3,001
	(11.5)	(33.3)	(8.2)	(5.7)	(3.7)	(16.9)	(20.7)	
1992	488	1,339	354	306	110	693	514	3,804
	(12.8)	(35.2)	(9.3)	(8.1)	(2.9)	(18.2)	(13.5)	

Note: Numbers in parentheses are production share by region (%) in the given year.
Source: USDA, *Sugar and Sweetener Situation and Outlook*

Sugarbeets are harvested quickly and stored in piles until they are processed. The storage time is limited by weather conditions. Processing facilities in the northern growing areas can store beets longer because of the cold winter temperatures. American Crystal in the Red River Valley is capable of processing sugarbeets until late March or early April. This allows them to spread the fixed costs over more production.

Sugar Consumption and Trade

The United States has excess capacity in the sugar refinery industry. Several refineries along the East Coast have closed. The substitution of HFCS for sugar has reduced raw sugar imports, further reducing the demand for refinery capacity. Table 5 shows the location and capacities of U.S. and Canadian refineries.

The United States imports raw sugar from more than 40 countries. The major exporters are the Dominican Republic, Brazil, Philippines, and Australia. Each country has an allotment for sugar exports. The export allotment has decreased substantially.

To begin compliance with GATT, the United States tariffied its sugar import quota. Sugar is imported into the country at the wholesale price of 21.31 cents per lb. in 1992. Any sugar imported above the quota level is levied an extra 16 cents per lb. tariff.

Table 5. U.S. Imports of Raw Sugar Under Quota and Tariffs, 1991/92

Country	Quota	Imports
	----------tons----------	
Argentina	62,630	62,334
Australia	120,892	121,366
Belize	16,022	16,085
Bolivia	11,653	12,388
Brazil	211,195	211,124
Canada	*	40,576
Colombia	34,956	33,333
Congo	8,001	8,139
Costa Rica	21,774	21,848
Dominican Republic	256,348	252,526
Ecuador	16,022	16,700
El Salvador	37,903	37,870
Fiji	13,109	13,405
Gabon	8,001	7,945
Guatemala	70,108	69,913
Guyana	17,478	17,665
Haiti	8,001	0
Honduras	14,347	14,565
India	11,653	11,459
Jamaica	15,732	16,022
Madagascar	8,001	7,870
Malawi	14,565	15,012
Mauritius	17,478	17,476
Mexico	7,765	8,001
Mozambique	18,934	19,307
Nicaragua	13,299	30,587
Panama	42,256	42,239
Papua New Guinea	8,001	8,027
Paraguay	8,001	8,156
Peru	59,718	59,308
Philippines	196,630	194,568
South Africa	33,500	33,904
St. Christopher	7,923	8,001
Swaziland	23,304	23,876
Taiwan	23,304	17,469
Thailand	20,392	20,237
Trinidad	10,090	10,195
Uruguay	8,001	8,127
Zimbabwe	17,478	17,669
Total	1,524,876	1,481,258

*Canada is exempt from quota restrictions

Source: USDA, *Sugar and Sweetener Situation and Outlook*

Canada does not restrict imports because the domestic production is limited. Australia, Cuba, and Swaziland are the largest exporters of raw sugar to Canada. Canada imports about 84% of its domestic consumption.

Domestic consumption of sugar has been decreasing for the past 20 years. Figure 3 shows that sugar has been substituted by HFCS and non-caloric sweeteners. Sugar consumption amounted to 94% of the sweetener market in 1974, but it was 46% of the sweetener market in 1992. Figure 4 shows the growth of the HFCS and non-caloric market. Production of HFCS and non-caloric sweeteners increased from 1 million tons in 1974 to 10 million tons in 1992.

Figure 5 shows the industry uses for sugar. Domestic uses of sugar dropped from 10 million tons in 1972 to a little more than 7 million tons in 1993. The major change was the substitution of HFCS in the soft drink industry. Sugar use in soft drinks has dropped from 2.5 million tons to 200,000 tons.

Sugar prices varied greatly during the 1970s, but stabilized. Figure 6 shows prices for sugar and HFCS. Midwest wholesale sugar has stayed approximately 15 cents/lb above the Caribbean price. HFCS has maintained its price between 5 and 8 cents/lb under sugar.

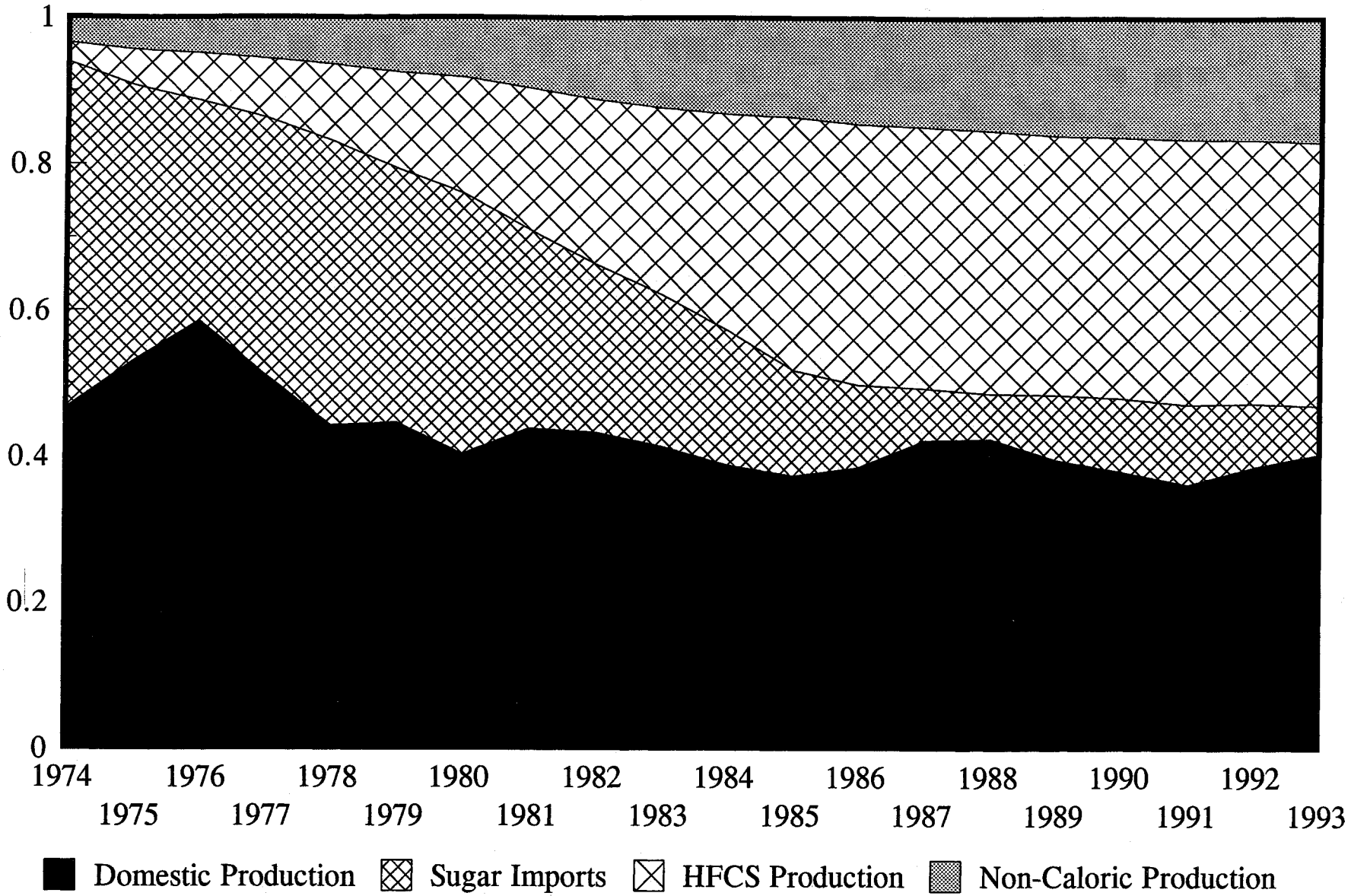


Figure 3. United States Market Share for Sweeteners

Source:USDA-ERS. Sugar and Sweetener Situation and Outlook

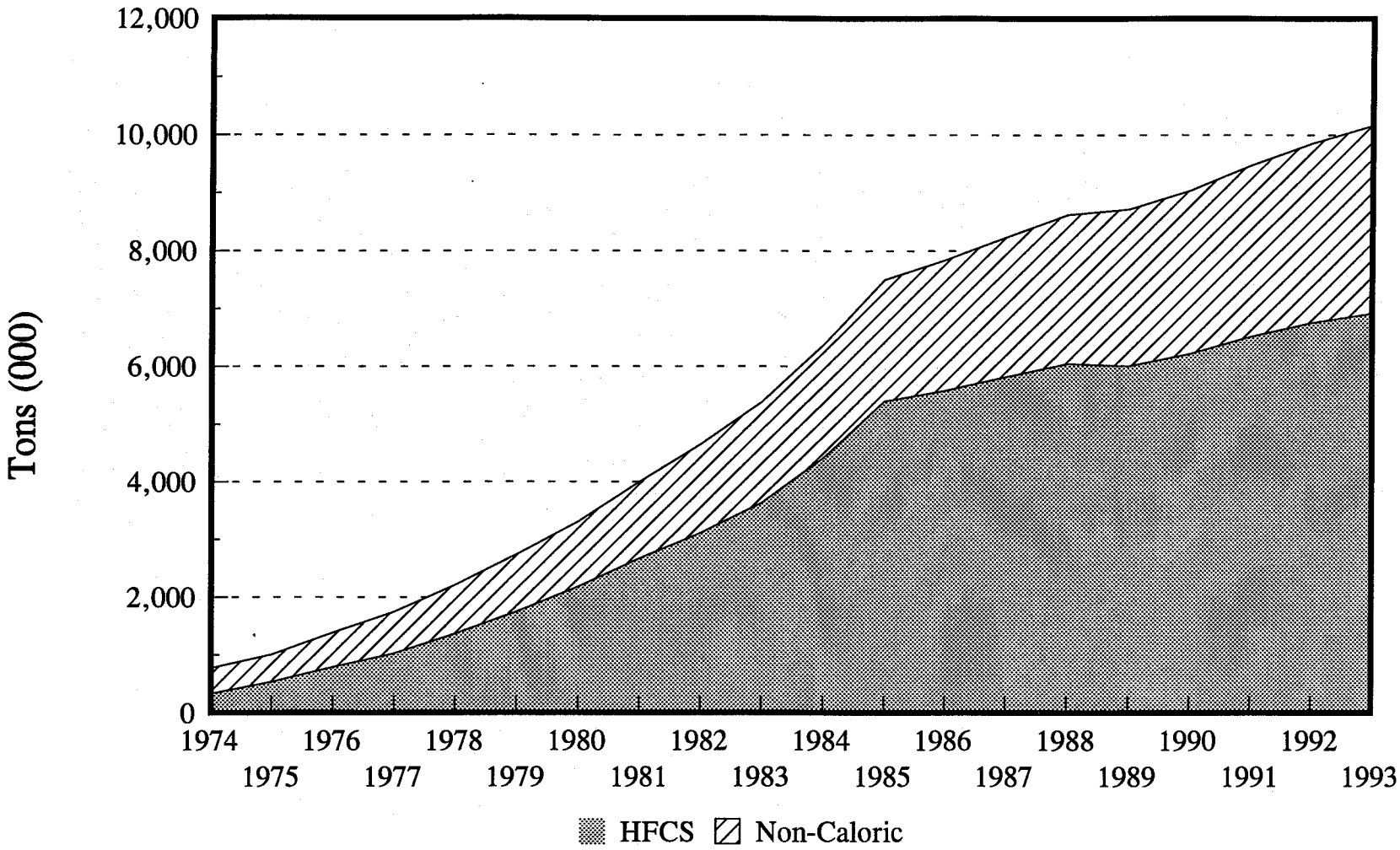


Figure 4. U.S. HFCS and Non-Caloric Sweetener Production

Source: USDA-ERS. Sugar and Sweetener Situation and Outlook.

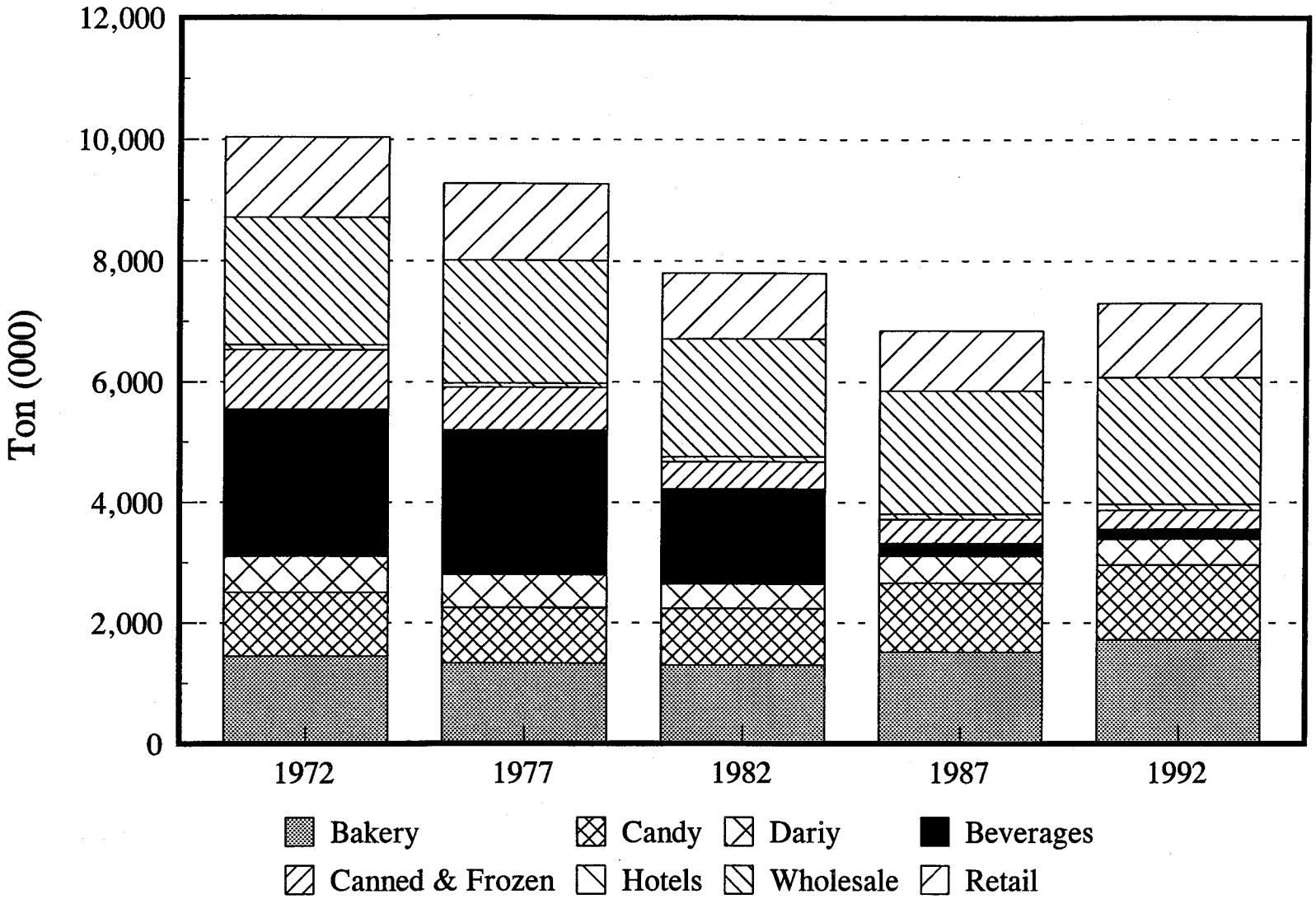


Figure 5. U.S. Industrial Deliveries of Sugar

Source: USDA-ERS. Sugar and Sweetener Situation and Outlook.

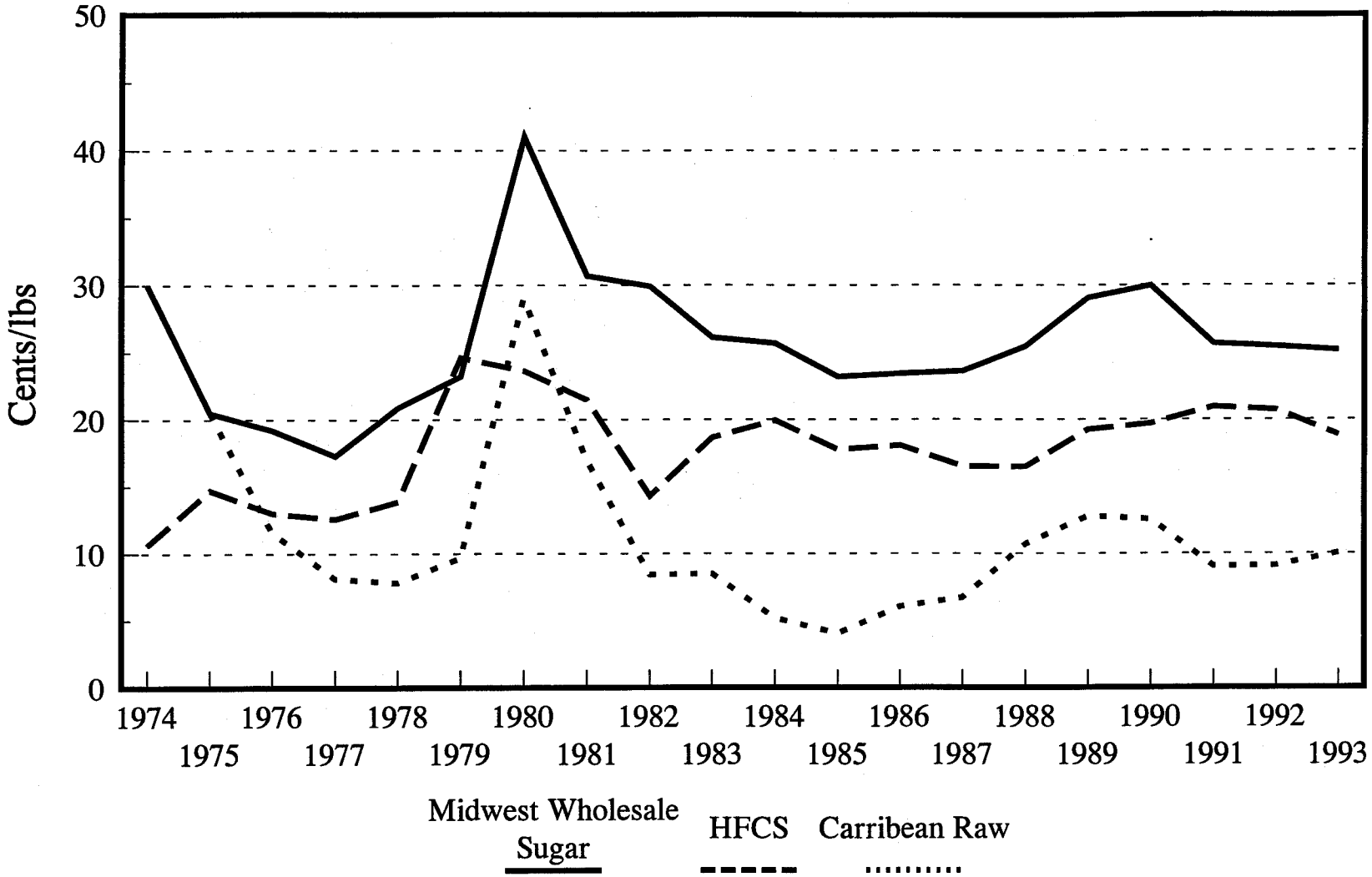


Figure 6. U.S. Sugar and HFCS Price

Source: USDA-ERS. Sugar and Sweetener Situation and Outlook.

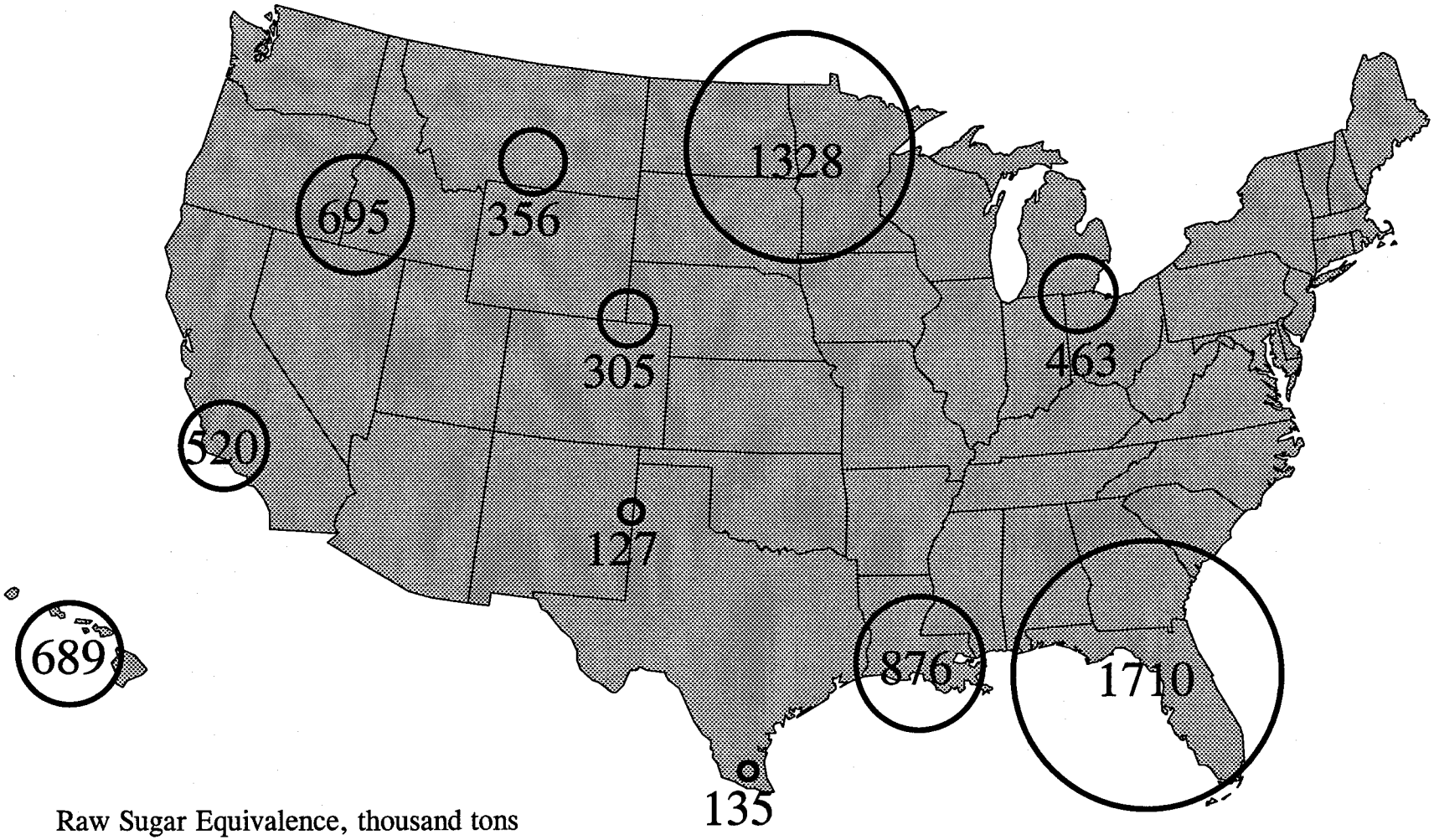
Development of Empirical Model

A spatial programming model based on a mathematical programming algorithm was developed to evaluate the impacts of existing and alternative sugar programs on the U.S. sugar industry. The United States is divided into 11 sugar producing regions (7 regions for sugarbeet and 4 regions for sugarcane), and Canada is divided into 2 sugarbeet producing regions (Figures 7 and 8). Producing regions in the United States are southeastern Florida, Mississippi Delta of Louisiana, south Texas, and Hawaii for sugarcane production; and Great Lakes (Michigan and Ohio), Red River Valley, Northwest (Idaho), Northern Great Plains (Montana and Wyoming), Central Great Plains (Nebraska and Colorado), Southern Great Plains (Texas and New Mexico) and California for sugarbeet production. Canadian producing regions are located in Manitoba and Alberta. The United States is divided into 36 consumption regions (Figure 9) and Canada is divided into 7 consumption regions (Figure 10). This model also includes sugar processing plants for sugarbeet and sugarcane and sugarcane refineries. This study assumed that sugarbeets or sugarcane are moved to processing plants by trucks and sugar is moved from processing plants to consuming regions by railroad.

Beet sugar produced in sugarbeet processing plants and cane sugar produced in refineries are perfect substitutes for each other, but the production processes are totally different. The production, transportation, processing, and delivery of sugarbeets and sugarcane are kept separate in the model. Imported raw sugar is refined at domestic sugar refineries, and the refined sugar is delivered to consumption regions.

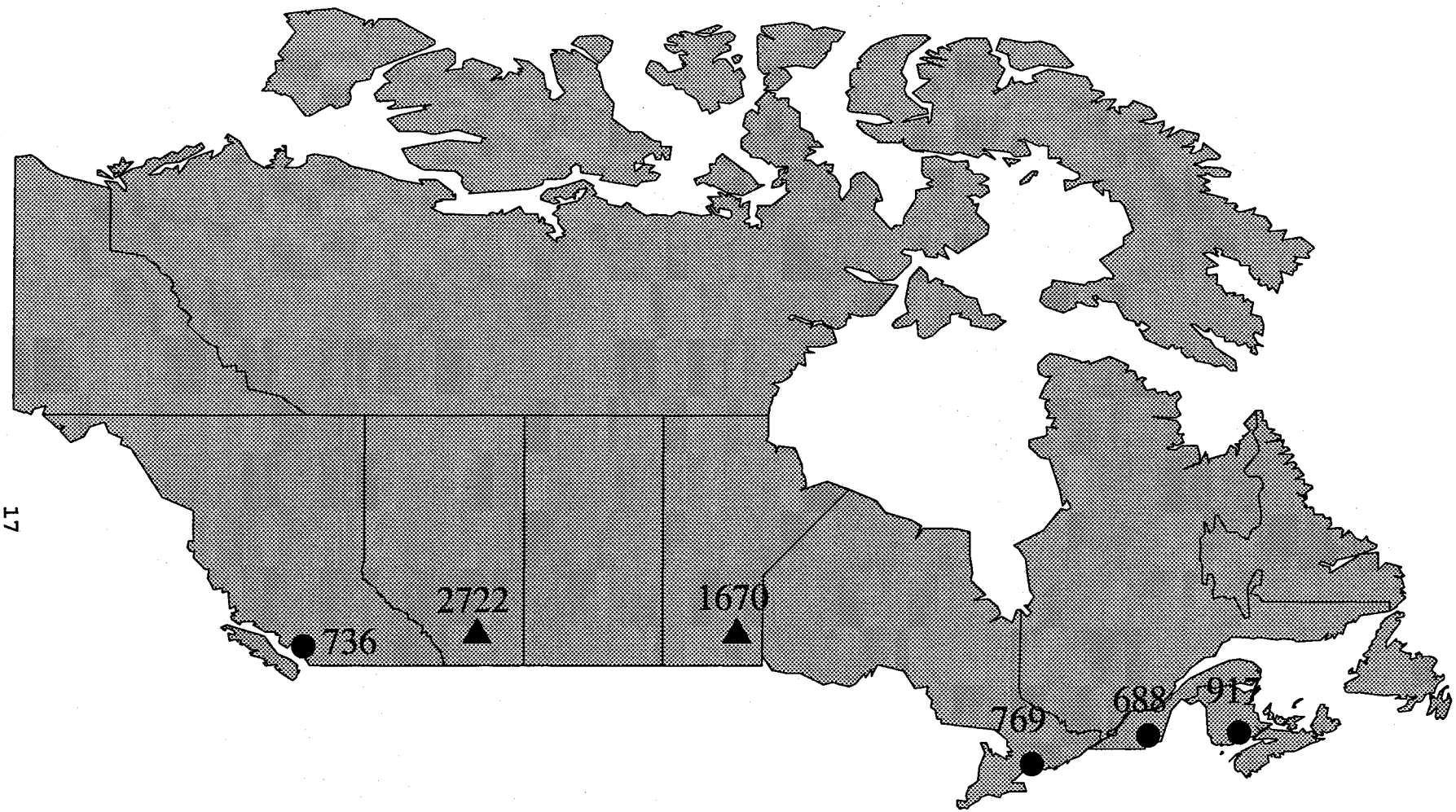
Figure 11 displays production, processing, distribution, and imports of sugar in the North American sugar industry. Seven beet production regions in the United States and two regions in Canada ship sugarbeets to nearby processing plants. Sugar refined at the plants moves to consumption regions in the United States and Canada. Sugarcane producing regions ship sugarcane to nearby mills. Raw sugar processed at cane mills and imported from foreign countries is moved to raw sugar refineries. Cane sugar refined at cane sugar refineries moves to consumption regions in the United States and Canada. Refined sugar imported from foreign countries moves to consuming regions in the United States and Canada. Sugar imports are restricted by a tariff/quota and individual allotments.

The model used for this study is a static spatial programming model based on a mathematical programming algorithm. The objective function of the model is to maximize net returns generated by the North American sugar industry through sugarbeet and sugarcane production, processing, distribution, and imports. This objective function is optimized subject to a system of linear constraints. The constraints include land available for sugarbeet and sugarcane production, processing capacity in each producing region, refinery capacity for raw cane sugar, individual importing country's quota, and domestic sugar consumption in each region.



Raw Sugar Equivalence, thousand tons
Diameter of circle represents amount of sugar produced

Figure 7. U.S. Sugar Production Regions



● Sugarcane refinery, short tons per day, melting capacity, raw sugar

▲ Sugarbeet Plants, short tons per day, slicing capacity, raw beets

Figure 8. Canadian sugar processing and refinery industry

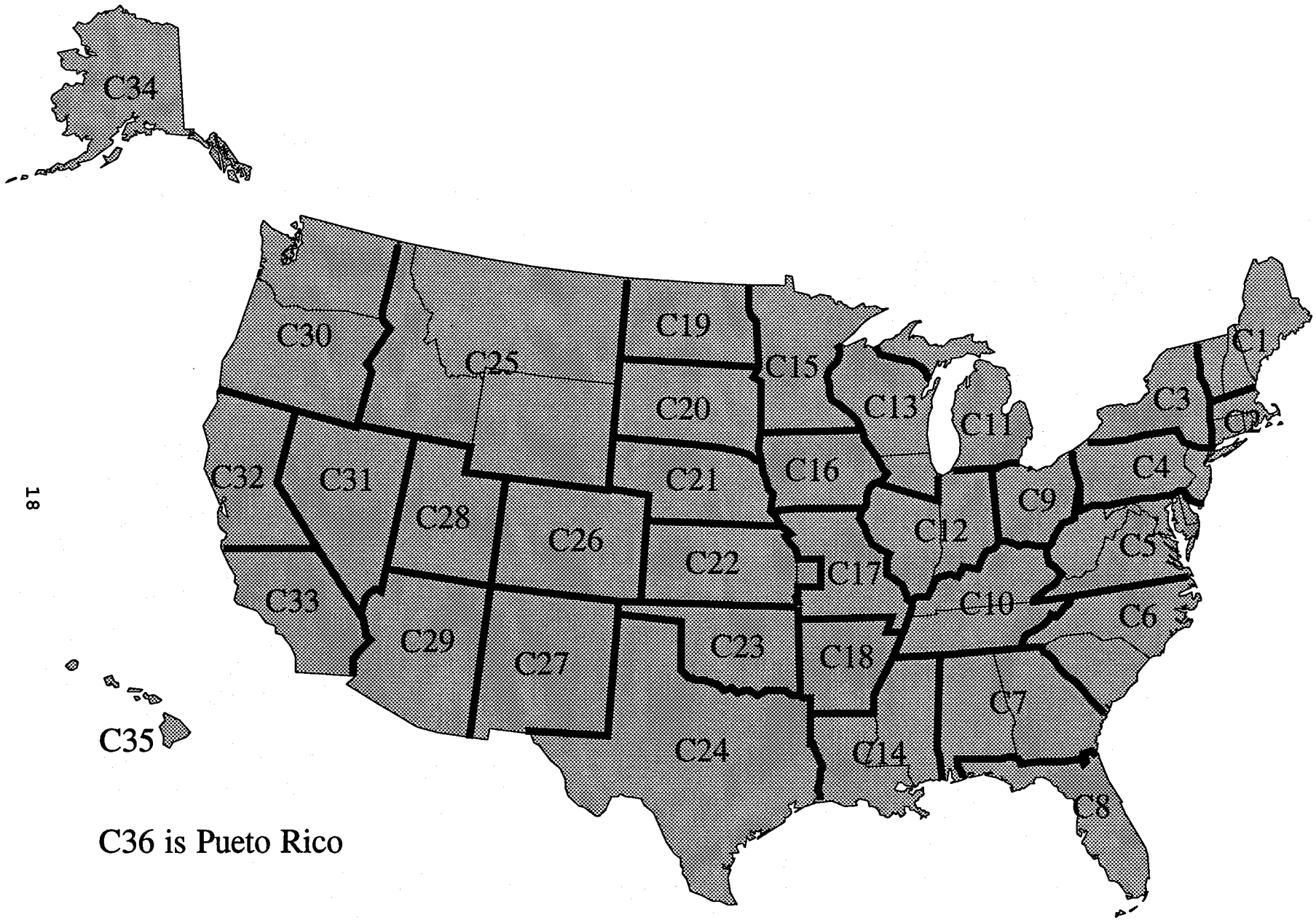


Figure 9. U.S. consumption regions

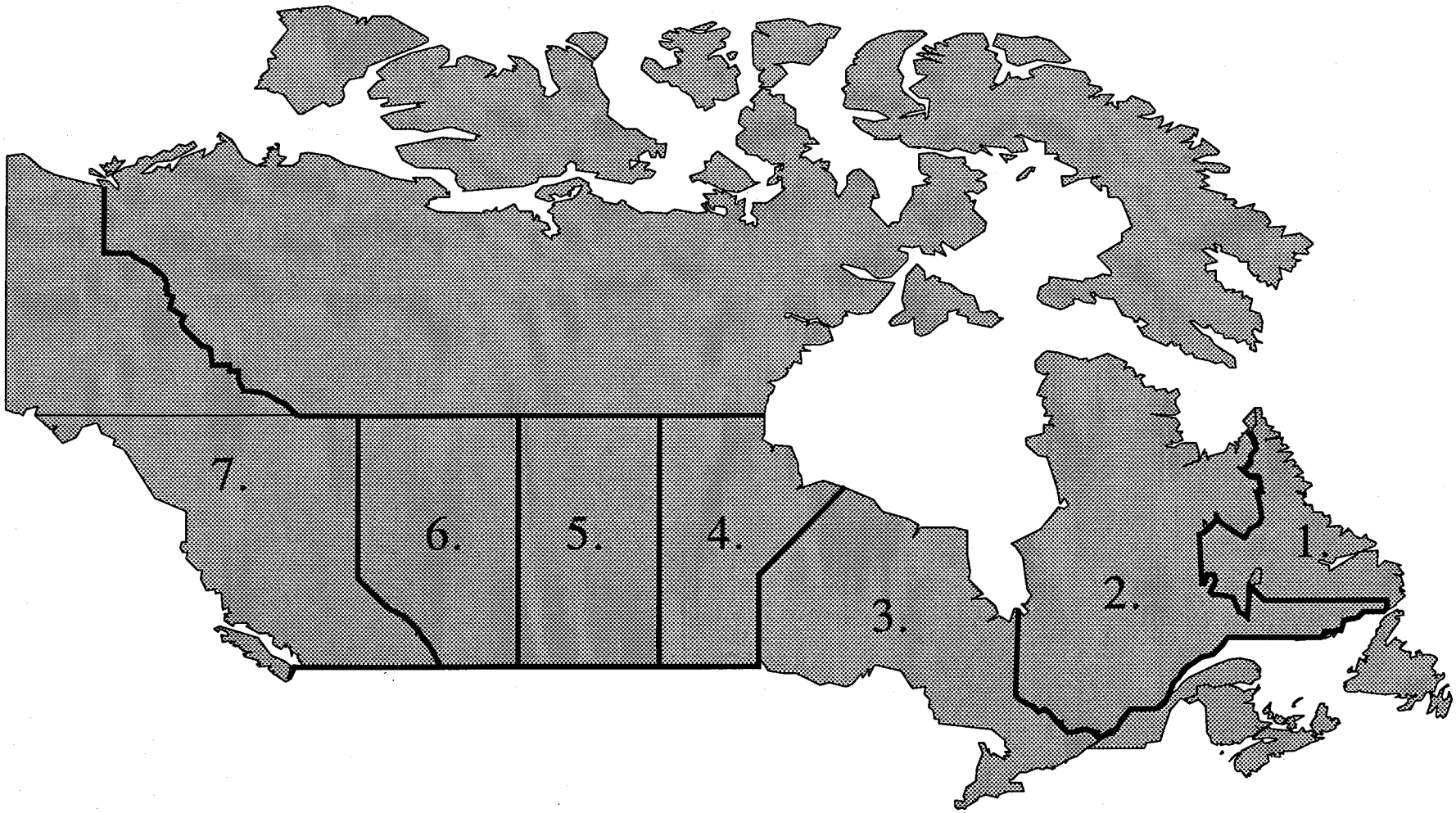


Figure 10. Canadian consumption regions

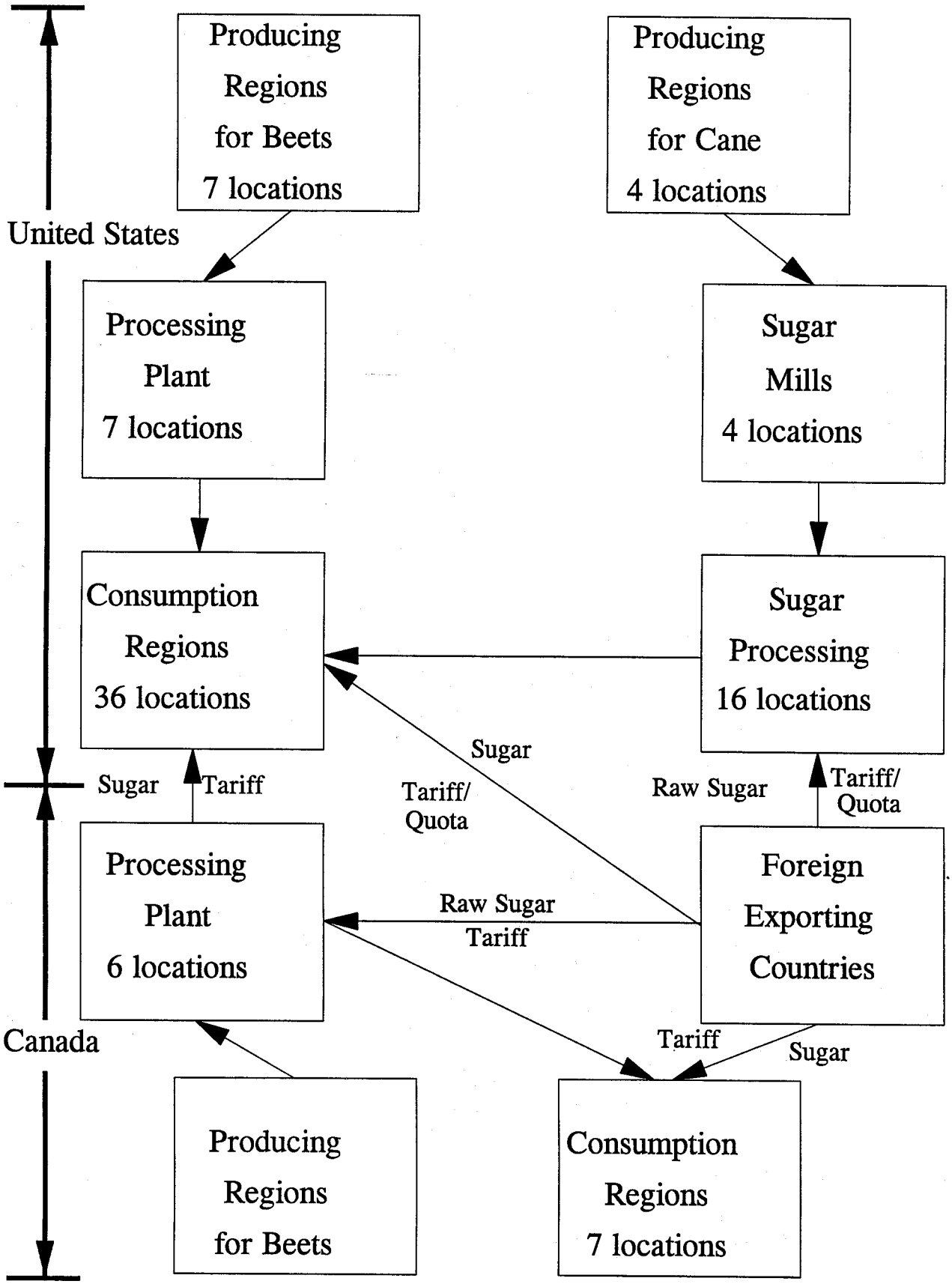


Figure 11. Structure of the sugar simulation model

Mathematical Model

The objective function of the model is mathematically expressed as follows:

$$(1) \quad Z = \sum_c S_c P_c - \sum_i PC_i A_i - \sum_j PC_j A_j - \sum_h C_h Q_h - \sum_m C_m Q_m$$

$$- \sum_n C_n RS_n - \sum_i \sum_h t_{ih} Q_{ih} - \sum_h \sum_c t_{hc} S_{hc} - \sum_j \sum_m t_{jm} Q_{jm} - \sum_m \sum_n t_{mn} RS_{mn}$$

$$- \sum_n \sum_c t_{nc} S_{nc} - \sum_e RS_e P_e^R - \sum_e S_e P_e - \sum_e \sum_p t_{ep} RS_{ep} - \sum_p \sum_n t_{pn} RS_{pn}$$

$$- \sum_e \sum_p t_{ep} S_{ep} - \sum_p \sum_c t_{pc} S_{pc}$$

where

c = index for consuming regions in the United States and Canada,
i = index for sugarbeet producing regions,
j = index for sugarcane producing regions,
h = index for sugarbeet refineries,
m = index for sugarcane mill,
n = index for sugarcane refineries,
e = index for sugar exporting country,
p = index for ports in the United States and Canada,
S = quantity of refined beet or cane sugar,
PC = production cost of sugarbeets or sugarcane,
A = acreage used to produce sugarbeets or sugarcane,
Q = quantity of sugarbeets or sugarcane,
RS = quantity of raw sugar produced at mills,
t = transportation cost in shipping sugarbeets or sugarcane, raw sugar, and refined sugar from producing regions or processing plants to consuming regions,
C = processing cost of sugarbeets or sugarcane at processing plant,
P^r = price of raw sugar,
P = price of refined sugar.

The first term in Equation 1 represents the total revenue generated by the North American sugar industry. The next two summation terms indicate the total production costs of sugarbeet and sugarcane in producing regions. The costs are calculated by multiplying production cost per acre (pc) by the total acres in production (A). The next three terms represent the total processing costs at sugarbeet plants, sugarcane mills, and sugarcane refineries. The next five terms represent transportation costs from sugarbeet or sugarcane producing regions to consuming regions. The next two terms are the total import costs of raw and refined sugar. The last four terms are transportation costs from exporting countries to domestic consuming regions through ports.

The objective function is optimized subject to the following constraints:

(2) $A_i \leq L_i$

(3) $A_j \leq L_j$

(4) $A_i \; Y_i = \sum_h Q_{ih}$

(5) $A_j \; Y_j = \sum_m Q_{jm}$

(6) $Q_h = \sum_i Q_{ih}$

(7) $Q_m = \sum_j Q_{jm}$

(8) $RS_n = \sum_m RS_{mn}$

(9) $\sum_h S_{hc} + \sum_n S_{nc} + \sum_p S_{pc} \geq D_c$

(10) $S_c = D_c$

(11) $\sum_i \alpha Q_{ih} = \sum_c S_{hc}$

(12) $\sum_j \lambda_1 Q_{jm} = \sum_n RS_{mn}$

(13) $\sum_m \lambda_2 RS_{mn} = \sum_c S_{nc}$

(14) $\sum_e RS_{ep} = \sum_n RS_{pn}$

(15) $\sum_p RS_{pn} = \sum_c S_{nc}$

(16) $\sum_e \lambda_2 RS_{ep} + \sum_e S_{ep} \leq QT_p$

(17) $RS_e = \sum_p RS_{ep}$

(18) $S_e = \sum_p S_{ep}$

where

L = Maximum arable land for sugarbeet or sugarcane production,
Y = sugarbeet or sugarcane yields per acre,
α = extraction rate of refined sugar from sugarbeets,
QT = U.S. sugar quotas.

Equations 2 and 3 are land constraints, indicating that the total land used for sugarbeet or sugarcane production should be less than the total land available for the crop. Equations 4 and 5 stipulate that the total sugarbeet or sugarcane produced in each producing region should equal the total quantity shipped to processing plants or mills. These constraints do not allow storage of sugarbeets or sugarcane at producing regions. The next three equations (6, 7, and 8) indicate that the quantities of sugarbeet, sugarcane, and raw sugar purchased equal the quantities processed in respective processing plants.

Equation 9 represents demand constraints for sugar consumption in consuming regions, indicating that the total amount of sugar consumed in each consuming region should be obtained from sugarbeet processing plants, sugarcane refineries, and foreign exporting countries. Equation 10 indicates that the total amount of sugar purchased in each consuming region equals the amount consumed. Equations 11, 12, and 13 are inventory clearing conditions at sugarbeet processing plants, mills, and sugarcane refineries, respectively. Equations 14 and 15 are inventory clearing conditions of imported sugar at ports and raw sugar refineries. Equation 16 indicates that total imports from all exporting countries should not exceed the U.S. import quota of sugar. Equations 17 and 18 indicate that the total amount of sugar purchased from foreign countries should be moved to consuming regions through ports.

The Base and Alternative Models

This study is based on one base and seven alternative models. The models are stated as follows:

Model 1 is the base model incorporating existing production, processing, and marketing conditions under the current agricultural and trade policies.

Model 2 is the base model with a 20% increase in production and processing capacity in each region.

Model 3 is the base model with a 50% increase in production and processing capacity in each region except Florida and Louisiana. These two states are allowed to increase production by 20% because of land constraints.

Model 4 is the base model with a 20% increase in the U.S. sugar import quotas. The refined sugar price is lowered 11% because of the added supplies.

Model 5 is the base model with a 50% increase in the U.S. sugar import quotas. The refined sugar price is lowered 20% because of the added supplies.

Model 6 is the base model with a 100% increase in the U.S. sugar import quotas. The refined sugar price is lowered 30% because of the added supplies.

Model 7 is the base model with a 15% decrease in U.S. sugar price with a 20% increase in production and processing capacity.

Model 8 is the base model without tariff-rate quota on imported sugar. The price of sugar is assumed to decrease to 16 cents per pound.

The base model imposes a minimum production constraint of 50% of base production in each producing region to investigate marginal loss on the region's production capacity under alternative policy options. In the base model, imports of sugar are restricted at the current import quota level in the United States and are not restricted in Canada. The prices of sugar and consumption of sugar in each consuming region are fixed in the base model.

Models 2 and 3 were developed to evaluate the competitiveness of different growing and processing regions in North America. Models 4, 5, and 6 were developed to evaluate the impacts of increases in sugar imports on regional sugar production. Model 7 was developed to analyze the impacts of a decrease in domestic sugar price on regional competitiveness. Model 8 evaluates the impacts of a eliminating the tariff-rate quotas on imported sugar on the U.S. sugar industry.

Collection of the Data

Transportation Costs

Transportation costs were divided into four parts: transportation of raw product to beet plant or cane mill, transportation of raw sugar to refineries, transportation of refined sugar to final destination, and transportation of raw sugar from exporting country to U.S. and Canadian ports. The transportation costs of shipping sugarbeets and sugarcane to processing plants were assumed to be zero because of the short distances between growing and processing areas.

A rail freight rate function for sugar from processing plants to domestic consuming regions was estimated with actual rail freight rates from selected sample routes as follows:

$$\ln R_{ij} = -3.86181 + 0.583 \ln D_{ij} + 0.098 \ln W_i$$
$$\quad (-37.39) \quad (10.80) \qquad (6.61)$$

$R^2 = .65$

t-values in parentheses

where R_{ij} = freight rates for sugar shipments between origin i and destination j,
D_{ij} = distances between origin i and destination j
W_i = distances between origin i and the nearest water port

This equation was used to estimate the transportation cost of shipping raw sugar from mills to refineries. The rail mileages (D_{ij}) were calculated using AutoMap Version 2 software by Automap, Inc. and distances between producing region and water access points (W_{ij}) were obtained from *Rand McNally Road Atlas of the United States and Canada.* Sample rail rate data were obtained from American Crystal Sugar Company.

Ocean freight rates from exporting countries to U.S. and Canadian ports were calculated from the estimated ocean freight rate function, which was estimated with actual ocean freight rates from the selected sample routes. The estimated function is as follows:

$$\ln OR_{pn} = 1.257873 + 0.098 \ln OD_{pn}$$
$$(4.47) \quad (5.54)$$
$$R^2 = .69$$
t-values in parentheses

where

OR_{pn} = ocean freight for raw sugar between origin p and destination n
OD_{pn} = ocean mileage between origin p and destination n

Ocean mileages were calculated using *The Times Atlas of Oceans* (Times Books Limited). The sample ocean freight rate data were obtained from *Chartering Annual* (Maritime Research Inc.).

Tariffs and Import Quotas

The United States imports raw sugar from over 40 countries. Exporting countries export sugar to the United States based on the U.S. import quotas. Table 5 in section 2 shows the U.S. sugar quota and actual imports for 1992. The import quotas on sugar were obtained from *Sugar and Sweetener Situation and Outlook* (USDA). Since the GATT negotiations, the United States has converted the sugar quotas to tariff-rate quotas. Exporting countries are allowed to export sugar into the United States up to the quotas. Sugar exports above the quotas are subject to a 16 cent/lb. tariff. Canada does not impose import quotas on imported sugar; import tariff is .94 cent/lb. on imported sugar. Total U.S. imports in 1984 were 2,675 thousand tons of raw sugar. In 1992, 1,360 thousand tons of sugar were imported into the United States which is about 15% of the domestic consumption.

The United States government allows extra importation of raw sugar that is refined and then exported overseas. In 1992, 400,000 tons of imported raw sugar were refined and exported.

Sugarcane and Sugarbeet Production and Processing

Table 6 shows production and processing cost for sugarbeets and sugarcane. They were obtained from Landell Mills Commodities Studies (1993) and *Sugar and Sweetener Situation and Outlook* (USDA). Processing costs for sugarbeets are not divided for individual regions. The eastern area processing costs are $98.2 per ton, and the western area processing costs are $86.5 per ton.

Table 6. North American Production and Processing Costs, Acres, and Yield for Sugarbeets and Sugarcane, 1992

Production regions	Production* costs	Processing** costs	Acres	Yield
	----------$/ton----------		---thousand tons/acre---	
Sugarbeets				
Great Lakes	347.50	98.20	175.56	15.64
Red River Valley	304.10	98.20	541.88	17.37
Northern Great Plains	361.10	86.50	116.52	21.32
Central Great Plains	361.10	86.50	109.94	21.94
Southern Great Plains	354.40	86.50	35.94	22.02
North West	357.70	86.50	201.44	24.03
California	354.40	86.50	171.40	25.50
Manitoba	300.00	98.20	37.00	14.00
Alberta	350.00	86.50	30.00	16.00
Sugarcane				
Florida	232.00	48.60	416.40	34.90
Louisiana	249.50	102.80	287.20	22.10
Texas	275.20	88.70	34.12	32.40
Hawaii	285.80	135.40	70.60	86.90

Source: *Landell Mills Commodities Studies, 1993
**USDA, *Sugar and Sweetener Situation and Outlook*

Total land available for sugarbeet and sugarcane production in each producing region is defined as 12% larger than the planted acreage for 1992. Processing capacity for beet plants and cane mills was calculated by multiplying daily capacity times the length of the processing campaign. Processing capacity was increased 12% to allow a feasible base solution. Minimum production and processing capacity was assumed to be 50% of the actual production. Total sugar refinery capacity was calculated by multiplying the daily melting capacity by 300 days. Minimum capacity was assumed to be 1/3 total capacity for each refinery.

Acres available for production and yield data were obtained from the *Sugar and Sweetener Situation and Outlook*, USDA. Beet and cane processing capacity data and sugar refinery data were obtained from Outlook '93 Conference, Sweeteners Outlook Session #28, U.S. Sugar Production and Processing Statistics. The location of sugarbeet plants was obtained from *Directory of American Beet Sugar Companies (1989-90)*. Refinery capacities for North American refineries were obtained from American Crystal Sugar Company (Table 7). Sugar import data and sugar prices were obtained from *Sugar and Sweetener Situation and Outlook*, USDA. Most Canadian production and price data were obtained from "Canadian Sugar and HFCS Industries and U.S. Trade" in *Sugar and Sweetener Situation and Outlook* (USDA), and the remaining were obtained from Statistics Canada.

Table 7. Location and Capacity of Sugar Refineries for United States and Canada

Location	Capacity
	(thousand tons/year)
Yonkers, NY	657
Brooklyn, NY	730
Baltimore, MD	1,077
Port Wenthworth, GA	1,095
South Bay, FL	265
Clewiston, FL	292
Chalmette, LA	1,040
Gramercy, LA	292
Donaldsonville, LA	730
Sugarland, TX	712
Crockette, CA	1,095
Aiea, HI	73
St. John, NB	312
Montreal, QU	234
Toronto, OT	262
Vancouver, BC	251

Source: USDA, *Sugar and Sweetener Situation and Outlook*

Demand for Sugar

The USDA divides the country into five regions for sugar distribution. Per capita sugar consumption is calculated by dividing consumption of sugar in each distribution region by the population in those regions. Total demand for sugar in each consuming region in the United States and Canada is calculated by multiplying the calculated per capita consumption of sugar by the population within each consumption region. Table 8 shows sugar consumption within each consuming region. The U.S. population was obtained from the U.S. Department of Census. Sugar consumption was obtained from the USDA. Canadian population and sugar consumption were obtained from Statistics Canada.

Results

Production, Consumption, and Imports

The total amount of sugar produced in North America is 7.17 million tons (7.08 million tons in the United States and 0.09 million tons in Canada) in the base model (Table 9). The total land used for sugarbeet production is 1,489,000 acres and the total for sugarcane production is 885,000 acres. North America imports 2.45 million tons of raw sugar and 0.01 million tons of refined sugar in the base model. The raw sugar imported from foreign countries is refined at refineries located in the southeastern states. The sugar industry's net profit is $848 million in the base model.

The total amount of sugar consumed in North America is 9.47 million tons (8.4 million tons in the United States and 0.99 million tons in Canada). About 15% of the domestic consumption of sugar is imported from more than 40 countries and the remaining 85% is produced in North America in the base model. The amount of total land used for sugarbeet production is 1.5 million acres in North America. Sugarbeets produced in the United States and Canada are moved to nearby processing plants, and refined sugar produced at the plants is moved to consuming regions in the countries. The total amount of beet sugar produced in the United States is 3.76 million tons and in Canada is 84,700 tons in the base model. The total amount of land used for sugarcane production is 0.88 million acres in North America. Sugarcane produced in Florida, Louisiana, Texas, and Hawaii is moved to the nearby mills, and the raw sugar produced at mills is moved to refineries. The refineries also get raw sugar from foreign exporting countries (2.45 million tons). The refined sugar is moved to consuming regions in the United States and Canada.

Table 8. Total Sugar Consumption in Consumption Regions, North America

Consumption regions	States	Total consumption	Per capita consumption
		-----tons----	----pounds----
United States			
Northeast	ME VT NH	50,809	17.4
	MS RI CT	179,190	17.4
North Atlantic	NY	654,189	36.1
	PA NJ	714,810	36.1
South	MD VA WV DE	398,585	27.7
	NC SC	289,643	27.7
	AL GA	301,871	27.7
	FL	373,990	27.7
	TN KY	243,421	27.7
	LA MS	191,348	27.7
	AR	66,518	27.7
	OK	89,061	27.7
	TX	489,559	27.7
North Central	OH	546,776	49.6
	MI	468,403	49.6
	IL IN	459,965	49.6
	WI	616,364	49.6
	MN	222,363	49.6
	IA	139,572	49.6
	MO	179,181	49.6
	ND	31,567	49.6
	SD	35,290	49.6
	NE	79,713	49.6
	KS	203,800	49.6
West	MT ID WY	58,639	24.9
	CO	86,329	24.9
	NM	39,333	24.9
	UT	45,105	24.9
	AZ	95,335	24.9
	WA OR	201,842	24.9
	NV	33,014	24.9
	N.CA	257,993	24.9
	S.CA	509,942	24.9
	AK	14,603	24.9
	HI	28,859	24.9
Puerto Rico	PR	78,000	*
Canada	MART	86,500	40.8
	ONT	251,900	40.8
	QUE	362,500	40.8
	MAN	40,500	40.8
	SAS	37,200	40.8
	ALB	91,900	40.8
	BC	119,400	40.8

*Includes only United States exports to Puerto Rico

Source: USDA, *Sugar and Sweetener Situation and Outlook*; NASS, *Sugar Marketing*

Table 9. Total Production, Consumption, and Imports of North American Sugar Under Alternative Models

Model	Harvested Acres		Prod.*	Cons.*	Imports		Objective value
	beet	cane			Ref	Raw**	
	------thousand-------		----------million tons----------				-million$-
1	1,489.3	885.4	7.17	9.47	0.01	2.45	847.99
2	1,607.3	775.7	7.15	9.47	0.02	2.46	1,091.56
3	1,890.1	588.3	7.15	9.47	0.02	2.46	1,139.39
4	1,483.9	769.0	6.88	9.47	0.02	2.75	488.52
5	1,483.9	689.3	6.51	9.47	0.02	3.15	233.86
6	1,365.4	578.7	5.80	9.47	0.02	3.91	-41.01
7	1,607.3	775.7	7.15	9.47	0.02	2.46	601.91
8	795.0	452.7	3.76	9.47	0.02	6.09	-14.33

*Refined
**Raw

Figure 12 shows the flow of sugar from beet plants and sugar refineries to consumption regions in the base model. Major flows of beet sugar are from the Red River Valley to the Chicago area, from the Northwest to Oregon, and from the Central Great Plains to Iowa. Major flows of cane sugar are from Florida and Georgia to mid-Atlantic states; from Louisiana to Texas, Kentucky-Tennessee, and Alabama; and from California to northern California. Refineries in Florida and Louisiana do not refine imported sugar in the base model. Cane refineries in New York and Texas and beet plants in the Great Lakes Region do not ship sugar to other states.

When production and processing capacities are increased in Models 2 and 3, the total sugar production is the same as that in the base model (Table 9). However, sugarbeet production is increased substantially with major reductions in sugarcane production. This indicates that sugarbeet production is more competitive than sugarcane production in the United States. Sugar imports in Models 2 and 3 are the same as those in the base model. The sugar industry's net profits are $1,092 million in Model 2 and $1,139 million in Model 3, which are larger than the net profits in the base model. The increases in the industry's net returns are due mainly to shifts in sugar production from high cost regions to low cost regions.

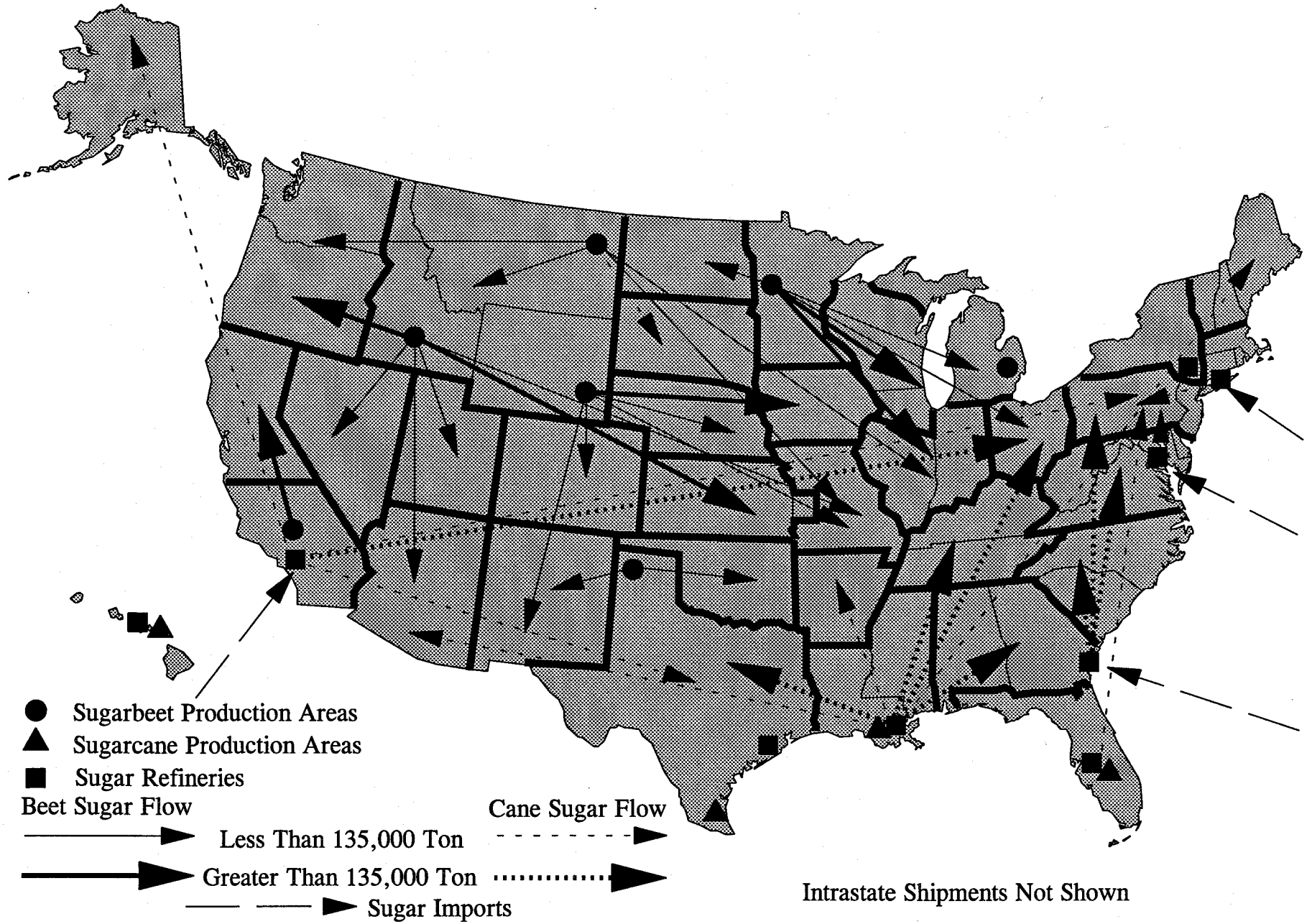


Figure 12. United States refined sugar flows

When sugar imports are increased by 20%, 50%, and 100% in Models 4, 5, and 6, respectively, domestic sugar production is decreased from 7.17 million tons to 6.88 million tons in Model 4, to 6.51 million tons in Model 5, and to 5.5 million tons in Model 6. The reductions in domestic sugar production are replaced with imported sugar. Raw sugar imports are increased from 2.45 million tons in the base model to 2.75 million tons in Model 4, to 3.15 million tons in Model 5, and to 3.91 million tons in Model 6.

While sugarcane acres are reduced substantially in Models 4, 5, and 6 compared to the base model, sugarbeet acres are reduced slightly from 1,489 thousand acres in the base model to 1,365 thousand acres in Model 6. This indicates that increases in sugar imports by relaxing the existing import quota adversely affect the sugarcane industry more than the sugarbeet industry.

The U.S. sugar industry's net profit decreases substantially from $849 million in the base model to $488 million in Model 4, to $234 million in Model 5, and to negative profit in Model 6. The reduction in the industry's net returns is mainly because imported sugar lowers sugar production in the United States and the model forces each region to produce sugar at the lower limit even though domestic price is not high enough to cover production costs in most producing regions in the United States.

With a 15% decrease in U.S. sugar price, the total sugar production remains almost the same as that in the base model. The only major changes are an increase in sugarbeet acres and a decrease in sugarcane acres. The sugar industry's net profit in Model 7 ($601 million) is smaller than that in the base model.

Under a free trade condition, by eliminating the import quotas in Model 8, domestic sugar production decreases from 7.17 million tons in the base model to 3.76 million tons, which is the minimum domestic production constraints imposed in the models. If the constraint is eliminated, domestic sugar production would be zero. This implies that domestic sugar production will be completely replaced with imported raw sugar if the U.S. government eliminates the sugar programs unilaterally. Since the imported raw sugar should be refined in the United States, all refineries in the United States operate at their full capacity. The sugar industry's net profit is negative mainly because the import prices of raw sugar are lower than the domestic production costs, and the model forces each region to produce at its minimum production constraint.

Sugarbeet and Sugarcane Production

Table 10 shows the sugar production in each region in the base and alternative models. In the base model, beet sugar production is the largest in the Red River Valley, followed by the Northwest. Cane sugar production is the largest in Florida, followed by Louisiana. Total sugar production in the United States is 7.2 million tons; production shares of beet and cane sugar production are 53% and 47% of the total sugar production, respectively, in the base

Table 10. Total Beet and Cane Sugar Production for North America in Each Producing Region

Production region	Models							
	1	2	3	4	5	6	7	8
	thousand tons							
Beet sugar								
1. Great Lakes	402.2	201.1	201.1	402.2	402.2	201.1	201.1	201.1
2. Red River V	1,379.9	1,654.7	2,068.3	1,379.9	1,379.9	1,379.9	1,654.7	689.4
3. N. Gr. Plains	236.9	284.2	355.3	236.9	236.9	236.9	284.2	181.9
4. C. Gr. Plains	340.3	408.4	510.5	340.3	340.3	340.3	408.4	176.7
5. S. Gr. Plains	115.9	57.9	57.9	115.9	115.9	57.9	57.9	57.9
6. Northwest	709.1	850.9	1,063.7	709.1	709.1	709.1	850.9	354.6
7. Calif.	578.4	694.0	603.5	578.4	578.4	578.4	694.0	320.2
8. Manitoba	36.6	37.9	37.9	37.9	37.9	37.9	37.9	37.9
9. Alberta	48.1	35.2	35.2	35.2	35.2	35.2	35.2	35.2
Total beet sugar prod.*	3,847.4	4,224.3	4,933.4	3,835.8	3,835.8	3,549.2	4224.3	2,054.9
Cane sugar								
1. Florida	1,888.0	2,251.8	1,493.3	1,888.0	1,888.0	1,454.3	2,251.8	944.0
2. Louisiana	790.9	412.3	412.3	492.5	412.3	412.3	412.3	412.3
3. Texas	1,43.6	71.8	71.8	143.6	71.8	71.8	71.8	71.8
4. Hawaii	728.9	398.5	398.5	728.9	433.4	398.5	398.5	398.5
Total cane sugar prod.**	3,551.3	3,134.4	2375.9	3,253.0	2,805.5	2,336.9	3,134.4	1,826.6
Total sugar production*	7,166.8	7,154.0	7,154.2	6,876.4	6,458.1	5,733.5	7,154.0	3,762.2

*Refined
**Raw

model. When the production capacities are increased in Models 2 and 3, the Great Lakes, Louisiana, Texas, and Hawaii reduce their production to their lower limits, while most beet sugar producing regions increase their production. This implies that, in general, beet sugar producing regions are more competitive than cane sugar producing regions. Only the Red River Valley and Northwest Regions produce sugar at their maximum capacities, indicating that these areas have the potential to increase sugar production compared to other regions under the given production conditions and policies.

Model 4, 5, and 6 increase sugar imports by 20%, 50%, and 100%, respectively. Total beet sugar production decreases slightly in Models 4, 5, and 6 compared to the base model, while cane sugar production decreases substantially in the models. This indicates that

increases in U.S. sugar imports by relaxing the import quota will hurt sugarcane producers and processors more than sugarbeet producers and processors. Louisiana production decreases by 38% in Model 4. In Model 5, sugar production in Louisiana and Texas decreases to the minimum levels. Hawaii decreases its production by 41% in Model 5. All beet sugar producing areas maintain their base production in Models 4 and 5. The Great Lakes, Southern Great Plains, Louisiana, Texas, and Hawaii produce sugar at their minimum levels. Florida's production is reduced 23%. Only the Red River Valley and Northwest Regions consistently produce sugar at their maximum capacities, indicating that these two regions are the most competitive in the United States.

As shown in Figure 13, at a market price of 26 cents/lb., all areas except Hawaii are covering production and processing costs. When the price is lowered 11% (Model 4), Louisiana, Texas, and Hawaii are not covering their costs. The situation is the same when the price is lowered 20% (Model 5). When the price is lowered 30% (Model 6), only the Red River Valley and Manitoba are covering their production and processing costs.

Model 7 decreases the U.S. sugar price by 15%. Louisiana, Texas, Hawaii, the Great Lakes, and the Southern Great Plains reduce production to their minimum levels. The Red River Valley, North and Central Great Plains, the Northwest Region, California, and Florida increase production to replace production lost by other areas.

In Model 8, all areas produce sugar at their minimum levels, indicating that domestic sugar production could be replaced with imported sugar if the U.S. government eliminates import restrictions on sugar unilaterally.

Table 11 shows the total gross value of sugar production for each producing region. As production capacities are increased, beet sugar value increases while the value of cane sugar falls. When imports are increased (Models 4, 5, and 6), the value of beet production falls 35% while cane production falls 44%.

Sugar Production at Cane Sugar Refineries

Table 12 shows the total quantity of sugar refined at the North American refineries. The refineries in the United States receive raw sugar from domestic mills and foreign sugar exporting countries, while all refineries in Canada refine raw sugar imported from other countries. Canada produces only beet sugar. Baltimore, MD; Sugarland, TX; Gramercy, LA; and Crockett, CA, are the least efficient processors mainly due to location of processing plants and transportation costs. When production capacities are increased in Models 2 and 3, total cane sugar production is reduced while beet sugar production is increased. Sugar production is decreased in Sugarland, TX, and Crockette, CA, in these models. Models 4, 5, and 6 show an increase in sugar production at refineries because of the additional raw sugar imports. Sugar production is shifted from cane sugar to beet sugar in the United States in Model 7. In Model 8, most refineries produce sugar from raw sugar imported from other countries at their maximum capacities. Domestic production of beet and cane sugar is completely replaced with imported sugar with a complete elimination of import quota in this model.

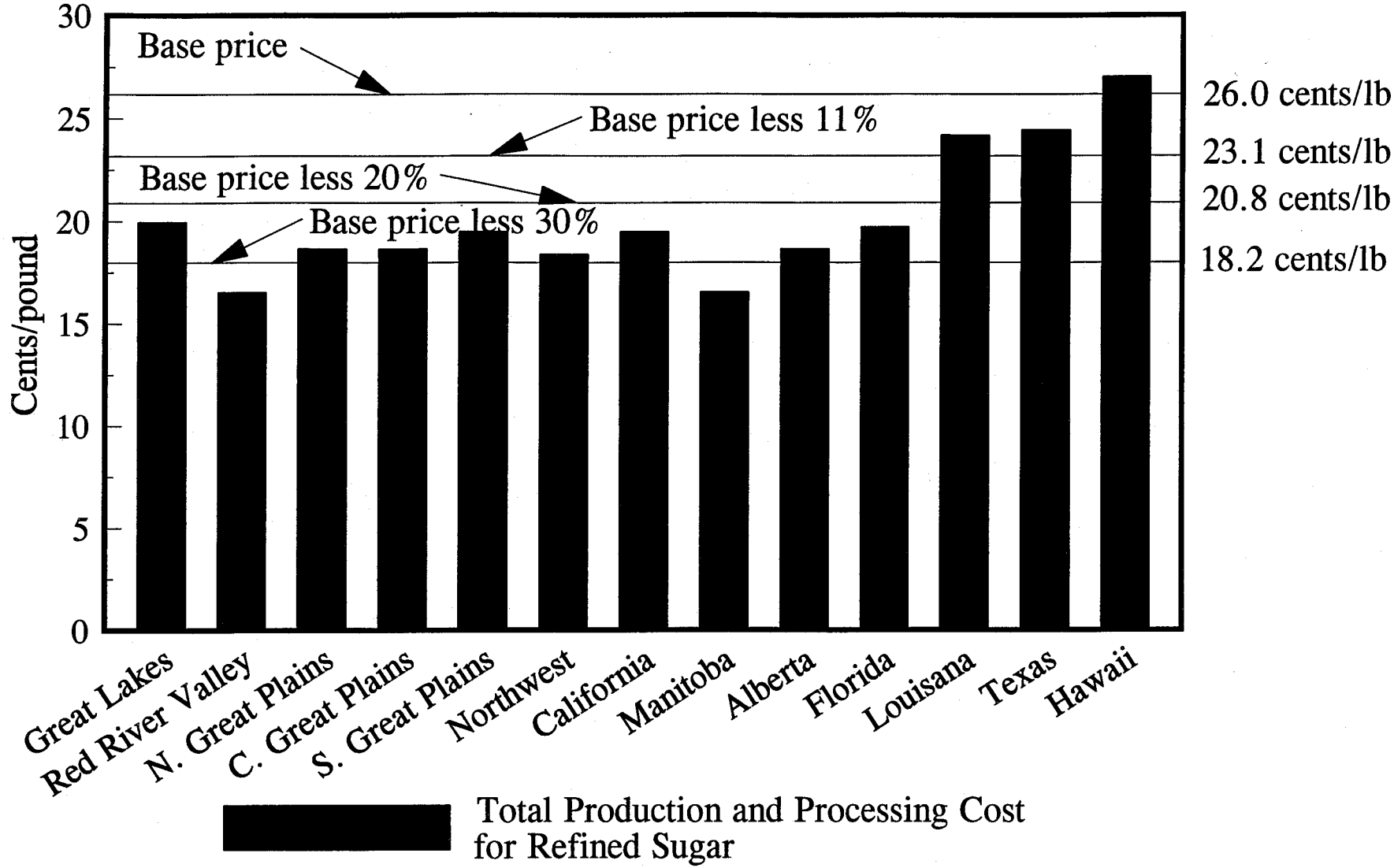


Figure 13. Break-even point for North American sugar producing regions

Table 11. Total Value of Beet and Cane Sugar Production for North America in Each Producion Region

Production region	Models							
	1	2	3	4	5	6	7	8
	million dollars							
Beet sugar								
Great Lakes	209.1	104.6	104.6	186.1	185.4	73.2	104.6	104.6
Red River V.	717.5	860.4	1075.5	638.6	636.1	492.3	860.4	358.5
N. Gr. Plains	123.2	147.8	184.8	109.6	109.2	86.2	147.8	94.6
C. Gr. Plains	177.0	212.4	265.5	157.5	156.9	123.9	212.4	91.9
S. Gr. Plains	60.3	30.1	30.1	53.6	53.4	21.1	30.1	30.1
Northwest	368.7	442.5	553.1	328.2	326.9	258.1	442.5	184.4
Calif.	300.8	360.9	313.8	267.7	266.6	210.5	360.9	166.5
Manitoba	19.0	19.7	19.7	17.5	17.5	13.8	19.7	19.7
Alberta	25.0	18.3	18.3	16.3	16.2	12.8	18.3	18.3
Total beet sugar value	2,000.6	2,196.6	2,565.4	1,775.2	1,768.3	1,291.9	2,196.6	1,068.5
Cane sugar								
Florida	917.7	1,094.5	725.8	816.7	813.5	494.8	1,094.5	458.8
Louisiana	384.4	200.4	200.4	213.0	177.7	140.3	200.4	200.4
Texas	69.8	34.9	34.9	62.1	30.9	24.4	34.9	34.9
Hawaii	354.3	193.7	193.7	315.3	186.8	135.6	193.7	193.7
Total cane sugar value	1,726.1	1,523.5	1,154.8	1,407.2	1,208.9	795.1	1,523.5	887.8
Total sugar value	3,726.8	3,720.1	3,720.2	3,182.4	2,977.2	2,087.0	3,720.1	1,956.4

Table 12. Total Sugar Production at North American Refineries

Production region	Models							
	1	2	3	4	5	6	7	8
	thousand tons							
Yonkers, NY	594.0	594.0	594.0	594.0	594.0	594.0	594.0	594.0
Brooklyn, NY	660.0	660.0	660.0	660.0	660.0	660.0	660.0	660.0
Baltimore, MD	3.2	3.2	3.2	3.2	3.2	238.2	3.2	973.5
Port Wentworth	990.0	990.0	990.0	990.0	990.0	990.0	990.0	990.0
South Bay, FL	239.3	239.3	239.3	239.3	239.3	239.3	239.3	239.3
Clewiston, FL	264.0	264.0	264.0	264.0	264.0	264.0	264.0	264.0
Chalmette, LA	761.3	651.4	380.5	761.3	940.5	940.5	651.4	940.5
Gramercy, LA	264.0	93.9	264.0	264.0	264.0	264.0	93.9	264.0
Donaldsonville	394.8	660.0	22.0	394.8	582.9	660.0	660.0	660.0
Sugarland, TX	143.6	71.8	71.8	143.6	71.8	71.8	71.8	643.5
Crockette, CA	662.9	332.5	332.5	662.9	367.4	332.5	332.5	652.7
Aiea, HI	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0
St. John, NB	282.8	282.8	282.8	282.8	282.8	282.8	282.8	282.8
Montreal, QU	212.2	212.2	212.2	212.2	212.2	212.2	212.2	212.2
Toronto, OT	236.9	236.9	236.9	236.9	236.9	236.9	236.9	236.9
Vancouver, BC	227.0	227.0	227.0	227.0	227.0	227.0	227.0	227.0
Total sugar production	6,002.0	5,585.0	4,846.2	6,002.0	6,002.0	6,279.2	5,585.0	7,906.4

Regional Competitiveness in Sugar Production

The concept of marginal returns on the land used for sugarbeet or sugarcane production is used to evaluate competitiveness of each producing region in the base and alternative models. The marginal returns (Table 13) are positive in the Red River Valley, Great Lakes, Southern Great Plains, and the Northwest Regions for sugarbeet production and Florida and Texas for cane sugar production in the base model. This indicates that these regions have comparative advantage over other regions in producing sugarbeet and sugarcane under current production conditions and the government policies. The marginal returns on land for sugar production in the Southern Great Plains and the Northwest Regions are larger than in the Red River Valley, indicating that these two regions have greater potential to increase beet production under given production conditions. Sugar production in the two regions is smaller than in the Red River Valley.

Table 13. Marginal Returns in Each Beet and Cane Sugar Producion Region, 1992

Production region	Models							
	1	2	3	4	5	6	7	8
	U.S. dollars							
Beet sugar regions								
1. Great Lakes	498.37	0.00	0.00	498.37	0.83	0.00	0.00	0.00
2. Red River V.	954.38	117.83	90.31	954.38	401.81	94.06	123.09	0.00
3. N.Gr. Plains	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. C.Gr. Plains	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5. S.Gr. Plains	1,047.60	0.00	0.00	1,047.60	347.10	0.00	0.00	0.00
6. Northwest	1,414.95	251.64	219.64	1,414.95	650.51	224.76	279.62	0.00
7. California	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8. Manitoba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9. Alberta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cane sugar regions								
1. Florida	1,403.77	0.00	0.00	1,403.77	483.34	0.00	0.00	0.00
2. Louisiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. Texas	711.80	0.00	0.00	711.80	0.00	0.00	0.00	0.00
4. Hawaii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

When capacity for sugar production is increased in Models 2 and 3, the marginal returns on land are positive in only the Red River Valley and Northwest Regions, indicating that these two regions have economic potential to increase beet production further after expanding production by 50%. The Southern Great Plains are no longer competitive with a 20% increase in production capacity. The marginal value in the Northwest Region is larger than that in the Red River Valley in Models 2 and 3, indicating that the Northwest Region is more competitive than the Red River Valley under the given production capacities.

When the U.S. sugar import quota is increased by 20% in Model 4, the marginal returns in Model 4 are the same as those in the base model. However, the U.S. import quota is increased by 100% in Model 6, only the Red River Valley and Northwest Regions are competitive in sugar production. With a 15% decrease in U.S. sugar price in Model 7, the marginal returns are all zero except for the Red River Valley and the Northwest Regions, indicating that only these two regions can compete with imported sugar. The marginal returns are all zero in Model 8, indicating that none of the current sugar producing regions are competitive under a free market condition.

Summary and Conclusions

This study analyzed the impacts of existing and alternative sugar programs and trade policies on the U.S. sugar industry and the competitiveness of the Red River Valley sugar industry.

The method used for this study was a spatial equilibrium model based on a mathematical programming algorithm. Sugar was divided into cane and beet sugar to incorporate unique characteristics in producing cane and beet sugar. In the model, the United States was divided into 11 producing regions and 36 consuming regions based on 5 distribution centers. The model also included 7 processing plants for sugarbeets, 4 processing plants (mills) for sugarcane, and 16 raw sugar refineries. The objective function of the model was to maximize net returns generated by the North American sugar industry through sugarbeet and sugarcane production, processing, distribution, and imports. This objective function is optimized subject to a system of linear constraints associated with production, processing, distribution, and import activities.

Total amount of sugar produced in the United States is 7.17 million tons in the base model: 3.85 million tons for beet sugar and 3.32 million tons for cane sugar. In general, beet sugar production is more competitive than cane sugar production in the United States. Some cane sugar production is replaced with beet sugar production as producing regions are allowed to increase their production and processing capacities. The Red River Valley and Northwest Regions produce sugar at their maximum capacities with the increases in production capacities.

The industry's net returns are higher with increased production capacities (Models 2 and 3) than in the base model mainly because sugar production shifts from high cost regions to low cost regions. This implies that allowing producing regions to increase their production capacities would make the industry more competitive. This would be especially true in the Red River Valley and Northwest Regions where they produce sugar at their maximum capacities after increasing capacities by 50%. This study indicates that the Red River Valley and the Northwest Regions should increase their production 50% to maximize their net profit.

When the U.S. government increases imports by relaxing the sugar import quota, the U.S. cane sugar industry is affected more than the U.S. beet sugar industry. In fact, 20% and 50% increases in sugar imports do not affect total beet sugar production in the United States. A 100% increase in sugar imports reduces beet sugar production slightly. However, cane sugar production is substantially reduced with increases in sugar imports. This implies that increases in sugar imports by relaxing the existing import quotas adversely affect the cane sugar industry more than the beet sugar industry. However, cane sugar refineries operate at near capacities to refine raw sugar imported from foreign countries. The study also indicates that the industry's net revenue reduces substantially with increases in imports.

Domestic sugar production will be completely replaced with imported raw sugar if the U.S. government unilaterally eliminates the sugar programs. However, cane sugar refineries operate at their full capacities since raw sugar imported should be refined in the facilities. All producing regions produce sugarbeet and sugarcane at their minimum levels, indicating none of these regions produce sugar under the free trade condition.

The Red River Valley and the Northwest Regions are the most competitive in producing sugarbeets, and Florida is the most competitive in producing sugarcane. Among these regions, the Red River Valley and the Northwest Regions are more competitive than Florida. The Red River Valley and the Northwest Regions have potentials to increase their sugar production if acreage restrictions are eliminated in producing sugarbeet and sugarcane.

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