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# The Effects of Shifts in Supply on the World and U.S. Sugar Markets

by

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## Introduction

Sugar is one of the few agricultural products produced in the United States at a cost of production exceeding estimated costs for the rest of the world. Demand for sugar in the U.S. is remarkably stable. For most of this century per capita sugar consumption has been around 100 pounds, raw value. Domestic producers have supplied about half of domestic needs since the early 1900's. Before then the majority of U.S. consumption was imported.

The first tariff on imported sugar was imposed by Congress in 1789 (Ballinger). Since then, the U.S. sugar industry has been affected by some type of government program. Until recently the primary goal of the tariff on sugar was to generate funds for the Treasury. However, since about 1930, protection of the domestic industry has become an explicit objective of sugar policy.

Between 1933 and 1974 sugar policy was mandated by a series of Sugar Acts. In 1974 proposed sugar legislation was defeated by the House. Since then, except for the 1977 and 1978 crops, domestic sugar programs have been operated under continuing authorities provided by the 1933 and 1949 Agricultural Acts.

Current Administration sugar policy is keyed to the goal of supporting "a viable domestic sugar industry" (Hjort). The Administration is authorized to maintain this support through the use of quotas, loan

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programs, direct payment programs, and/or import fees. By one or a combination of these programs the domestic price can be kept above world price levels, and domestic producers are assured adequate returns to continue producing a significant proportion of domestic needs. Except for a few occassions when the world price of sugar rose sharply and exceeded U.S. target levels, government programs have contributed vital support to the domestic industry.

When sudden price increases do occur, programs geared to establishment of a price floor become irrelevant. Attention shifts from the producer to the consumer. In 1920, 1974, and late 1979 the world price rose above domestic support levels. The duration of the period of high prices such as those and the magnitude that prices may reach are questions of great concern to producers, consumers, and policy makers alike. Many factors contributed to the dramatic increases in the past. However, it was generally true that shortages of world sugar supplies were prevalent during each price surge.

Last year Congress defeated a proposed program that would have mandated a 1979 crop support level of 15.8 cents per pound, raw value, protected by a variable fee on imported sugar. To fully cover the estimated national average cost of producing raw sugar of 16.3 cents 1/, the remaining .5 cents would be paid by the government directly to producers. Future support would be changed in proportion to changes in costs of production, but would not exceed 7 percent per year.

A major factor which led to the proposal's defeat was its anticipated inflationary impact. During the period this bill was being debated the world price was about 8 cents and it was projected to reach 17.5 cents by the 1982/83 crop year (House of Representatives). The world price was projected to increase at a faster rate than the domestic administered price. The duties and fees needed to provide support to U.S. producers were expected to be reduced to minimum levels in 1982 when the world price would be high enough to sustain the U.S. industry. Debate of the 1979 Sugar Bill ended with its defeat in October, 1979.

From September, 1979 through February, 1980 the world price increased steadily. In February, 1980 the world price averaged over 23 cents, well above the level deemed necessary to maintain the U.S. industry. Many reasons have been cited to explain the sudden price rise. Poor crops in some major producing areas, slow movement of price-stabilizing stocks onto the world market, and unusually heavy speculative activity in sugar futures markets have all been attributed as exerting significant influence on the price level (Badenhop). Except for the effect of speculation, the factors mentioned are basically deviations from expected levels of supply.

The purpose of this paper is to examine the sensitivity of the U.S. and world sugar markets to shifts in supply. Econometric and mathematical programming models encounter serious prediction problems when subtle structural changes occur (such as sudden changes in futures market activity). However, when no significant structural changes have been observed or are expected, these models can serve as useful tools to gauge the sensitivity of the market to certain changes in economic activity. A two-region spatial equilibrium model is used here to examine the effects on the U.S. and rest of the world sugar markets from selected shifts in rest of the world supplies for the 1979 crop year 2/.

## The Model

Issues of primary concern to sugar policy are generally international in scope. Raw sugar is a homogeneous product produced in many countries. Trade of sugar occurs worldwide. Many less developed countries produce sugar as a major source of foreign exchange. For many years sugar has been a highly political commodity. Only a small proportion of the total world supply is traded on the world "free market" 3/. However, it is from that market that the U.S. obtains about one half of its consumption requirements.

In this setting a mathematical programming model provides obvious advantages. Policy instruments can be readily imposed by choosing appropriate constraints. International trade flows can be directly determined, in a normative sense, by using the spatial equilibrium approach. Bates and Schmitz and Ryland and Guise have demonstrated that spatial equilibrium models can be used to represent the sugar market.

U.S. sugar policy is based on comparison between the U.S. and the "rest of the world" sugar markets. Prices in these two markets are geared to single locations. The U.S. market price is a landed New York price, while the "rest of the world" price is f.o.b. Caribbean ports. Transportation charges are explicitly considered in U.S. import fee calculations, and they are based on Caribbean to New York rates. Thus, to proxy the world sugar market as a two-region model we follow guidelines already established by policy makers and industry market analysts.

A quadratic programming model discussed by Takayama and Judge was used to represent the world sugar market. Demand and supply equations in each region were specified and estimated. A transportation cost matrix was derived from unpublished USDA sources.

## Specification and Estimation of Regional Supply and Demand

Samuelson has developed the approach to optimizing trade behavior between spatially separated markets where transportation costs are known and the goods traded are homogeneous. By maximizing producers' and consumers' surplus in all regions, net of transportation costs, the optimal trade policy for the universe under study can be obtained. Equilibrium prices and trade flows that maximize net social payoff are given in the solution to such a model. Takayama and Judge extensively discuss models of this type in the context of quadratic programming.

To obtain model solutions using the quadratic programming approach, the model must be formulated with linear supply and demand relations for each region. Supply and demand equations can be either quantity or price dependent; however, in practice, price dependent equations are generally used. Therefore, price dependent supply and demand equations, linear in quantity, were estimated directly for the U.S. and the rest of the world.

Supply price curves were hypothesized as functions of the current quantity available to the market and the set of predetermined variables that entered into the decision to produce that quantity. The set of predetermined variables in the equation includes expected price, costs of production, prices of substitute alternatives, and the level of fixed investment in production facilities. Because of the highly aggregated markets being represented, effects of weather and other influences are assumed random and contained in the error term. Thus, the theoretical supply price relation is formulated as

$$P^r_{s,t} = f(Q^r_{s,t}, PE^r_t, CP^r_t, FI^r_t, u_t), \quad (1)$$

where $P^{r}_{s,t}$ is the supply price in region r in year t; $Q^{r}_{s,t}$ is the quantity supplied in region r in year t; $PE^{r}_{t}$ is the expected price in region r in year t; $CP^{r}_{t}$ is production costs in region r in year t; $FI^{r}_{t}$ is the level of fixed investment in sugar production facilities in region r in year t; and $u_t$ is the disturbance term.

The rest of the world supply equation was estimated with world price lagged one year to represent expected price and rest of the world acreage harvested lagged one year to proxy for fixed investment. On a worldwide basis, production costs and alternate crop prices vary sufficiently to preclude use of a single data series as a proxy. Therefore, these effects were ignored. The equation was estimated by 2SLS and the results were 4/:

$$P^{r}_{s,t} = \underset{(1.49)}{10.88} + \underset{(2.20)}{.00077}\, Q^{w}_{s,t} + \underset{(4.01)}{.70}\, P^{w}_{s,t-1} - \underset{(2.04)}{.004}\, AH^{w}_{t-1} \tag{2}$$

$$\bar{R}^2 = .51 \qquad \text{Standard error of regression} = 4.25$$

where $P^{w}_{s,t-1}$ and $AH^{w}_{t-1}$ are lagged world price and rest of world acreage, respectively. The world price flexibility implied by this equation is 6.83.

Empirical testing of (1) for the U.S. failed to provide acceptable results, so a quantity dependent equation was estimated. The 2SLS results were:

$$\begin{aligned} Q^{us}_{s,t} = {} & \underset{(1.58)}{2007.7} + \underset{(.47)}{18.96}\, P^{us}_{s,t}/CP^{us}_{t} - \underset{(.47)}{4.24}\, GR^{us}_{t-1}/CP^{us}_{t-1} \\ & + \underset{(.54)}{38.86}\, P^{us}_{s,t-1}/CP^{us}_{t-1} + \underset{(3.91)}{4.04}\, AH^{us}_{t-1} \end{aligned} \tag{3}$$

$$\bar{R}^2 = .71 \qquad \text{Standard error of regression} = 369.72$$

where $GR^{us}_{t-1}$ is a lagged composite index of prices received by farmers for food and feed grains, and accounts for expected price of alternate crops. Other variables are as defined above. The supply elasticity implied by this equation is .03.

The demand prices in each market were hypothesized according to conventional demand theory to be functions of the current quantity available for purchase, income, and population. Other influences on demand were either insignificant or impractical for econometric applications. They were assumed random and are represented in the error term. Thus, the theoretical demand price relation is:

$$(4) \qquad P^r_{d,t} = g(Q^r_{d,t}, Y^r_t, N^r_t, v_t),$$

where $P^r_{d,t}$ is the demand price in region r in time t; $Q^r_{d,t}$ is the quantity demanded in region r in time t; $Y^r_t$ is income in region r in time t; $N^r_t$ is population in region r in time t; and $v_t$ is the disturbance.

Since the recognizable effects on world sugar consumption from changes in aggregate world income would be spurious, income was not included in rest of world demand relation. Results of 2SLS estimation of the rest of the world demand price equation were:

$$(5) \qquad P^w_{d,t} = \underset{(1.91)}{-83.15} - \underset{(1.51)}{.0014}\, Q^w_{d,t} + \underset{(1.78)}{.05}\, N^w_t$$

$$\bar{R}^2 = .32 \qquad \text{Standard error of regression} = 5.03$$

The rest of the world demand price flexibility implied by this equation is 11.23.

The population variable in (4) was deleted from the U.S. demand price equation due to its high collinearity with income. A dummy variable with a value of one in 1973 and 1974, when the U.S. price was abnormally high, and zero elsewhere was added. The 2SLS results for the U.S. demand price equation were:

(6) $$P^{us}_{d,t} = \underset{(2.42)}{6.72} - \underset{(1.11)}{.0004}\, Q^{us}_{d,t} + \underset{(10.88)}{.011}\, Y^{us}_{t} + \underset{(18.18)}{13.59}\, D$$

$\bar{R}^2 = .97$ Standard error of regression = .98

The U.S. demand price flexibility given by this equation is .39, much lower than would be expected. One possible explanation for the inflexible nature of the U.S. demand price is the fact that the U.S. price is determined to a considerable extent by government interference in the sugar market, rather than by conventional market forces.

## Model Simulation

The estimated relations given in the preceding section were used to form the spatial equilibrium model. The U.S. supply equation was normalized to the price dependent form of the rest of the model. In order to simulate market activity for the 1979 crop year, predetermined variables were assigned calendar 1980 projected values, and price equations were defined as functions only of quantity. The model was solved to give a baseline solution.

Initial baseline solutions did not result in world price levels above the announced U.S. support price of 15.8 cents. To achieve a U.S. price near the 15.8 cent target level, import fees were added to the transportation cost from the rest of the world to the U.S. After experimentation with various fees, the baseline result presented in Tables 1 and 2 was obtained.

Given the baseline solution as the conventional model prediction for the 1979 crop year, selected shifts in the rest of the world supply curve were imposed to test the sensitivity of the solution. By plotting the supply curve and observing the triangle formed by its intersection with the price and quantity axes, it was possible to impose given parallel shifts in supply by appropriate changes of the intercept term.

Thus, the effects of ten and twenty percent reductions and increases in the rest of the world supply were simulated with the model. Table 1 shows the results of these simulations.

Parallel leftward shifts of the rest of the world supply by 10 and 20 percent result in actual reductions in supply of 4.8 and 11.4 percent, respectively. U.S. demand, due to the inflexible demand curve used in the model, shows the most dramatic response in the market, falling from nearly 11.6 million metric tons (mmt) to 5.5 mmt. World prices increase substantially from 12.6 to 17.00 cents. U.S. prices remain relatively stable because import duties and fees are reduced in response to world price increases.

The 20 percent leftward shift most nearly approaches current USDA estimates for the 1979 crop.5/ However, U.S. consumption predictions are seriously understated. At the given price levels, the optimal solution contains no trade between the two regions. This is not a realistic result.

To compensate for the weakness of U.S. demand, a constraint was imposed on the model to maintain U.S. demand at a minimum level of 9mmt. This implies a reduction of .9mmt from 1978 consumption, and recent developments in the corn sweeteners market justify such a possiblity. Rest of the world consumption was constrained not to fall below 64mmt, about a 10 pound per capita reduction from 1978 levels. Results of the constrained model simulations, with the same assumptions regarding shifts of the rest of the world supply are presented in Table 2.

Table 1. Simulation Results of the Unconstrained Model

| World Supply Shift | U.S. Import Fee & Duty | U.S. Price | World Price | U.S. Supply | World Supply | U.S. Demand | World Demand | U.S. Imports | U.S. Exports |
|---|---|---|---|---|---|---|---|---|---|
| | | Model Solution Values | | | | | | | |
| | ¢/lb | | | 1,000 metric tons | | | | | |
| Baseline | 2.4 | 16.19 | 12.59 | 5,475 | 91,066 | 11,586 | 84,956 | 6,111 | 0 |
| 10% left | .625[a] | 17.00 | 15.17 | 5,489 | 86,917 | 9,328 | 83,078 | 3,839 | 0 |
| 20% left | .625 | 18.35 | 16.97 | 5,511 | 81,765 | 5,511 | 81,765 | 0 | 0 |
| 10% right | 3.6 | 15.15 | 10.35 | 5,458 | 95,649 | 14,518 | 86,589 | 9,060 | 0 |
| 20% right | 5.6 | 14.44 | 7.64 | 5,446 | 99,628 | 16,512 | 88,562 | 11,065 | 0 |

a. The statutory minimum duty on raw sugar is .625 cents per pound.

Table 2. Simulation Results of the Constrained Model

| World Supply Shift | U.S. Import Fee & Duty | U.S. Price | World Price | U.S. Supply | World Supply | U.S. Demand | World Demand | U.S. Imports | U.S. Exports |
|---|---|---|---|---|---|---|---|---|---|
| | | Model Solution Values | | | | | | | |
| | ¢/lb | | | 1,000 metric tons | | | | | |
| Baseline | 2.4 | 16.19 | 12.59 | 5,475 | 91,066 | 11,586 | 84,956 | 6,111 | 0 |
| 10% left | .625 | 17.00 | 15.17 | 5,488 | 86,917 | 9,327 | 83,078 | 3,839 | 0 |
| 20% left | .625 | 20.51 | 18.68 | 5,547 | 83,974 | 9,000 | 80,521 | 3,453 | 0 |
| 10% right | 3.55 | 15.13 | 10.38 | 5,458 | 95,686 | 14,576 | 86,568 | 9,119 | 0 |
| 20% right | 5.3 | 14.32 | 7.82 | 5,444 | 99,854 | 16,864 | 88,435 | 11,419 | 0 |

The 10 percent leftward shift in rest of the world supply was not affected by the constraint. However, the solution obtained with the 20 percent lefward shift was significantly improved over the unconstrained case. Optimal U.S. demand was at the constrained level of 9mmt. Rest of the world consumption and production were at reasonable levels. Prices were in the range of current expectations.

An issue of considerable current concern to sugar policy analyst is the effect of reduced world supplies on the world price. Results of the model presented here reveal in the unconstrained case that an 11.4 percent reduction in rest of the world supply will lead to a 34.8 percent increase in world price. In the constrained model an 8.4 percent decrease in supply results in a 48 percent increase in world price. Increases in rest of the world supply similarly result in much more than proportional decreases in world price. It should be noted that price effects mentioned here relate to the sensitivity of the baseline projection for the 1979 crop. The baseline result predicts a price 50 percent above the average price for 1978.

## Conclusion

Slight changes in the level of world sugar production can have significant effects on world sugar prices. Shifts in the world supply curve for sugar can lead to dramatic changes in the market price level. Psychological influences may also play an important role in price determination; however, the results of the model presented here indicate that the current rise in sugar prices can be explained in large part by the effects of production falling below expected levels.

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## Footnotes

1. All sugar prices cited in this paper refer to a raw value basis.

2. The 1979 crop year for the world is defined as September 1, 1979 to August 31, 1980.

3. Of the 1979 crop, less than 20 percent of world production will enter the free trade market.

4. All equations were estimated using data for the period 1954-78. Data were obtained from the USDA, Foreign Agricultural Service and unpublished sources in the Economics, Statistics, and Cooperatives Service.

5. In the February 1980 Sugar and Sweetener Report, expected 1979 crop rest of the world production and consumption were reported to be 82mmt, U.S. production 4.6mmt, U.S. imports 4.5mmt, U.S. consumption was expected to be less than the 9.9mmt level of 1978, and both U.S. and world prices were expected to be in the 20-25 cent range.

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