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Do Corn Farmers Have Too Much Faith in the Sugar Program?

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Corn producers frequently have been told that the sugar program provides an important stimulus to corn demand through its positive influence on the high fructose corn syrup sector. In this article we quantify the extent of this support and find it to be very small—not more than 3¢ per bushel, and probably less. Previous studies have overstated this effect due a lack of attention to the interindustry linkages in the sweetener complex.

Key words: corn, high fructose corn syrup, program interaction, sugar, sugar program.

Introduction

The U.S. sugar program, which maintains a high domestic sugar price, has found an unexpected "advocate" in corn farmers. The National Corn Growers Association, representing about two dozen state organizations, has publicly endorsed this controversial and expensive program. Why would they lend support to a program which at times imposes over a billion dollars in consumer costs annually (Babcock and Schmitz) and was not even designed for their benefit? Is this endorsement in their best interest, or could it be a liability?

The sugar program has done more than protect U.S. sugar cane and sugar beet farmers from foreign competitors; it also has encouraged a competitor here at home. High fructose corn syrup (HFCS), a sugar substitute, has come into its own under the umbrella of protection offered by the sugar program, expanding rapidly in the last decade and a half. Domestic shipments of HFCS have gone from 525,000 tons (dry weight basis) in 1975 to 6,225,000 tons in 1991 [U.S. Department of Agriculture, Economic Research Service (USDA/ERS), *Sugar and Sweetener Situation*]. HFCS use has grown to 35% of total caloric sweeteners consumed in the U.S. over this same time span. This has translated into increased corn usage in the U.S. wet milling industry.

Table 1 displays selected information about the wet corn milling sector over the period 1975–92. From column one it can be seen that HFCS demand for corn has increased more than eight-fold over this period. The final column shows that the percentage of the corn crop going to wet milling for all purposes more than doubled over this period. With this kind of evidence, the corn sweetener industry is making the case to the corn farmer that: "The sugar program protects you." Advertisements by wet millers in the farm press consistently claim that wet milling adds $.25 to the price of a bushel of corn (*Farm Journal*; *Indiana Prairie Farmer*).

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The views expressed are the authors' and do not necessarily represent policies or views of the USDA or Purdue University.

Table 1. Corn Use in the Wet Milling Industry, 1975-92

Marketing Year (Sept.–Aug.)	Corn Used for HFCS	Corn Used for All Other Wet Milling[a]	U.S. Corn Production	Percent of Corn Crop for Wet Milling
	(million bu)			
1975	45	328	5,840	5.6
1976	62	352	6,289	5.6
1977	80	384	6,505	5.9
1978	105	414	7,268	5.7
1979	127	442	7,928	5.6
1980	165	490	6,639	7.4
1981	183	507	8,119	6.2
1982	214	599	8,235	7.3
1983	265	682	4,174	16.3
1984	310	765	7,672	10.0
1985	327	822	8,875	9.3
1986	338	868	8,226	10.6
1987	358	897	7,131	12.6
1988	361	910	4,929	18.5
1989	368	952	7,526	12.7
1990	379	983	7,934	12.4
1991	390	1,009	7,474	13.5
1992[b]	398	1,027	8,575	12.0

Sources: USDA/ERS: *Feed Yearbook: Situation and Outlook,* February 1989 and February 1992; *Sugar and Sweetener Situation and Outlook: Yearbook,* 1992.
[a] Includes glucose/dextrose, corn starch, modified corn starches, and, from 1980, fuel ethanol. Though probably conservative, we assume that half of the corn used for fuel alcohol went through the wet milling sector.
[b] Data for 1992 are preliminary.

Overview of Sweetener Production

Cane is grown and milled (turned into raw sugar) in the warm climates of Florida, Louisiana, Texas, and Hawaii. Before it is consumed in the U.S., the raw sugar is refined. Raw sugar from overseas is indistinguishable from domestic raw sugar, so it is at this point, after the cane has been milled and before it reaches the refinery, that the import restriction[1] is imposed. Sugar beets, on the other hand, are grown in more temperate regions of the U.S. and are processed directly into refined sugar. This operation is performed by processors typically located in close proximity to the sugar beet farms.

Corn-based sweeteners are produced by the wet-corn milling industry in conjunction with other by-products. One bushel of corn entering this sector typically is converted into about 33.3 lbs. of HFCS (dry weight), roughly 16 lbs. of gluten meal and gluten feed, and 1.6 lbs. of crude corn oil. These "by-products" represent an important component of industry revenue. For example, in 1982 only 52% of this sector's revenues came from sweeteners. Much of the remainder comes from the sale of these by-products, which typically are dried and shipped overseas for use as animal feed. These feedstuffs are inexpensive enough to enter the input mix when competing with higher-priced European grains, and this is the major market for gluten feeds, although some also are fed domestically.

An important consequence of this multiple product characteristic of the wet-corn milling sector is that when HFCS production is encouraged, for example due to a rise in the sugar price, the production of these by-products also increases. *Ceteris paribus,* this dictates a decline in the price of corn gluten meal and feed, which makes these feedstuffs more competitive with other ingredients including corn grain. Thus the net addition to corn demand, which might be naively estimated by simply looking at the corn requirements associated with increased HFCS production, will tend to overstate the associated benefits to corn producers. Simply put, *HFCS production does not exhaust the feed value of the corn.*

Analytical Framework

In order to quantitatively assess the impact of the sugar program on corn prices, we have constructed a simulation model which captures critical economic relationships within the sweetener complex, as well as links between these industries and the remainder of the economy. The model is a two-region, general equilibrium framework which has been explicitly constructed to provide a thorough analysis of the U.S. sugar program. We did **not** choose the general equilibrium approach because of large anticipated GE feedback effects. Indeed, we expect such effects to be quite small. Rather, we had the following advantages in mind: (*a*) exhaustive treatment of interindustry relationships, (*b*) ease of incorporating econometric estimates of key elasticities, (*c*) straightforward welfare analysis in a second-best setting, and (*d*) the availability of state-of-the-art simulation software. In this article we focus on the first two points, while also exploiting (*d*). (We develop a complete welfare analysis of the sugar program in another paper.) The particular software package employed in this study is MPS/GE (Rutherford), and the model is available in MPS/GE format from the authors upon request.

Sectoral and Product Coverage

Table 2 provides a complete listing of the sectors and commodities which are broken out in the model. At the U.S. farm level, single product activities include: sugar beets, sugar cane, livestock, feedgrains, oilcrops, and other agriculture. Domestic agricultural processing sectors include: sugar cane milling, raw sugar refining, beet processing, wet-corn milling, prepared feeds, oilseed processing, soft drink and confectionery products, livestock processing, and other foods. Nonfood products are aggregated into other manufactures and services.

Foreign production is disaggregated to match this level of detail, thereby supplying competing imports to the U.S. With the exception of foreign sugar, these supply relationships are not central to our analysis and are handled through a simple, production possibilities frontier. Foreign sugar competes with other products for a common factor of production, but it also employs a specific factor of production which permits us to calibrate the rest of the world's sugar supply response in light of econometric evidence.

Domestic Factor Markets

In the domestic economy, assumptions about factor markets play a key role in determining the intersectoral effects of the sugar program. Our basic model is oriented towards obtaining insights into the short-run (one-year) effects of the sugar program. Thus our base case mobility assumptions permit labor to be mobile across activities, but capital is assumed to be sector-specific.[2] Farmland is partially mobile among crop and livestock uses, except for sugar production. This partial mobility is governed by a constant elasticity of transformation function. The associated transformation parameter is chosen to replicate observed, short-run acreage response elasticities. In the cases of sugar cane and sugar beets, we assume that acreage is fixed in the short run. This reflects annual contract commitments in sugar beet production, and the fact that a single planting of cane is harvested over multiple years.

To provide a sense of what a longer-run outcome might entail, we also consider the case whereby domestic capital is permitted to move freely across uses, until after-tax rates of return are equalized. Also, land is now permitted to move between sugar and nonsugar uses, subject to the constant elasticity of transformation. This increases sectoral supply

Table 2. Producing Sectors, Products, and Factors of Production

Sector	Products	Price Elasticities: Acreage	Yield	Total Supply
Agriculture				
Beets	Sugar beets	0.0	.48	.48
Cane	Sugar cane	0.0	.23	.23
Livestock/dairy/poultry	Livestock, dairy, poultry	1.61	.51	2.12
Feed grains	Corn, barley, oats, etc.	.40	.44	.84
Oilseed crops	Soybeans, rapeseed	.14	.29	.43
Other agriculture	Fruits, forestry, etc.	.66	.45	1.11
Processing				
Cane milling	Raw sugar			1.0
Sugar refining	Refined sugar			1.0
Beet processing	Refined sugar			1.0
Wet corn milling	HFCS and other sweeteners; feed and other by-products			1.0
Feed and grain processing	Mixed feed, milled grain			1.0
Oilseed milling	Oil meal, oil, etc.			1.0
Soft drinks/confectionery	Soft drinks, bakery and confectionery products			1.0
Livestock processing	Processed meat, dairy, eggs			1.0
Other food processing	Processed foods			
Nonagriculture				
Manufacturing	Mined and manufactured goods			
Services	Includes government services and transportation			
Primary Inputs				
Labor				
Capital				
Sugar beet land				
Sugar cane land				
Other farm land				

response and tends to dampen the price increases resulting from, e.g., a tightening of the sugar quota (or increase in tariff). It also dissipates any rents which might accrue to fixed capacity in the short run.

Technology

Producers in the model all are assumed to maximize profits subject to exogenously given prices and production functions which are of the general nested-CES class. Figure 1 displays the nesting strategy and associated substitution parameters for a generic domestic industry in the model.[3]

At the top of this "production tree," imports are combined with domestic output subject to the "Armington" elasticity of substitution given by σ_1. These elasticities determine the import demand responsiveness of the U.S. They also have counterparts in the rest of the world, where they serve to determine the export demand elasticities for U.S. products. It will be useful to defer discussion of their values until we come to the foreign household. The one exception to this specification is raw sugar, which is treated as a homogeneous product in the model.

At the next level of the tree outlined in figure 1, domestic output is produced by combining value-added, sweeteners (where relevant), and other intermediate inputs. Here we have chosen to depart slightly from the conventional assumption of no substitutability, instead setting σ_2 equal to .1.

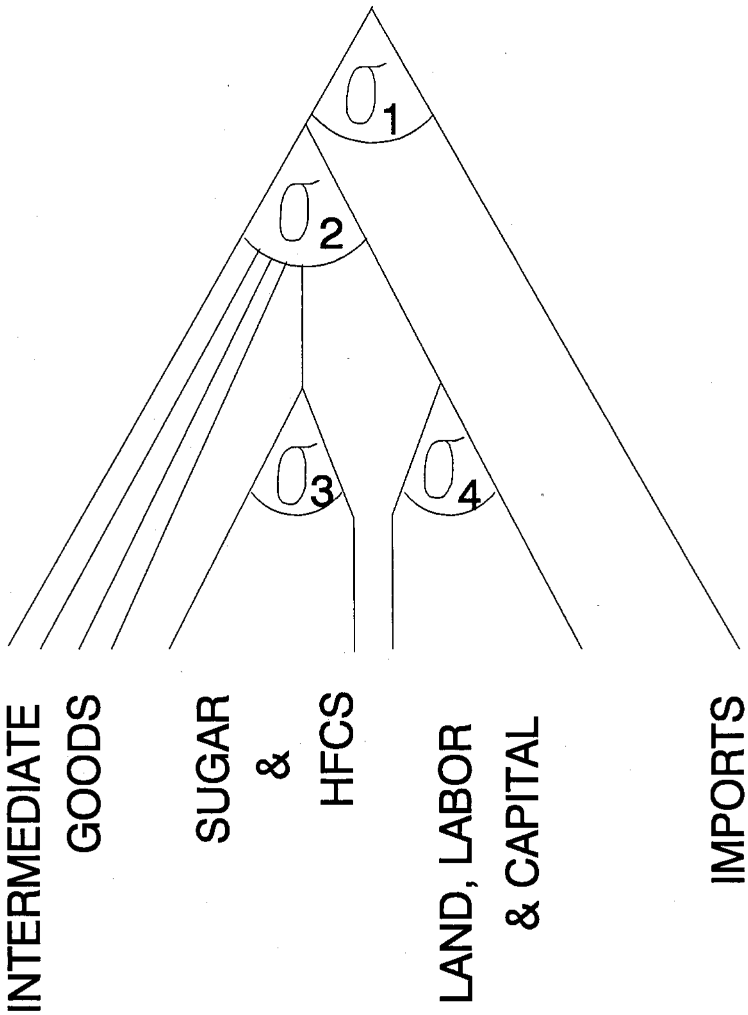

Figure 1. Generic industry production function

Value-added is produced at the lowest level of figure 1, by combining land, labor, and capital subject to the constant elasticity of substitution given by σ_4. In those industries where one of these factors is (quasi-)fixed, the value of σ_4 plays a key role in determining sectoral supply response. This is because output can be expanded only by substituting variable inputs for the fixed factor. In the case of the farm sectors, it is land which is in limited supply. Consequently, σ_4 is sector-specific, and is chosen (conditional on the other substitution elasticities discussed above) to provide the desired yield response. This, together with the acreage response elasticities discussed above, determines each commodity-specific supply response. We have chosen values to replicate the supply elasticities of Lopez, in the case of beet and cane sugar, and Ball, in the case of other farm products. In the case of nonfarm sectors, σ_4 is chosen to produce a short-run supply elasticity of unity when capital is fixed. These elasticities are summarized in table 2.

For those sectors which employ sweeteners, we also must specify the elasticity of substitution between HFCS and sugar (σ_3), as this is a critical link in the chain of events leading from a restriction of the sugar imports to a rise in the price of corn. Empirical evidence suggests that the absolute value of the market demand elasticity for sweeteners is very small. This translates into little substitution between sweeteners and other products. However, it does not address the issue of substitution among alternative types of sweet-

Table 3. Partial Equilibrium, Output-Compensated Price Elasticities of Demand Used in the Model for HFCS, Sugar, and Sweetener

	Services			Livestock Products			Soft Drinks			Other Foods		
	HFCS	Sugar	All Sweet-ener	HFCS	Sugar	All Sweet-ener	HFCS	Sugar	All Sweet-ener	HFCS	Sugar	All Sweet-ener
HFCS	−1.4	1.3	−.1	−1.4	1.3	−.06	−1.9	1.8	−.04	−1.7	1.6	−.05
Sugar	1.6	−1.7		1.6	−1.7		1.1	−1.2		1.3	−1.4	

eners. Indeed, the rapid increase in the use of HFCS in place of sugar suggests very large values for the parameter σ_3. Since the econometric evidence on this matter is unsatisfactory, we have chosen to begin with a value of 3, reflecting rather significant substitution possibilities. We subsequently vary this key parameter over a wide range in order to examine the sensitivity of our results to its assumed value.

Table 3 presents the domestic, output-constant, derived demand elasticities for HFCS and sugar which result from these assumptions about production functions in the sweetener-using sectors. When combined with consumer demand (where HFCS and sugar substitute in a similar fashion), they result in an aggregate, market demand elasticity for sweeteners of −.05 (Lopez). However, the demand elasticities for sugar and HFCS **individually** are considerably larger.

Consumer Preferences

Analogous to the producers, consumers are assumed to maximize utility subject to a nested CES utility function. The elasticity of substitution among composite consumption goods is not critical to our analysis of the impact which the sugar program has on corn producers. This is because most of the sugar, HFCS, by-products, and corn are intermediate inputs. It is the substitution possibilities there which dominate our estimates of the magnitude of this cross-commodity support. Thus we employ the simple assumption of fixed budget shares, i.e., a Cobb–Douglas utility function, over the composite commodities in both the U.S. and the rest of the world (ROW).

However, in the ROW some important substitution relationships are embedded in lower levels of the foreign household's utility function. (This is necessary, since we have not explicitly broken out the production structure in the ROW, due to the lack of an input–output table.) In particular, this is where the substitution between U.S. and foreign goods takes place. Each composite consumption good in the ROW is made up of foreign and domestic commodities which are combined with the same Armington parameter as is employed in the U.S.

The values of the ROW Armington elasticities of substitution determine the export demand elasticity for U.S. exports. Indeed, if the U.S. share of the domestic market in the ROW is relatively small, then this elasticity of substitution is roughly equal to the absolute value of this export demand elasticity. For this reason, we pick values of .8 for the agricultural commodities, in order to reflect the tendency for other countries to insulate their markets for farm products in the short run. By contrast, we assume a larger value (2) for other products. (Larger values for the agricultural export demand elasticities, as might be expected in the longer run, would lead to *smaller* changes in the corn price than those presented below.)

Benchmark Equilibrium

The data base used for this study was obtained from the USDA (Hanson and Robinson). It reflects the most recently published, disaggregated input–output table available for the United States. Unfortunately, these tables are made available with a considerable lag, so that our basic set of social accounts applies to the year 1982. While many of the input–

output coefficients change very slowly, this is not the case with HFCS use, where consumption has grown almost 94% since 1982. This rise is partly due to an increase in corn sweetener's share of total caloric sweeteners, and partly due to an increase in total sweeteners consumed. For this reason, we have updated the wet milling data used in our study from the original 1982 base to 1988 to reflect the increased importance of the HFCS industry.

In addition, it was necessary to introduce a binding quota with rents commensurate with those observed in recent times. This was done by imposing the quota and increasing supplies in the ROW until the U.S. price was twice the world price.

Simulation Results

Our simulation experiments involve solving the model at alternative quota[4] levels, ranging from autarky to the situation where the quota is no longer binding (free trade in sugar). Bear in mind that the base case simulations are oriented towards analyzing the likely *short-run* implications of changing the quota when capacity in the HFCS and sugar refining industries (and other sectors as well) cannot be altered. We also assume that sugar beet and sugar cane acreage is fixed in the short run, while corn acreage is only marginally responsive.

We begin by examining the impact which the quota has on raw sugar. This is where the "stone hits the water." We then follow the ripples as they move out through the economy, with a particular emphasis on the coarse grains sector. The top part of figure 2 plots the prices of raw and refined sugar, in cents per pound, against the simulated quota level. At the 1982 base quota level, the model reproduces a raw sugar price of about 20¢ per pound. As the quota is tightened (a leftward movement in the figure), the domestic availability of sugar is reduced. In the short run, with limited supply responsiveness from domestic sugar producers, complete elimination of imports (zero on the horizontal axis) causes a near tripling (260%) of raw sugar prices and a doubling (190%) of the price per pound of refined sugar. This in turn pulls up the price of HFCS (panel 2), and the increased demand for corn adds 1.5¢ to farmers' per bushel receipts (bottom panel).

Increased supply response, for example, due to increased mobility of land and capital, as occurs in the *long run,* dampens the price-enhancing effects of a tightened sugar quota. This can be seen in the bottom panel of figure 2, where the long-run corn price increase is negligible. There are two reasons for this. First, with a more responsive domestic supply of sugar, the tendency for raw sugar prices to rise is diminished. This lessens somewhat the long-run incentive to expand HFCS production. Secondly, in the long run, corn producers are more easily able to supply the increased wet milling purchases.

The effects of unilaterally relaxing the sugar quota (a rightward movement in fig. 2) are opposite in direction and rather different in absolute magnitude from the previous results. We find that many of the short-run benefits of a loose quota accrue to sugar refiners, whose services are now in greater demand. Consequently, even if the quota were immediately eliminated, it would take some time for the benefits to be passed on to consumers in the form of lower refined sugar prices. Thus the impact on the related HFCS market is also small.

In the long run, increased investment in sugar refining results in lower prices for this product as well as for HFCS. This translates into lower corn demand and a 3¢ per bushel drop in the farm level price of corn, if the quota were completely eliminated.

Since the issue of how well HFCS and sugar substitute for one another in various sweetener-using sectors is not known with certainty, our results might be criticized as having too high or too low a value. To test the sensitivity of the results to changes in demand elasticity, we varied the crucial parameters (σ_3 in fig. 1) by first halving, then doubling each of these parameters. The results were, in fact, very robust.

Halving the elasticity of substitution between HFCS and sugar was considered first. When sugar policy moves in the direction of autarky, the price of raw sugar rises more

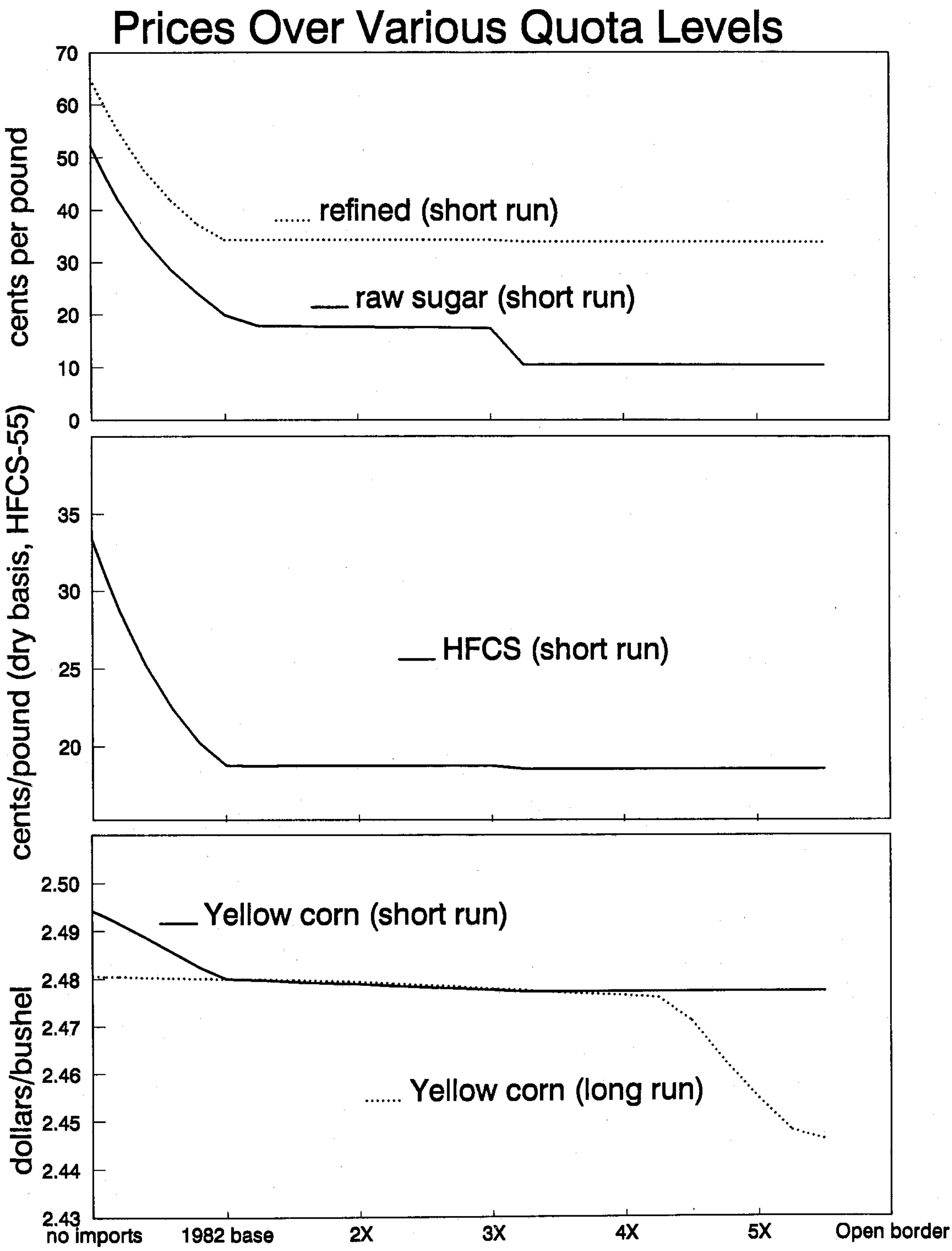

Figure 2. Impact of the sugar quota on sugar, HFCS, and corn prices

than it would in the base case (nearly 4% more), and the refined sugar price also rises more (in excess of 3%). The effect is the opposite for HFCS; its price rises less than in the base case (3% less). Feed grain prices, the sector in which corn is included, are virtually unaffected. Indeed, regardless of whether the elasticities are halved or doubled, or in which direction the quota is moved, feed grain prices never change more than a few tenths of a percent relative to the base case displayed in figure 2.

Insights from the Model

In this article, we have verified that the sugar program does indeed raise feed grain prices. However, the extent of the price rise is small. A policy of eliminating sugar imports has the potential to raise the price of feed grains by about 2¢ per bushel in the short run, though even this gain disappears in the long run. The price-depressing effect of free trade in sugar would be greatest in the long run, perhaps causing a drop of about 3¢ per bushel in the price of feed grains. How can this be reconciled with industry assertions about the potential benefits of the sugar program to corn producers?

We believe that the benefits of the sugar program to corn producers are generally overstated due to a failure to account for important interactions within the sweetener industry. Four points stand out. First, there is a tendency to equate HFCS production with the entire wet corn milling industry. However, wet corn milling production serves more than the sweetener market. Alcohol production, for example, accounted for 22.9% of wet milling corn use in 1989, as opposed to 1.5% in 1975. By 1990, starch production also accounted for a large share (17.9%) of wet milling corn use. These goods are not affected directly by the sugar program, and thus the demand for corn derived from their use is little affected.

A second, closely related, reason why previous studies may have overstated the impact of the sugar program on the HFCS industry is due to a neglect of the market for by-products, commodities such as corn oil and gluten feeds that are produced as a consequence of HFCS, alcohol, or starch production. As noted above, a large share of wet milling revenues comes from the sale of nonsweetener products. When the demand for sweeteners falls and production contracts, the price that can be charged for these by-products rises. This tends to dampen somewhat the overall rate of decline in industry profitability. Consequently, while loosening of the quota reduces the demand for corn, this decline is smaller than it would be if HFCS were the sole product of this sector.

This argument also works in reverse. When sweetener prices rise and more HFCS is produced, more by-products, corn oil, and gluten feeds also are produced as a consequence. Since their prices fall (*ceteris paribus*), total returns to the HFCS industry rise less rapidly than otherwise would be the case. This limits the incentive to expand HFCS production. Furthermore, the increased supply of feed substitutes such as corn gluten compete with corn grain in livestock rations. In other words, the production of HFCS does not fully exhaust the feed value of the input. Consequently the derived demand for corn increases less than might be expected when HFCS production increases. We have largely abstracted from this latter phenomenon by greatly limiting the substitutability among feedstuffs. *Explicitly introducing the potential for substitution among alternative feed ingredients would further reduce the corn price changes owing to changes in the sugar quota.*

A third reason why existing analyses likely overstate the benefits of the sugar program to corn producers is that they often assume corn sweeteners would be eliminated with free trade, when, in fact, as our analysis shows, HFCS would continue to be produced even if the U.S. eliminated sugar import restrictions, albeit at a more modest level.

A final reason why some previous studies may have overstated the impact of the sugar program on corn prices is the failure to recognize that the import quota more directly affects the price of raw sugar than refined sugar. Yet it is the latter product which is the primary competitor for HFCS. Thus, when the quota is tightened, the refined sugar price rises more slowly than the raw sugar price because it embodies more inputs than raw sugar alone. The price of these other inputs is largely unaffected. Indeed, the return to refining capacity actually falls, as the derived demand for its services declines with declining sugar consumption.

When the quota is loosened, this effect works in the other direction. Now the demand for refining capacity becomes more acute and the returns to this capacity rise quite rapidly. Consequently, the refined sugar price declines more slowly than the price of raw sugar. This means that there is less substitution of refined sugar for HFCS than might be expected if one used the raw sugar price as a gauge. Therefore, corn producers are not hurt as much by free trade in sugar as might be expected at first glance. Indeed, even in the long run, when refining capacity expands and earns only a normal market rate of return, the increase in corn price is very small indeed. This price increase would be further dampened if we were to raise the export demand elasticity for corn to reflect a longer-run time horizon.

Summary

The sugar program looks good to corn farmers at first glance, but a second, more careful look shows that there are probably much better ways to spend energy and political capital than lobbying for the sugar program. Indeed, if a failure to agree to free trade in sugar were to obstruct the possibility of liberalization in other countries' agricultural trade policies, it is easy to see how corn producers—increasingly dependent on export markets—might actually end up losing.

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Notes

[1] From 1982 until last year, an import quota was used to maintain the domestic price of raw sugar above the world price. A tariff currently is being used for this purpose.

[2] Farm capital is assumed to be mobile across alternative on-farm uses, but immobile between the farm and nonfarm sectors.

[3] In some industries it contains irrelevant information. For example, only a subset of the sectors use sweeteners, and similarly for farmland.

[4] Each quota level has an equivalent tariff rate that results in the same level of imports. The results in the tariff case are the same as the quota except that the tariff generates domestic revenues and quota rents are returned to the ROW, reflecting policy which until this year allowed foreign sellers to receive U.S. prices for raw sugar.

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