The Cost of the U.S. Sugar Program Revisited

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Abstract

We revisit the cost of the U.S. sugar program by analyzing the welfare implications of its removal. We use a multimarket model of U.S. sweetener markets, which includes raw crops, sugar extraction and refining, high-fructose corn syrup, and sweetener users (food-processing industries and final consumers). Our approach addresses the industrial organization of food industries using sweeteners and treats the United States as a large importer. We estimate that, with the removal of the program, cane growers, sugar beet growers, and beet processors would lose $307 million, $650 million, and $89 million (1999 prices), respectively. Sweetener users would gain $1.9 billion (1999 prices). The deadweight loss of the current sugar program is estimated at $532 million (1999 prices). World prices would increase by 13.2 percent with the removal of the program.

JEL Classification: Q18, Q17, F13.

Key words: Sugar program, sweetener, trade, agricultural policy.

THE COST OF THE U.S. SUGAR PROGRAM REVISTED

Introduction

The sugar program has used farm commodity and trade policy instruments to maintain domestic sugar prices at levels that exceed world prices without requiring the government to buy large quantities of domestic sugar in most years.[1] Our paper analyzes the effects of eliminating the sugar program on prices, production, and welfare using a multimarket model of the domestic and world sweetener markets. We estimate the economic welfare effects of the program by gauging welfare losses and gains resulting from the elimination of the sugar program as an estimate of the gains (losses) accruing to each group potentially affected by the presence of the program. Our analysis includes the U.S. markets for sugar beet and sugarcane production, corn and high-fructose corn syrup (HFCS) production, sugar refining, food processing, and the final consumption of sugar and food products containing sweeteners. We imbed this domestic model into a world sugar model to estimate the impact of the U.S. sugar program on world prices of sugar. In addition, we estimate the net loss to the U.S. economy (economic welfare gains minus losses) resulting from artificially high sweetener prices. This net loss includes economic inefficiencies (deadweight losses) and economic rent transfers to foreign sugar exporters.

Our analysis deals explicitly with three issues that often have been raised in the context of U.S. sugar policy but never addressed simultaneously in previous work (Sumner 1999; USGAO 1993; CRS). First is the recognition that the United States is a large country in the world sugar market and that U.S. policy changes affect the import price of sugar. Second is a focus on the linkage between sugar market prices and prices paid by the consumer for goods containing sugar. The price of sugar influences the cost and price of sweetener-intensive food items and creates a pass-through effect of the sugar program on processed food to consumers. Third is the inclusion of imperfect competition and profit margin considerations in food processing. The presence of a profit markup influences the extent of the pass-through of sweetener costs to consumers and therefore the distribution and size of the welfare gains from removing the sugar program.

We estimate that with the removal of the program, U.S. cane growers, sugar beet growers, and beet processors would lose about $307 million, $650 million, and $89 million (1999 prices), respectively. Sweetener users would gain about $1.9 billion (1999 prices). The deadweight loss of the current sugar program is estimated at around $532 million (1999 prices). World sugar prices would increase by 13.2 percent with the removal of the U.S. sugar program. The magnitude of these aggregate gains is insensitive to changes in assumptions regarding the industrial organization of the food industry, the extent of price pass-through, and the time horizon considered. However, these assumptions affect the distribution of gains within sweetener users (food industry, final consumers). We elaborate on this point later in the paper.

Several motivations underlie our investigation. First, the divergence of interests between the domestic coalition of sugar crop growers and raw cane processors on one side and cane refiners and food processors on the other has been rapidly widening with the recent increasing disparity between domestic and world raw cane prices. Second, the U.S. sugar program is a disproportionate contributor to the aggregate measure of support (AMS) monitored by the World Trade Organization (WTO) under the Uruguay Round Agreement on Agriculture. Among U.S. farmers, sugar producers received the highest policy transfer (in percentage of crop value) for the policies falling under the scrutiny of the WTO in the so-called amber box. The 1998-2000 average AMS for sugar was equal to 50 percent of crop value, compared to an average of 7 percent for all crops during this period (Hart and Babcock). The new round of WTO negotiations and the domestic policy debate regarding the 2002 farm bill have just started. The two policies are now more interdependent than ever because of increased WTO pressures to lower agricultural support levels through trade-distorting policies (Sumner 2000). Hence, it is propitious to revisit the social cost of such large transfers and distortions in the double context of the changing political economy of the sugar program and the ongoing debates on farm and trade policy reforms.

The U.S. sugar program has been repeatedly analyzed over the years, not only because it has evolved but also because it somehow resisted trade liberalization and has become one of the last bastions of protectionism in U.S. agriculture. Examples of recent analyses of distortions in the U.S. and world sugar markets include Sheales et al.; Wohlgenant; Haley; and Boyd, Doroodian, and Power. These studies combine various degrees of sophistication in their assessment of the U.S. sugar program and its impact on world markets and in their treatment of sweetener demand by food processing and final consumers. Our comprehensive approach is a novel and useful complement to these previous studies.

In the next sections, we first provide a description of the U.S. sugar program and the policy scenario considered. Then we provide an overview of our modeling approach. Results and conclusions complete the paper. A first appendix provides a detailed discussion of the underpinnings of our U.S. sugar model, including the approach used to estimate welfare gains and losses for participants in the various affected markets. This appendix also describes the data and data sources used in our analysis. A second appendix provides a description of the world sugar model used to assess the impact of the U.S. sugar program on world markets.

Description of the U.S. Sugar Program

The sugar program functions as a price floor mechanism by guaranteeing sugar producers a minimum price by offering sugar processors loans at a rate established by law, which is shared with beet and cane farmers. This system of price support is made possible by tight trade barriers imposed on imports of sugar via a set of bilateral tariff rate quotas (TRQ) managed by the United States Department of Agriculture (USDA). The out-of-quota imports are taxed at a prohibitive tariff rate, which precludes importing more than the TRQ. For most years, imports are managed, such that the U.S. market prices of raw cane sugar and beet sugar remain above the loan rate level, so USDA does not have to buy up sugar forfeited under the loan program in most years (USGAO 1999). In 2000, however, out-of-quota sugar imports originating in Mexico combined with a large domestic supply led to sugar forfeitures of about 800,000 short tons (CRS). WTO commitments constrain USDA’s efforts to tighten sugar imports, and forfeitures should occur whenever domestic supply is large. The U.S. sugar industry is vigorously challenging Mexican imports (USDA; Buzzanell).

The Federal Agriculture Improvement and Reform Act of 1996—the 1996 farm bill—modified the sugar program without fundamentally decreasing the support received by sugar growers. The changes were to (1) legislatively establish USDA's loan rate at 18¢ per pound for raw cane sugar and 22.9¢ per pound for refined beet sugar, (2) assess a 1¢ penalty on each pound for raw cane sugar and a 1.07¢ penalty on each pound of refined beet sugar forfeited to the government, (3) eliminate a requirement that the sugar program operate at no net cost to the taxpayer, (4) limit processors' opportunities to forfeit sugar to the Commodity Credit Corporation (CCC) by not allowing forfeitures if the TRQ is 1.5 million tons or less, (5) eliminate USDA's authority to impose marketing allotments for sugar, and (6) increase the assessment on processors to 0.2475¢ per pound for raw cane sugar and 0.2654¢ per pound for beet sugar (USGAO 2000). The latter measure was suspended for fiscal year 2000/2001, saving the producing industry about $83 million (CRS).

Provisions of the 1996 farm bill also require USDA to annually establish a TRQ import level. When the TRQ level is at or below 1.5 million tons, loans made through the CCC are recourse in nature. Congress repealed this authority to make recourse loans in its 2001 agriculture appropriation measures (CRS). For years when the TRQ is set above 1.5 million tons, loans made to the CCC are nonrecourse in nature. The nonrecourse nature of the loan provides processors the option of forfeiting the sugar pledged on their CCC loan instead of repayment. This option becomes important to processors if domestic sugar prices drop below USDA's loan rate plus transportation and interest costs but minus the 1¢-per-pound penalty (USGAO 2000).

Policy Reform Scenario

The policy scenario for this analysis removes the TRQs for imported raw and refined sugar and USDA's loan program for sugar processors that supports the price of domestic sugar (see Moschini for a discussion of the economics of the TRQ). Figure 1 shows the effects of removing both the raw sugar TRQ and USDA's loan program. The first panel, (a), represents the domestic raw sugar market, while the second panel, (b), represents the world raw sugar market.

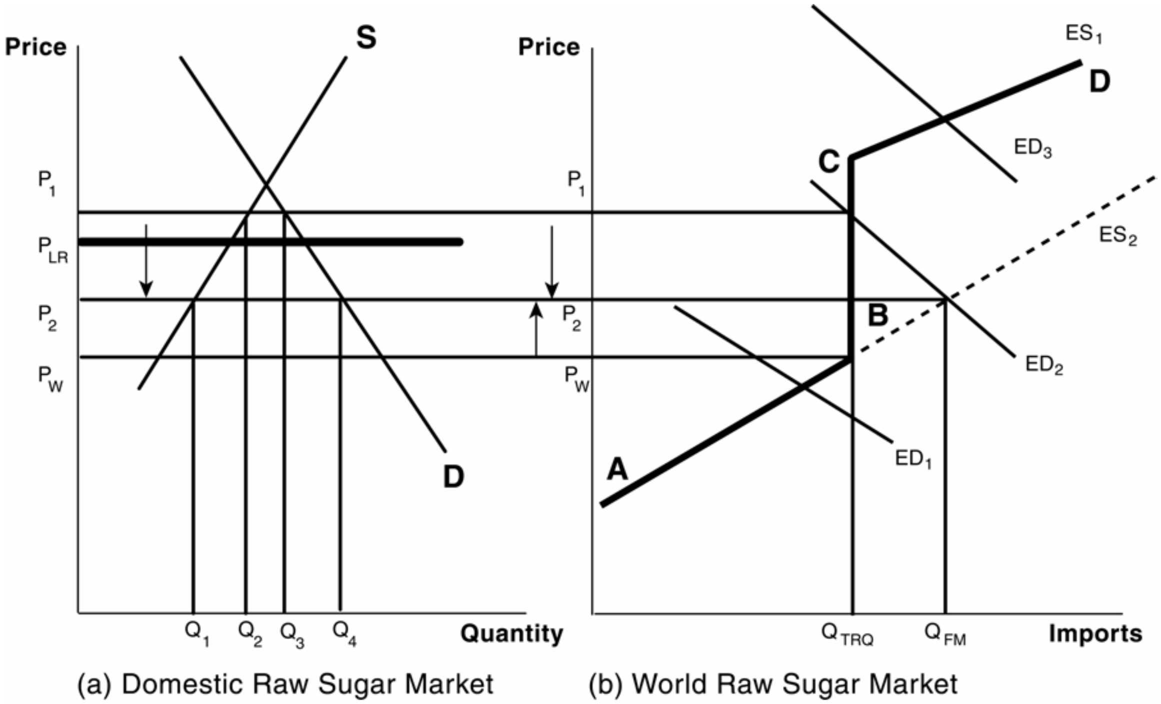

FIGURE 1. Effects of removing the TRQ and USDA's loan program on U.S. prices and quantities of raw sugar

In panel (b), we show two world excess supply situations, ES_1 and ES_2, corresponding to different trade scenarios. In the presence of a TRQ, the United States faces a kinked world excess supply function, as in the bold line ABCD on ES_1. The vertical line segment BC on ES_1 represents the level of the TRQ, below and beyond which there is a supply response to price by foreign exporters. Moreover, below the level of the quota, Q_{TRQ}, the in-quota tariff applies, and beyond that level, the out-of-quota tariff applies. The excess supply curve ES_2 corresponds to the world excess supply in the absence of import restrictions in the United States.

The effect of the TRQ on U.S. imports and prices depends on the location of the U.S. excess demand for imports relative to the excess supply. In panel (b), we display three potential U.S. import demand situations, ED_1, ED_2, and ED_3. The excess demand curve ED_1 represents the import demand below the level of the TRQ, while the excess demand curve ED_3 represents the import demand above the level of the TRQ. At excess demand ED_2, the TRQ is binding. Price and quantity reach equilibrium at the intersection of the

U.S. excess demand curve ED_2 and the kinked excess supply curve ES_1 on its vertical segment BC. With the removal of the TRQ, increased world imports of raw cane sugar drive down domestic prices. At the same import demand, this situation corresponds to a new equilibrium level: the point where ED_2 intersects ES_2, the excess supply curve without import restrictions in the United States, with increased import demand of Q_{FM}.

Because of USDA's loan program for sugar processors, however, domestic prices would still not be free to drop to the world price level. Under the loan program, producers would still be eligible to forfeit their sugar to the government and receive the loan rate, P_{LR}. The loan rate mechanism provides a price floor for domestic sugar producers, maintaining sugar prices at the loan level, P_{LR}, as in panel (a). However, with the simultaneous elimination of the TRQ and the sugar loan program, the domestic sugar price is free to fall below the loan rate level. In panel (b) of Figure 1, this situation corresponds to a new price and trade equilibrium level. In the domestic market in panel (a), this corresponds to imports increasing from Q_2Q_3, the original quota Q_{TRQ} in panel (b), to Q_1Q_4, or Q_{FM} in panel (b). These increased imports lead to a drop in the domestic price from P_1 to P_2. However, P_2 is higher than the original world price of P_W.

Similarly, we remove the TRQ for imported refined, or "white," sugar. World trade in refined sugar has increased because of policies in the European Community, the entry of toll refiners,[2] and a decrease in freight and refining costs. In general, removing the TRQ for refined sugar would have the same effect as removing the TRQ for raw sugar: the U.S. price for refined sugar would decrease with an increase in the demand for refined sugar imports. A lower U.S. refined sugar price would then cause a decrease in the quantity of domestic refined sugar supplied and a subsequent decline in the demand for domestic raw sugar.

Overview of the Modeling Approach

Our approach to quantifying the welfare gains and losses from the U.S. sugar program uses the following steps. First, we simulate the elimination of the program to determine price and production responses in both domestic and international sugar markets. This simulation involves specifying complete U.S. and world sweetener models in the presence of the U.S. sugar TRQ and commodity loan program. To do this, we used an international sugar model developed by the Center for Agricultural and Rural Development (CARD) at Iowa State University (see Appendix 2), which, for the purpose of this analysis, contains an added multimarket module of the U.S. domestic sweetener economy as one of its component countries. The multimarket domestic sweetener model includes such markets as corn, sugar crops, raw and refined sugar, food processing, and HFCS. Appendix 1 presents this U.S. domestic model in detail.

In the U.S. domestic model, we simulate the sugar program's elimination by removing the two TRQs and allowing more domestic demand to be satisfied by lower-priced world imports. Simultaneously, as the U.S. demand for sugar increases, the world sugar prices rise somewhat. We also remove USDA's loan program for sugar processors and allow the domestic market prices of sugar to fall below the loan rate levels. After these program changes, U.S. domestic raw and refined sugar prices reach world price levels by arbitrage and abstracting from transportation cost.

On the supply side of the domestic market, we use the domestic component of the CARD international sugar model to estimate the welfare changes due to the change in the price of sugar. The new U.S. raw sugar price filters through the domestic U.S. sugarcane and sugar beet markets, lowering the price of all these products and leading to new production quantities. By arbitrage, the new domestic refined sugar price determines how much of the refined sugar use will be sourced domestically or imported. The allocation of domestic production between beet processors and raw cane sugar refiners is determined by equating their new marginal cost to the new refined sugar price. In food processing sectors using sweeteners, the relative price of the HFCS and sugar sweetener has changed. These sectors adjust their sweetener mix accordingly. This adjustment feeds back into the HFCS and corn market.

For each of these producing industries, we measure the changes in realized profits that would result from a change in the quantity demanded and/or the price if the sugar program were eliminated. Within the domestic sweetener model, we estimate welfare changes for a comprehensive demand sector, including sugar processors and refiners, sweetener-using industries, and the final consumer. We estimate the changes in realized profits resulting from higher sweetener prices for sweetener-using food industries, at the four-digit Standard Industrial Classification (SIC) level. We specify the marginal cost of production of these industries as well as their derived demand for sweeteners. We calibrate the marginal cost and derived demand by assuming they use an initial markup (price-marginal cost) of 20 percent to price their goods.

As part of this analysis, we consider two polar assumptions about the market power of these industries: full retention of cost savings by sugar-using food industries, and full pass-through of cost savings to consumers. Furthermore, we assume that consumers would be affected by the sugar program's elimination through the change in the prices of both the refined sugar and the food items purchased containing a significant amount of sweetener. We apply an incomplete demand system approach to sweetener-intensive food and sugar consumption based on LaFrance (LINQUAD[3]) and LaFrance et al. and use an exact welfare measure (equivalent variation)[4] to estimate these changes in consumers' expenditures.

In the first polar case, consumers' welfare increases because of lower retail sugar prices but prices for other food goods remain unchanged. The food industry, by increasing its markup, is the major beneficiary from the reform and absorbs the cost savings. This is the most pessimistic outcome often argued by the sugar lobby. In the second and opposite case, consumers benefit from lower food prices in addition to the lower retail sugar price. Food processors keep their initial markup but pass on to consumers the decrease in marginal cost induced by lower refined sugar prices. This is the most optimistic outcome.

Finally, we aggregate all welfare gains and losses from these groups to estimate the welfare loss (gain) experienced from eliminating the sugar program as an estimate of the gain (loss) accruing to each group from the presence of the program. The difference between welfare gains and losses is the net loss to the U.S. economy, which consists of transfers to foreign producers that result from artificially high prices for the raw sugar exported to the United States, and economic inefficiencies (pure efficiency losses). These inefficiencies result from the use of higher-cost domestic resources to produce sweeteners (instead of importing lower-cost sugar) and reduced total sugar consumption.

The model is calibrated to 1996 and 1998 data, the most recent available data on sweetener use in the U.S. food industry. We explain the calibration of the model in the appendices. One possible limitation of our model is that a more general equilibrium approach of the entire agricultural sector may have been able to give us more long-run effects by, for example, identifying what alternative crops would be produced in the absence of the program or how many producers would leave the industry entirely. However, general equilibrium models take a more broad-based approach, often leaving out important market details (see Boyd, Doroodian, and Power for an example of such a trade-off). Our approach is designed to represent a compromise between capturing the most important sweetener market relationships with the available data and keeping the model itself tractable.

Results

We compare the actual domestic and world prices for sugar, HFCS, and other sweeteners with the estimated domestic and world prices if the sugar program were eliminated. Both the estimated costs of the sugar program to sweetener users and the estimated benefits to sugar beet and sugarcane producers were higher in 1998 when the difference between the domestic and world prices for sugar was greater.

As shown in Table 1, our findings suggest that the sugar program cost domestic sweetener users–sugarcane refiners, food manufacturers, and final consumers–about $1.5 billion in 1996 and about $1.9 billion in 1998. We find that the total welfare gains by domestic sugar beet and sugarcane producers were about $788 million in 1996 and about $1 billion in 1998. Approximately 70 percent of these benefits went to sugar beet growers and processors, while the remaining 30 percent went to sugarcane producers.

We also find that HFCS producers did not receive welfare gains from the sugar program in either 1996 or 1998 primarily because the possibilities for substitution between sugar and HFCS are more limited now than they were in the early 1980s. The decreased substitution among sweeteners arises because technological advances have improved the HFCS products and created more specialized sweetener markets (Evans and Davis). Thus, HFCS producers would not need to lower their price (move along their

TABLE 1. Welfare gains and losses from the sugar program, 1996 and 1998 (1999 million dollars)

Category	1996	1998
Welfare gains accruing to producers	$788	$1,045
Sugarcane producers	241	307
Sugar beet growers	490	650
Sugar beet processors	58	89
HFCS manufacturers and corn growers	(1)	(1)
Welfare losses accruing to sweetener users	(1,471)	(1,938)
Net loss to the U.S. economy	(683)	(893)
Economic inefficiencies	(273)	(532)
Transfers to foreign suppliers	(410)	(361)

Note: Numbers in parentheses are economic losses. Full pass-through is assumed.

marginal cost curve) further to remain competitive if the sugar program were eliminated.[5] Therefore, the sugar program marginally affects corn producers. This finding on HFCS and corn is consistent with the earlier assessment of Rendleman and Hertel.

Our investigation shows that the sugar program resulted in net losses to the U.S. economy of about $683 million in 1996 and $893 million in 1998 because total welfare losses exceeded gains. These net losses included (1) production and consumption inefficiencies of $273 million in 1996 and $532 million in 1998 and (2) transfers of $410 million in 1996 and $361 million in 1998 to foreign countries allocated a portion of the tariff rate quota (TRQ) for sugar imports to the United States.

The distribution of the welfare losses resulting from the sugar program among the sweetener user groups depends on assumptions about the extent to which refiners' and manufacturers' cost reductions from eliminating the sugar program would be passed on to consumers. If the sugar program were eliminated, consumers would evidently benefit. However, it is difficult to predict the extent to or speed with which intermediate users of sweeteners would pass through lower sugar costs to final consumers.

Table 2 presents two estimates of how the benefits of eliminating the sugar program might be distributed based on the two polar cases discussed previously. The first set of estimates assumes that competition induces sugar refiners to pass cost reductions on to

TABLE 2. Estimated distribution among user groups of benefits of eliminating the sugar program under different pass-through assumptions, 1996 and 1998 (1999 million dollars)

Category	1996		1998	
Distribution of Benefits	**Partial Pass-through**	**Full Pass-through**	**Partial Pass-through**	**Full Pass-through**
Final consumers	$587	$1,434	$769	$1,960
Food manufacturers	715	(60)	999	(85)
Sugarcane refiners	95	97	61	63
Total	$1,397	$1,471	$1,829	$1,938

Note: The partial pass-through results represent a full pass-through by sugar refiners to food processors and no pass-through by food processors to consumers. The full pass-through results assume all cost reductions are passed through to final consumers. Numbers in parentheses are economic losses.

final consumers in the form of lower prices for table sugar, but that manufacturers of sugar-containing foods would retain their cost savings. Under this "partial pass-through" assumption, final consumers would have gained about $587 million using 1996 data and about $769 million using 1998 data if the sugar program had been eliminated. Dead-weight losses would be reduced by $416 million as compared to $532 million under full pass-through in 1998.

Total welfare gains from eliminating the sugar program would have been about $1.4 billion in 1996 and $1.8 billion in 1998 if only sugarcane refiners had passed cost reductions through to consumers. Our different pass-through assumptions result in slightly different estimates of the total gains to sweetener users if the sugar program were eliminated, primarily because consumers would increase their consumption of cheaper sweetener-intensive foods, hence reducing deadweight losses further under the full pass-through case. The assumption of price discipline in the refined sugar market is motivated by the homogeneous nature of white sugar. In contrast, when products are highly differentiated, as many sweetener-containing food products are, firms may use nonprice forms of competition, such as greater advertising.

The second set of estimates based on the "full pass-through" assumption yields an upper-bound estimate of the potential benefits to consumers. Under this assumption, we estimate that the benefits to final consumers of eliminating the sugar program would have been about $1.5 billion using 1996 data and about $1.9 billion using 1998 data.

Table 3 compares actual sugar prices and production in 1996 and 1998 with our simulation results, which assume the termination of the sugar program. In particular, our results show that if the sugar program had been eliminated, the domestic price of raw sugar would have dropped from about 22¢ per pound to about 14.9¢ per pound in 1996 and to about 12.5¢ per pound in 1998, with comparable declines in the wholesale price of domestic refined sugar. Still based on our simulations, raw sugar imports would have increased by 1.1 million tons in 1996 and by 1.6 million tons in 1998 if the sugar program had been eliminated, reflecting both the increased domestic demand for sugar and the decreased domestic production of sugar beets and sugarcane.

TABLE 3. Estimated effect of eliminating the sugar program on prices and production

	1996		**1998**	
	Actual	**Without the Sugar Program**	**Actual**	**Without the Sugar Program**
U.S. raw sugar price	22.40	14.91	22.06	12.46
World raw sugar price [a]	12.24	13.41	9.68	10.96
U.S. wholesale refined sugar price	29.20	21.77	26.12	16.12
World wholesale refined sugar price [b]	16.64	19.77	11.59	14.12
Sugarcane				
Acres harvested[c]	953,700	941,300	931,500	916,200
Production	29.1	28.7	30.0	29.5
Sugar beets				
Acres harvested[c]	1,420,100	1,350,300	1,428,300	1,338,600
Production	28.1	26.7	29.9	28.0
Raw sugar imports	2.2	3.3	1.7	3.3

Note: Price is in cents per pound and production and imports are in millions of short tons (raw value).
[a]The world price for raw sugar is based on a Caribbean location. As compared with the U.S. price, the world price does not include 1.5¢ per pound in cost to transport the sugar to New York.
[b]As compared with the U.S. price, the world price for refined sugar does not include 2¢ per pound in cost for transportation.
[c]Acreage harvested during the previous crop year.

The previous results pertain to the short run, to the extent that the elasticities used in the model reflect short-term rigidities in agricultural supply both in the United States and in the rest of the world. Table 4 presents our estimates of the welfare changes that would have resulted from eliminating the sugar program in 1998, using larger supply elasticities than the ones we used to obtain our primary estimates to simulate shorter-term changes. Supply elasticity estimates are arc elasticities evaluated for 1998 between historical and post-reform values. In particular for the U.S. market, our short-run domestic supply elasticities were 0.05 for sugarcane and 0.10 for sugar beets, and our short-run import supply elasticity was 7.26, reflecting rigidities in foreign agriculture supply. The latter is an excess supply from the rest of world faced by the United States, which explains the seemingly large magnitude.

To obtain longer-run welfare estimates, we used a double Nerlovian domestic supply response with supply elasticities of 0.20 for cane and 0.26 for sugar beets and an import supply elasticity of 10.17. The results from this second set of simulations can be interpreted as the welfare gains and losses after more time has passed for the economy to adjust to the lower sugar prices that would result from eliminating the sugar program.

TABLE 4. Long-term welfare effects of eliminating the sugar program (1998 data)

Category	Gain or (loss) (million dollars)
Producers' losses	($1,017)
Sugarcane producers	(301)
Sugar beet growers	(530)
Sugar beet processors	(187)
HFCS manufacturers and corn growers	1
Gains to sweetener users	1,947
Final consumer	1,953
Food manufacturers	(84)
Sugarcane refiners	78
Deadweight loss	572
Transfers to foreign suppliers	358
Net gain to the U.S. economy	$930

Note: These results assume a doubling of supply responses in agriculture and a full pass-through of program costs to final consumers. Numbers in parentheses are economic losses.

The long-term net gain from eliminating the sugar program might be higher—$930 million compared with $893 million and with deadweight loss increasing from $532 to $572 million. This implies that the net loss to the U.S. economy from maintaining the program may be similarly larger in the longer term because the actual sugar price with the program would be compared with the price after fuller adjustments had been made. The increase in world prices is moderate relative to the short-term impact of the policy reform. The raw sugar price increases by 12.5 percent on the world market although U.S. imports of raw sugar increase dramatically to 3.8 million short tons, decreasing domestic production of crops and raw sugar but boosting the domestic production of refined cane sugar based on imported raw sugar.

Conclusions

Using a multimarket approach we assessed the welfare cost of the U.S. sugar program by investigating the impact of its removal, accounting for endogenous world sugar prices, the pass-through of lower sugar prices in refining to food processing and eventually to consumers, and the industrial organization of the food industry, which could limit the pass-through of cost savings.

We found that with the removal of the program, cane growers, sugar beet growers, and beet processors would lose rents of about $1 billion (1999 prices), with the largest losses occurring in agriculture. Sweetener users would gain about $1.9 billion (1999 prices). The deadweight loss or the social cost of the current sugar program was estimated at around $532 million (1999 prices). World prices would increase by 13.2 percent with the removal of the program. These findings are quite robust to changes in assumption regarding the extent of sugar price pass-through to food retail prices. However, the distribution of gains is influenced by whether full pass-through exists (major gains to final consumers) or does not exist (major gains to food processors).

Our findings are well within the ballpark of welfare impacts found in previous studies, which had a less comprehensive approach to sweetener demand and abstracted from pass-through issues in food processing (Wohlgenant; Sheales et al.). For example, Wohlgenant finds a 10 percent increase in world price resulting from a trade policy reform liberalizing sugar trade in developed countries. Sheales et al. found that removing the U.S. sugar program would lift world prices by about 17 percent and induce a net U.S. welfare gain of $452 million, saving U.S. consumers about $1.6 billion per year (1998-99 dollars).

Our finding that corn producers have become marginal stakeholders in the sugar program resonates an earlier finding by Rendleman and Hertel. In our paper, the small gains/losses to corn growers hinge on the recent evolution in sweetener technology in food processing. The substitution between sugar and HFCS has decreased as sweetener use has become more specialized by food item. This finding is in contrast to Gardner, who found that the ethanol program could raise corn growers' welfare considerably. Gardner's analysis looked at a different policy (the ethanol subsidy) and, in addition, was based on a different modeling approach than ours and used earlier data. The two results provide an interesting contrast and show how different distortions in related markets affect the corn market differently.

Endnotes

1. Large quantities of sugar were forfeited to the government in 2000 because of large imports from Mexico and larger-than-expected domestic supply.

2. Toll refiners export refined sugar processed from imported raw sugar. See Poonyth et al. for a recent analysis of EU sugar policies.

3. The LINQUAD is a functional form within the incomplete demand system approach that provides a practical model for estimation that reflects theoretically sound preference ordering. In particular, the LINQUAD quasi-expenditure function produces demand functions that are linear in deflated income and linear and quadratic in deflated prices.

4. Equivalent variation (EV) is the amount of money that, when paid to the consumer, achieves the same level of utility before the change that the consumer would enjoy with the economic change. EV represents the minimum amount that a consumer would require to willingly forgo the change.

5. Executives from the Corn Refiners' Association, which represents HFCS manufacturers, agree with our current results. They believe the domestic HFCS market is "decoupled" from the domestic sugar market—that is, HFCS prices are no longer linked to sugar prices—and the soft drink industry has relied on competition among HFCS manufacturers to minimize its sweetener prices.

6. We have the following definitions: $\lambda = b_s + b_g(P_g/P_f)$ and $\mu = b_b/P_f$. If the price of a competing crop changes, then parameter λ will change as well.

7. Because we assume constant returns to scale in sugarcane processing (constant marginal cost), there will be no welfare or rent changes for these processors.

8. In the nonhomothetic transformation of a Cobb-Douglas functional form, the cost shares of inputs are not held constant.

9. We assumed that the derived demand for sugar, as well as for HFCS, is price inelastic and small (less than 0.2 in absolute value). References to the small price elasticities of demand for sugar and other agricultural inputs include Devadoss, Kropf, and Wahl; Lopez and Sepulveda; and Goodwin and Brester.

10. Conjectural variation is a parameterization of strategic behavior that measures how firms with market power recognize their mutual interdependence in output space. Specifically, it is the percentage change in all other firms' output that a firm expects in response to a 1 percent change in its own output. This variable can also be defined in terms of price behavior.

11. The parameter θ can be defined as the firm's conjectural variation elasticity divided by its own-price elasticity of demand (see McCorriston, Morgan, and Rayner; and Bhuyan and Lopez).

12. See Bhuyan and Lopez; and Morrison.

Appendix 1

Detailed Description of the U.S. Sugar Model

This section of the appendix describes our framework for modeling the economic gains and losses to the various groups affected by the removal of the sugar program. First, we describe the agricultural markets that transform sugar beets and sugarcane into white sugar and corn into HFCS, a substitute for sugar in soft drinks and other food products. The removal of import restrictions under the TRQ would affect the raw cane and refined beet and cane sugar markets by allowing free imports in these domestic markets. Second, we estimate the welfare effects to sweetener processors, such as cane refiners, as well as to HFCS and beet processors. A lower price for refined sugar would increase its demand and might decrease the price and/or the use of HFCS. The lower price for refined sugar would also lead to a decrease in the quantity supplied by refiners, which in turn would decrease the demand for sugar beets and sugarcane and thus the price received by their producers. Third, on the consumer side, lower prices for refined sugar and HFCS would, other things being equal, lower the cost of production to sweetener-intensive food goods industries. Moreover, the final consumers of these industries would gain from lower prices for these foods as well as from a lower price for white table sugar.

Welfare Changes for Domestic Sugar Beet and Sugarcane Producers

Using the CARD sugar model, we assess the welfare effects to sugar beet producers by specifying the supply of sugar beets, BS, as a function of its price, P_b, the price of competing crops, P_g, and the price of an aggregate input, P_f. Assuming a quadratic form for profit in beet production, we can obtain a linear sugar beet supply by taking the first derivative of profit with respect to the price of beets:

$$BS=b_s+b_b(P_b/P_f)+b_g(P_g/P_f)=\lambda+\mu P_b, \quad (1.1)$$

with λ and μ summarizing the information on parameters b_i and prices P_g and P_f.[6]

Similarly, the supply of cane, CS, is a function of the price of cane, P_c, and the price of an aggregate input, P_f. As in the case of beets, the extended CARD domestic sugar model simultaneously solves for sugarcane prices, acreage, yield, and production levels. Using these parameter estimates, we again assume quadratic profits in cane production and obtain a linear supply of cane:

$$CS=c_s+c_c(P_c/P_f) = \alpha+\beta P_c. \quad (1.2)$$

Assuming a constant extraction margin, a_{ce}, and constant marginal cost pricing in cane extraction,[7] the cost function of raw cane sugar production is $C_{rcs}=[(1/\gamma_c)P_c+a_{ce}]RCSS$. As noted before, prices in agricultural sugar production obey the following arbitrage condition to express marginal cost pricing in the extraction of raw sugar from cane:

$$P_{rcs}=(1/\gamma_c)P_c+a_{ce}. \tag{1.3}$$

Welfare changes to sugarcane processors from price changes due to an elimination of the program. Thus, we estimate changes in economic welfare by the changes in quasi-profit or producer surplus realized by cane and beet producers, $\Delta\prod_c$ and $\Delta\prod_b$, defined as

$$\Delta\prod_c=\int_{P0}^{P^1} CS(P_c, P_f)\, dP_c =\int_{P0}^{P^1} (\alpha+\beta P_c)dP_c= [\alpha P_c+(1/2)\beta P^2{}_c]^{p1}_{p0} \tag{1.4}$$

and

$$\Delta\prod_b=\int_{P0}^{P^1} BS(P_b, P_v, P_f)\, dP_b =\int_{P0}^{P^1} (\lambda +\mu P_b)\, dP_b = [\lambda P_b+(1/2)\mu P^2{}_b]^{p1}_{p0}. \tag{1.5}$$

Parameter estimates of α, β, λ, μ, γ_c and a_{ce} are all available from the CARD sugar model. In actually implementing the model, we multiplied an acreage response due to price changes from the program's elimination by a constant yield per acre.

Welfare Changes for Domestic Corn Producers

Likewise, with the lower price of sugar, the demand for corn decreases as food processors replace HFCS with sugar in production. We assume that the supply of corn, COS, is determined by the maximum of the loan rate for corn, LR_{corn}, or the market price of corn, P_{corn}:

$$COS=\delta + \kappa\, Max(LR_{corn}, P_{corn}), \text{ with } \kappa > 0. \tag{1.6}$$

If the market price were higher than the loan rate, as it was earlier in the 1990s, then corn farmers would respond to this price. With a decrease in the demand for corn caused by reduced HFCS production, corn farmers would lose through a decrease in corn price and production. Therefore, corn farmers would lose

$$\Delta\prod_{corn}=\int_{P0}^{P^1} COS(P_{corn})\, dP_{corn}. \tag{1.7}$$

However, when the loan rate is higher than the market price, as it currently is, the price signal perceived by corn farmers is the fixed loan rate. In this case, farmers are eligible to receive loan deficiency payments from the government. However, without the sugar program, government payments would be higher because of the increasing price wedge between LR and P_{corn}. The additional government cost in the corn market due to the sugar policy change would be just equal to this increased price wedge times the amount of corn production: COS (P^0_{corn}-P^1_{corn}).

Welfare Changes for Sugar Beet Processors

Domestic sugar beet processors would also experience changes in economic welfare from the extraction process. The domestic supply of white sugar, WSS, comes from two sources that are perfect substitutes in supply: beet sugar supply, WBS, and refined cane sugar supply. The supply of white sugar from beets is a totally inelastic derived demand that comes from the extraction of white sugar from sugar beets. With γ_b denoting the exogenous rate of extraction of sugar from beets, prices in beet production obey the following condition to express marginal cost pricing:

$$P_{wbs}=(1/\gamma_b)\ P_b+a_{be}WBS, \tag{1.8}$$

where a_{be} denotes the extraction margin parameter in beet sugar extraction.

Finally, the welfare change for beet processors is then estimated as

$$\prod_{wbs}= P^1_{ws}\ WBS^1- P^0_{ws}WBS^0_i - \int_0^{WBS^1} MC_{be}(P^1_b\ ,WBS)\ dWBS+ \int_0^{WBS^0} MC_{be}(P^0_b,WBS)\ dWBS. \tag{1.9}$$

Welfare Changes for HFCS Producers

Because HFCS is a substitute for sugar in many food items, a change in the price of sugar may affect the demand for HFCS, and in turn the price of HFCS, translating into a change in economic welfare for HFCS producers. The supply of HFCS, HFCSS, comes from extracting fructose from corn production with an increasing marginal cost of extraction, $P_{hfcs}=(1/\gamma_{corn})\ P_{corn}+a_{wm}HFCSS$, leading to the supply:

$$HFCSS=[P_{hfcs}-(1/\gamma_{corn})\ P_{corn}]/a_{wm}, \tag{1.10}$$

with a_{wm} denoting the marginal margin parameter in HFCS extraction and γ being the actual extraction rate for HFCS from corn. Because we extended the CARD sugar model to include linkages to the corn and HFCS markets, we obtained all parameter estimates for these markets, as well as extraction rates and margin parameters, from CARD. Rendleman and Hertel argue that because of feedback through by-product prices, HFCS supply is not very price responsive. Equation (1.11) estimates the change in the welfare of HFCS suppliers as captured by the change in the industry's producer surplus:

$$\Delta\prod_{hfcss}= \int_{P_{corn}0}^{Pcorn1} \int_{P_{hfcs}0}^{P_{hfcs}1} HFCSS(P_{hfcs},\ P_{corn})\ dP_{hfcs}dP_{corn}. \tag{1.11}$$

Welfare Changes for Cane Sugar Refiners

Cane sugar refiners experience changes in economic welfare with the elimination of the TRQs for raw and refined sugar. Domestic refined cane sugar comes from refining domestic and imported raw cane sugar. For cane sugar refining, we assume that the supply of white cane sugar, WCS, is competitive. Assuming the cost of producing refined cane sugar increases in output, this cost consists of the cost of raw cane sugar and the refining cost characterized by the margin parameter, arm. We also assume a fixed proportion, γrc , between raw cane sugar and refined sugar. The marginal cost of refining is equated to the output price to obtain a supply schedule:

$$WCS=(1/a_{rm})[P_{ws} -(1/\gamma_{rc})P_{rcs}]. \quad (1.12)$$

There is competitive price arbitrage between domestic sources of white sugar, which equates the marginal cost of white cane sugar and beet sugar to the white sugar price. Using this arbitrage condition and equations (1.1) and (1. 3), we have

$$P_{ws} =(1/ \gamma_{rc}) P_{rcs}+a_{rm} WCS=(1/ \gamma_{rc}) [(1/\gamma_c)P_c+ a_{ce}]+ a_{rm} WCS=(1/\gamma_b)P_b+a_{be}WBS. \quad (1.13)$$

Therefore, the welfare change for domestic cane sugar refiners is obtained by looking at the change in their quasi-profit, or producer surplus, $\Delta\prod_{wcs}$, resulting from the change in policy via P_{rcs} (P^0_{rcs} to P^1_{rcs}), output price (from P^0_{ws} to P^1_{ws}), and output change (from WCS^0 to WCS^1):

$$\Delta\prod_{wcs}= P^1_{ws} WCS^1- P^0_{ws}WCS^0_i - \int_0^{WCS^1} MC_{wcs}(P^1_{rcs} ,WCS)\, dWCS + \int_0^{WCS^0} MC_{wcs}(P^0_{rcs} ,WCS)\, dWCS. \quad (1.14)$$

Welfare Changes for Sweetener-Using Food Processors

We then estimate the economic welfare effects from changes in sweetener prices for food-processing industries by using two polar situations. The first case assumes a constant markup, and thus a full pass-through of benefits to consumers of lower input prices and thus output prices. The second case holds output prices constant but allows food processors to absorb the lower sweetener costs from eliminating the program in their marginal cost function and thus in their profit margin.

The derived demand for refined sugar comes from food-processing industries producing sweetener-intensive food goods. For food processing, we describe the total cost function of each industry i in food processing as

$$C_{fgi} = \{A + c^{\sim} (P_S, P_{HFCS}) \} * Q_{fgi} , \quad (1.15)$$

$$c^{\sim} = a +b*(P_S^{\alpha s} * P_{HFCS}^{\alpha hfcs}), \quad (1.15a)$$

where C represents total cost, $c^{\sim}$ represents the cost of a composite sweetener (sugar and HFCS), a is an intercept term, b is a scaling term, P_s is the price of white sugar, P_{HFCS} is the price of high-fructose corn syrup, Q_{fgi} is output produced by food sector i, and A represents information from the prices of other inputs. The derivative of the cost function (1.15), with respect to the price of sugar, is a nonhomothetic transformation of a Cobb-Douglas functional form[8] and represents the output-constant industrial white sugar demand:

$$DDWS_i= \partial C_{fgi}/\partial P_s= (a +b\, \alpha_{Si}* (P_S^{\alpha s-1} P_{HFCS}^{\alpha hfcs})* Q_{fgi} \quad (1.16)$$

for all i in sweetener-using food goods where a is an intercept term and b is a scaling factor to calibrate the own-price elasticity of demand between –0.1 and –0.2.[9] Similarly, the derivative of (1.15) with respect to the price of HFCS in each food-processing industry represents HFCS demand, HFCSD:

$$HFCSD_i = \partial C_{fgi}/\partial P_{HFCS} = (c + b * \alpha_{HFCSi} (P_S^{\alpha s} P_{HFCS}^{\alpha hfcs-1}) * Q_{fgi} \qquad (1.17)$$

for all i in sweetener-using food goods where c is an intercept term and once again b is a scaling factor to calibrate the own-price elasticity of demand between –0.1 and –0.2. Using this type of specification implies constant returns to scale in the cost structure. Starting from each industry's cost function (1.15), we derive the marginal cost underlying supply decisions:

$$MC_{fgi} = \{d + (P_S * (\text{sugar use})) + (P_{HFCS} * (\text{HFCS use}))\}/ Q_{FGI}, \qquad (1.18)$$

or, after substituting (A.16) and (A.17),

$$\begin{aligned} MC_{fgi} = đ &+ [a+b * \alpha_s *(P_S^{\alpha s-1} P_{HFCS}^{\alpha hfcs})] * P_S \\ &+ [c+b * \alpha_{HFCSi} (P_S^{\alpha s} P_{HFCS}^{\alpha hfcs-1})] * P_{HFCS} \end{aligned} \qquad (1.18')$$

where đ is an intercept term that reflects the cost of other inputs per unit of output.

From profit maximization with market power and conjectural variation,[10] we assume that food-processing firms set price above marginal cost with markup coefficient, θ, such that

$$\theta_i=(P_{fgi}-MC_{fgi})/P_{fgi}. \qquad (1.19)$$

Therefore, the price schedule of industry i is

$$P_{fgi}=(1/(1- \theta_i))\ MC_{fgi}. \qquad (1.20)$$

Equations (1.16), (1.17), (1.18), (1.19), and (1.20) determine the transmission of lower sweetener prices into lower prices P_{fgi} to consumers of sweetener-containing food goods. Several factors have a role in the price transmission: the cost share of sweeteners in the cost of food processing, the substitution possibilities within sweeteners (fructose and sugar) and between sweeteners and other inputs, and, finally, the markup and its evolution as prices change (McCorriston, Morgan and Rayner).[11] Equation (1.18) is calibrated to replicate a "historical" marginal cost for the industry using data from the Bureau of Economic Analysis on output price indexes for 4-digit SIC industries 2023 to 2099. The historical marginal cost is estimated to be the historical price divided by 1.2, or a constant 20 percent markup of price over marginal cost. We use a 20 percent markup of price over marginal cost as this figure is well within the estimates of other analyses of the food-manufacturing sector.[12]

Trade in food industries is ignored because net trade is a very small share of total consumption or production in all food industries; these industries tend to produce differentiated products, which do not face a strict price discipline from the world market; and trade data are scarce and only available up to 1994.

Hence, the equilibrium condition in the food-processing markets is found by equating the price schedule (1.20) of each industry to the corresponding Marshallian demand (1.24) as follows:

$$FGS_i = FGD_i(P_{ws}, P_{fgi}, M), \text{ for all i.} \tag{1.21}$$

The welfare effect of the sugar program on each food industry is estimated by the change in its profit, $\Delta\prod fgi$, resulting from the price and output changes induced by the policy reform (from P1 to P0 and from FGS0 to FGS1):

$$\Delta\prod_{fgi} = P^1_{fg}\, FGS^1_i - P^0_{fg} FGS^0_i - C_{fgi}(P^1_{ws}, P^1_{hfcs}, FGS^1_i) + C_{fgi}(P^0_{ws}, P^0_{hfcs}, FGS^0_i). \tag{1.22}$$

Welfare Changes for the Final Consumer

We estimated the welfare cost to the final sugar and HFCS consumer by assuming a representative consumer with expenditure function E(**P**, U). In this expenditure function, **P** is a vector of relevant consumer prices and U denotes utility. We are interested in two types of goods: white sugar, WS, and a vector of sweetener-containing food goods, FG. In addition, a third aggregate for other goods, OG, is included for completeness. We use an incomplete demand system approach–LINQUAD–as specified in LaFrance, LaFrance et al., and Agnew. This approach allows us to derive an exact welfare measure from an incomplete demand system. In addition, we impose restrictions on the structure of cross-price responses to reduce the number of parameters to be calibrated. The price vector **P** is decomposed into $\mathbf{P}=(P_{ws}, \mathbf{P_{fg}}, \mathbf{P_{og}})$, and income is denoted by M, with subscripts indicating the respective commodities. The subvector $\mathbf{P_{og}}$ is then dropped from the incomplete system. The Marshallian demands for the two types of goods of interest, white sugar and sweetener-containing food goods, denoted WSD and **FGD**, are

$$WSD(P_{ws}, \mathbf{P_{fg}}, M) = \xi_{ws}+\nu_{ws}P_{ws} +\chi_{ws}\, [M- \xi_{ws}P_{ws}- \boldsymbol{\xi_{fg}}'\mathbf{P_{fg}}-0.5\nu_{ws}P_{ws}{}^2-0.5\textstyle\sum_{fg} \nu_{fgi}'P_{fgi}{}^2] \tag{1.23}$$

and

$$FGD_i(P_{ws}, \mathbf{P_{fg}}, M) = \xi_{fgi}+\nu_{fgi}P_{fgi} +\chi_{fgi}\, [M- \xi_{ws}P_{ws}- \boldsymbol{\xi_{fg}}'\mathbf{P_{fg}}-0.5\nu_{ws}P_{ws}{}^2-0.5\textstyle\sum_{fg} \nu_{fgi}'P_{fgi}{}^2] \tag{1.24}$$

for all i industries containing sweeteners. We use a system of consensus estimates of own-price responses and income responses based on Devadoss and Kropf, Bhuyan and Lopez, and Wohlgenant to derive parameters ξ, ν, and χ. We solve the following system of equations: $\partial FGDi/\partial Pfgi= \nu fgi - \chi fgi\ (\xi fgi + \nu fgiPfgi)$, $\partial FGDi/\partial M= \chi fgi$, $\partial WSD/\partial Pws=\nu ws-\chi ws(\xi ws+\nu wsPws)$, $\partial WSD/\partial M=\chi ws$, and (1.23)-(1.24). The solution to this system allows us to exactly identify all cross-price responses of the system because ξ, ν, and χ are then known parameters.

Equations (1.23) and (1.24) lead to an equivalent variation, EV, equal to

$$EV=\{[M- \xi_{ws}P^1_{ws}- \xi_{fg}'P^1_{fg}-0.5\nu_{ws}(P^1_{ws})^2-0.5\textstyle\sum_{fg} \nu_{fgi}(P^1_{fgi})^2]\exp[-(\chi_{ws}P^1_{ws} +\sum_{fg}\chi_{fgi}\, P^1_{fgi})$$

$$+ (\chi_{ws}P^0_{ws} +\textstyle\sum_{fg}\chi_{fgi}\, P^0_{fgi})]\}-[M - \xi_{ws}P^0_{ws}- \xi_{fg}'P^0_{fg}-0.5\nu_{ws}(P^0_{ws})^2-0.5\sum_{fg} \nu_{fgi}(P^0_{fgi})^2]. \tag{1.25}$$

Thus, we compute the change in expenditure, which would produce a change in utility equivalent to the price changes with superscripts ^{0} and ^{1} denoting initial and final prices.

Summary of Total Welfare Gains and Losses from the Sugar Program

Finally, we list the welfare gains and losses from the presence of the sugar program to the various groups represented in the model.

Losses to consumers (all prices higher as a result of the program):

$$EV = -\{[M - \xi_{ws}P^1_{ws} - \xi_{fg}'P^1_{fg} - 0.5\nu_{ws}(P^1_{ws})^2 - 0.5\sum_{fg}\nu_{fgi}(P^1_{fgi})^2]\exp[-(\chi_{ws}P^1_{ws} + \sum_{fg}\chi_{fgi}P^1_{fgi}) + (\chi_{ws}P^0_{ws} + \sum_{fg}\chi_{fgi}P^0_{fgi})] - [M - \xi_{ws}P^0_{ws} - \xi_{fg}'P^0_{fg} - 0.5\nu_{ws}(P^0_{ws})^2 - 0.5\sum_{fg}\nu_{fgi}(P^0_{fgi})^2]\}. \quad (1.26)$$

Net losses to sweetener-using food processors (higher sweetener input prices and higher output price):

$$\sum_i\Delta\prod_{fgi} = -\{P^1_{fg}FGS^1_i - P^0_{fg}FGS^0_i - C_{fgi}(P^1_{ws}, P^1_{hfcs}, FGS^1_i) + C_{fgi}(P^0_{ws}, P^0_{hfcs}, FGS^0_i)\}. \quad (1.27)$$

Changes in quasi-profits to cane refiners (higher output price but significantly higher input prices):

$$\Delta\prod_{wcs} = -\{P^1_{ws}WCS^1 - P^0_{ws}WCS^0_i - \int_0^{WCS^1} MC_{wcs}(P^1_{rcs}, WCS)\,dWCS + \int_0^{WCS^0} MC_{wcs}(P^0_{rcs}, WCS)\,dWCS\}. \quad (1.28)$$

Gains to beet producers (higher output price):

$$\Delta\prod_b = \int_{P0}^{P^1} BS(P_b, P_v, P_f)\,dP_b = \int_{P0}^{P^1} (\lambda + \mu P_b)\,dP_b = [\lambda P_b + (1/2)\mu P^2_b]^{p1}_{po}. \quad (1.29)$$

Gains to beet processors (higher white sugar price partly offset by higher beet input prices):

$$\Delta\prod_{wbs} = P^1_{ws}WBS^1 - P^0_{ws}WBS^0_i - \int_0^{WbS^1} MC_{be}(P^1_b, WBS)\,dWBS + \int_0^{WBS^0} MC_{be}(P^0_b, WBS)\,dWBS. \quad (1.30)$$

Gains to cane producers (higher output price):

$$\Delta\prod_c = \int_{P0}^{P^1} CS(P_c, P_v, P_f)\,dP_c = \int_{P0}^{P^1} (\alpha + \beta P_c)dP_c = [\alpha P_c + (1/2)\beta P^2_c]^{p1}_{po}. \quad (1.31)$$

Net gains to HFCS producers (higher output price, net of slightly higher corn input price):

$$\Delta\prod_{hfcss} = \int_{P_{corn0}}^{Pcorn1}\int_{P_{hfcs0}}^{P_{hfcs}1} HFCSS(P_{hfcs}, P_{corn})\,dP_{hfcs}dP_{corn}. \quad (1.32)$$

Changes in quasi-profits to corn farmers:

$$\Delta\prod_{corn} = \int_{P0}^{P^1} COS(P_{corn})\,DP_{corn}. \quad (1.33)$$

Losses to taxpayers from the corn loan deficiency payment program cost increase (if corn prices were below the corn loan rate):

$$COS\ (P^0_{corn}\text{-}P^1_{corn}). \qquad (1.34)$$

However, these losses would be offset by an equal gain to producers.

Net gains to the foreign suppliers of raw sugar that have been given quota rights consisting of the unit rent times the total amount of the TRQ:

$$\Delta\prod_{fs} = (\text{Unit Rent}_{rcs})*\text{TRQ}_{rcs}. \qquad (1.35)$$

The net welfare loss is the difference between the additional costs of the sugar program to the users of sweeteners and the gains to domestic sweetener producers and processors:

$$\text{Net welfare loss} = (EV + \sum_i \Delta\prod_{fgi}. + \Delta\prod_{wcs}) - (\Delta\prod_{hfcss} + \Delta\prod_c + \Delta\prod_{wbs} + \Delta\prod_b + \Delta\prod_{corn}). \qquad (1.36)$$

This net welfare loss that results from the sugar program consists of production and consumption inefficiencies and the transfer of rents to foreign suppliers.

Data and Data Sources Used in the Model

On the supply side, all data, parameters, and extraction rates used in the U.S. component of the world sugar model are from CARD's international sugar model. To estimate welfare effects for the food-processing industry, we identified a subset of 21 sweetener-using industries at the 4-digit SIC level (2023 to 2099). These industries were taken from the major categories of (*a*) dairy and frozen desserts, (*b*) canned and preserved fruits and vegetables, (*c*) bread and bakery products, (*d*) confectionery and chocolate products, (*e*) beverages, and (*f*) miscellaneous food products industries. To calculate the demand and marginal cost for sweeteners from these industries, we used data on the value of shipments for each industry, the price of sugar and HFCS, and the total quantities of sugar and HFCS sold for the years 1996 and 1998. For 1998 HFCS cost data, we scaled each industry proportionately, using 1997 Bureau of the Census data, to reproduce the exact total disappearance of HFCS in 1998. For 1996 HFCS data, we used cost data on corn sweeteners from the Bureau of Economic Analysis. We obtained price data for sugar, HFCS-42, and HFCS-55, from USDA and industry sources.

For the LINQUAD model of final consumer demand, we used producer price index data from the Bureau of Labor Statistics for each of our 21 4-digit SIC industries, adjusted to1992 dollars using the consumer price index from the WEFA Group. USDA provided data on total deliveries of sugar and HFCS. As previously noted, we obtained data on income elasticities and own-price elasticities from several sources in the economics literature (see endnote 12). The income and price elasticities are then used to calibrate the LINQUAD demand system and generate cross-price response estimates as explained in Appendix 1.

Appendix 2

Structure of the CARD International Sugar Model

The CARD international sugar model is a nonspatial, partial equilibrium econometric world sugar model consisting of 29 countries/regions including a rest-of-the-world component to close the model. Major sugar-producing, -exporting, and -importing countries are included in the CARD model. The model specifies only raw sugar trade among countries/regions and does not disaggregate refined trade from raw trade. Consequently, there is no categorization between importers as refiners or toll refiners because those countries that specialize in that role are well known and stable over time. Country coverage consists of the following countries/regions:

Algeria	Argentina	Australia	Brazil
Canada	China	Columbia	Cuba
Eastern Europe	Egypt	European Union	Former Soviet Union (FSU)
Guatemala	India	Indonesia	Iran
Japan	Malaysia	Mexico	Morocco
Pakistan	Peru	Philippines	South Africa
South Korea	Thailand	Turkey	Venezuela
Rest of World			

The general structure of the country submodel includes behavioral equations for area harvested, yield, production for sugar beet and sugar cane on the supply side, and per capita consumption and ending stocks on the demand side. Equilibrium prices, quantities, and net trade are determined by equating excess supply and excess demand across countries and regions. The domestic price of each country or region is linked with a representative world price through exchange rates and other policy wedges such as tariffs and transfer-service margins. Because of the overall scope of the model, it is not feasible to include the complete empirical model in the text. The general framework for each country submodel consists of the following:

$AH_t = f\,(AH_{t-1}, RSPP_{t-1}, RGP_{t-1}, Trend)$,

$Yield = f\,(Yield_{t-1}, Trend)$,

Cane and Beet Production = f (AH, Yield),

Per capita sugar Consumption = f (RSP, PCRGDP), and

Ending Stocks = $f\,(ES_{t-1}, SC, RSP)$,

where AH is acreage, RSPP is cane or beet price, RGP is the price of alternative crops, PCRGDP is real income per capita, ES is ending stock, SC is sugar consumption, and RSP is the real raw sugar price. In many countries the beet or cane prices are set by policy and can be treated as being predetermined. Some countries lack information on agricultural price, and the raw cane sugar, RSP is used instead of the agricultural prices in the specification of the acreage response. In some countries, yield improvements are captured by a time trend.

Data for area harvested, yield, sugarcane production, and sugar beet production were gathered from the Food and Agricultural Organization (FAO) of the United Nations. Data for sugar production, consumption, and ending stocks were obtained from PS&D View of the United States Department of Agriculture. Cane and beet production is tied to sugar production through the extraction rate. Macroeconomic data such as real gross domestic product (GDP), consumer price index, population, and exchange rate were gathered from sources including WEFA, Project Link, and DRI.

The estimation period for the model is 1980 to 1998. Simple linear specifications and ordinary least squares are used in the estimation of these equations to save degrees of freedom, given the short time series used. This estimation approach overlooks the potential endogeneity of sugar prices and treats them as exogenous for the estimation purposes. The Caribbean raw sugar price is generally considered to be the world market price. The nominal world price of sugar has been increasing over time, although in a volatile fashion, while the real price has decreased.

Most elasticities in the CARD model are comparable to those of Devadoss and Kropf; Hafi, Connell, and Sturgiss; and Wohlgenant. The lagged own-price elasticities of sugarcane for Australia (0.02), Brazil (0.07), Columbia (0.05), Cuba (0.01), Guatemala (0.02), Mexico (0.002), South Africa (0.005), and Thailand (0.014) are highly inelastic in the short run. These are large producers of sugarcane and exporters of sugar. This is consistent with the fact that you harvest several annual crops, called ratoons, from one planting of sugarcane. Therefore, there is limited acreage adjustment to price fluctuations in the short run. The own-price supply elasticities for sugar beet production are generally not as inelastic as they are for sugarcane, except for the FSU (0.002). This is more the result of historic policy of acreage allotment.

The own-price consumption and income elasticities reflect the fact that in many developing countries sugar is considered a staple in the diet. Consumers look to sugar to fulfill basic caloric requirements. The elasticities implied in the CARD model are very comparable to the ones reported in the literature. In several countries, when more recent data were not available for the econometric estimation, elasticities were borrowed from Hafi, Connell, and Sturgiss and from Devadoss and Kropf.

Added Raw/Refined Sugar Link

Although the CARD international sugar model does not disaggregate raw and refined sugar, the existing model is complemented with an additional equation to endogenize the world price of refined sugar following the removal of the refined sugar TRQ in the United States. Using Hafi, Connell, and Sturgiss, a reduced form is specified to approximate the rest-of-the-world supply faced by the United States. However, there is no explicit aggregation of excess supply in the various countries to come up with this equation, as is the case for the raw sugar market.This equation is of the form

$$IWS_{row} = a(Pw_{ws})^{\varepsilon ws} (Pwrcs)^{\varepsilon cs},$$

where εws = 0.83 and εcs = -0.44. These elasticity values come form Hafi, Connell, and Sturgiss and are medium-run estimates. Parameter a is chosen to calibrate the IWS to the existing refined sugar TRQ level in the United States, prior to its removal. This equation is treated as the rest-of-the-world supply, which underlies the import supply faced by the United States. The latter is then equated to the U.S. excess demand of white sugar to close the white sugar market in the policy analysis, once the TRQ is removed.

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